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Developing an Interface Management (IM) Model for Construction Projects

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UNIVERSITY OF CALGARY

Developing an Interface Management (IM) Model for Construction Projects

by

Nesreen Ayed Weshah

A THESIS

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Abstract

Interface management (IM) is a main factor in the success of construction projects. Although there is no agreement about the definition of interfaces and IM, many researchers discuss the boundary conditions between tools, phases, systems, physical elements/components, people, organizations, and other elements. For the last two to three decades there has been less than necessary awareness of the essentials of IM and the severity of interface problems, and this has negatively affected project performance. Failure to properly manage interfaces impacts project performance as defined by scope control, quality, schedule, cost, safety, and resources.

The objectives of this study are twofold: (a) enhancing the IM among different project participants involved in the construction projects and (b) increasing the effectiveness of IM throughout the project lifecycle, focusing specifically on the engineering/design phase. The study uses both qualitative and quantitative approaches (mixed methods) to investigate, identify, and classify interface problem factors in construction projects.

This study is divided into three phases. The first phase categorizes IM factors contributing to interface conflicts among different project participants engaged in construction projects. The second phase then makes use of these variables to develop a multiple-regression analysis to develop models between underlying interface problem factors and project performance indicators. Finally, based on the results of the first and the second phases, the third phase consists of developing a conceptual framework (RIBA framework) and use case models to study the IM relationships among owner, contractor, and designer to identify the main responsibilities for each one, highlight the critical IM areas, and consequently provide suggestions for improving and enhancing IM.

The results of this research study could assist engineers, architects, and others within the construction industry to study and examine the interfaces and the project performance during the project's early stages. This could in turn serve to minimize project delay and cost overruns and reduce conflict among different project participants involved in the construction projects, which will influence project performance positively.

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Dedication

This thesis is dedicated to my father and mother for their unconditional love and incredible support, to my helpful husband (Hussam), to my beautiful sisters (Lubna and Doa'a) and brothers (Esam, Basheer, Alaa, and Hussien), to my sisters-in-law (Sheeren, Lubna, and Zainab) and my brothers-in-law (Tamir and Mansour), and to the lovely children in my life (Sheera, Celeina, Jumanah, Malak, Rama, Tala, Razan, Ahmad, Awse, Ayed, Yoseph, Esam, Own, and Nasiraldin). I could not have accomplished this dissertation without their patience, support, and immense love.

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List of Symbols, Abbreviations and Nomenclature

ACA	Alberta Construction Association
APEGA	Association of Professional Engineers and Geoscientists of Alberta
CAA	Consulting Architects of Alberta
CBS	Cost Breakdown Structure
CDT	Corporación de Desarrollo Tecnológico
CEA	Consulting Engineering for Alberta
C&E	Cause and Effect
CII	Construction Industry Institute
CWBS	Contracting Work Breakdown Structure
EPC	Engineering, Procurement and Construction
EPCM	Engineering, Procurement, and Construction Management
ES	Effect Size
FEL	Front End Loading
GDP	Gross Domestic Product
IM	Interface Management
IPM	International Project Management
IT	Information Technology
KPI	Key Performance Indicators
LWCIR	Lost Workday Case Incident Rate
MANOVA	Multivariate Analysis of the Variance
MRTS	Mass Rapid Transit System
NN	Neural Networks
OBS	Organization Breakdown Structure
PDS	Project Delivery Methods (Systems)
PPMC	Pearson Product-Moment Correlation
PMI	Project Management Institute
PM	Project Management
PMFG	Project Management Focus Group
PPC	Percentage of Plan Completed
RIR	Recordable Incident Rate
UML	Unified Modeling Language
WBS	Work Breakdown Structure

Chapter One: Introduction

1.1 Chapter Overview

This chapter provides an opening overview of this thesis. This includes a background on the research questions, the problem statement, and a general idea about interface management (IM). Moreover, this chapter lists the objectives, the scope of the work, the research methodology, and the arrangement of dissertation chapters. Parts of the materials in this chapter and in this thesis were included in Weshah, El-Ghandour, Cowe Falls, & Jergeas (2012a, 2012b, 2014a, 2014b, 2014c, 2014d) and Weshah, El-Ghandour, Jergeas, & Cowe Falls (2013a, 2013b).

1.2 Background

Interface management is a major factor in the success of construction projects (Chan, Chen, Messner, & Chua, 2005; Chua & Godinot, 2006; Collins et al., 2008; Morris, 1983; Nooteboom, 2004; Pavitt & Gibb, 2003; Shokri et al., 2012). Although there is no agreement among previous research about the definition of IM, many discuss the boundary conditions among physical elements, tools, equipment, phases, systems, people, organizations, processes, and others (Godinot, 2003; Wideman, 2002; Wren, 1967). Figure 1.1 illustrates the general concept of interface management, where A, B, and C could be any one of three elements: phases, tools, projects' groups, organizations, etc.

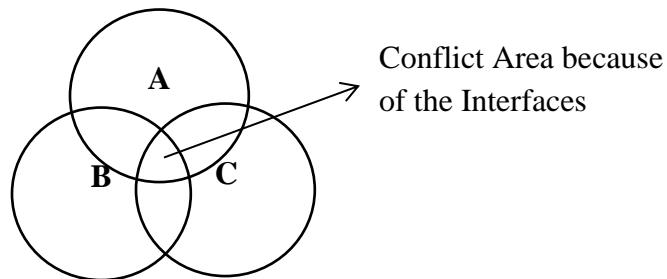


Figure 1.1 General Concept of Interface Management

The Project Management Institute (PMI) defined IM as “the management of communication, coordination and responsibility across a common boundary between two organizations, phases, or physical entities which are interdependent” (Project Management Institute, 2003). Basically, “IM is the “glue” that holds a project together” (Crumrine, Nelson, Cordeiro, Loudermilk, & Malbrel, 2005).

There are many reasons supporting the necessity for a comprehensive research study to enhance IM among different participants involved in construction projects. For the last two to three decades there has been less than necessary awareness of the essentials of IM and the severity of interface problems, and this has negatively affected project performance. Failure to manage interfaces impacts project scope control, quality, schedule, safety, and resources (Crumrine et al., 2005; Mortaheb & Rahimi, 2010; Pavitt & Gibb, 2003). For example, C. Huang (2007) concluded that the interface issues during the construction phase in the Tamsui Line MRT construction project in Taiwan/the Republic of China were accountable for approximately 18% of the total project delays. Shokri et al. (2012) mentioned that “poor management of interfaces may result in deficiencies in the project cost, time, and quality during the project life cycle execution, or may result in failures after the project has been delivered”.

Chen, Reichard, and Beliveau (2008) said that interface issues are “leading to low productivity, poor quality, waste, delays, claims, and cost overruns”. Additionally, Sundgren (1999) mentioned that failure to properly manage interfaces during the construction phase can waste time and make revisions necessary, which increase the costs of projects. Nooteboom (2004), the Vice President of Offshore Field Development with INTEC Engineering, said that in megaprojects there are usually more than 75,000 task-connected interfaces. In addition, IM accounts for approximately 20% of the total project cost (note: those numbers are purely

anecdotal). As well, the confusion related to interface problems among different project participants involved in the construction process is considered one of the greatest risk factors that contribute to cost and schedule uncertainty (Ku, Lin, Huang, & Shiu, 2010).

Interface management failures occurred frequently in the past, but captured the world's attention when the Three Mile Island nuclear accident happened in 1979. The investigation of this event found that the lack of communication among key people involved in the project led to the making of incorrect assumptions, which finally caused the disaster (Crumrine et al., 2005). It was also found that IM failure was the main cause of the Piper Alpha, Exxon Valdez, and Phillips Pasadena accidents (Crumrine et al., 2005).

In Canada the construction industry is very important and, in particular, makes an important contribution to Western Canada's economy (Statistics Canada, 2013). In 2013, according to statistics for Alberta construction projects, \$35.51 billion (10.7% of Alberta's gross domestic product (GDP)) was spent on construction projects (Alberta's Economic Development, 2013). Alberta construction projects involve many parties, such as engineering, architecture, design, procurement, fabrication, construction, commissioning, and small contractors. This complexity creates overlapping relationships that have plenty of interface problems among them; some examples are ineffective communication, lack of trust, hidden agendas, and poor coordination. These kinds of interface problems lead to time overruns, low productivity, quality impacts, cost overruns, disputes, arbitration, litigation, termination, claims, and waste (Chen et al., 2008; Morris, 1983; Mortaheb & Rahimi, 2010). Consequently, through the appropriate application of effective management and communication and coordination techniques among different project participants involved in the construction projects, these interface problems have to be cautiously, immediately, and effectively resolved.

Some studies of different types of construction projects outline the interface problems between two parties, such as between contractors and owners (Al-Hammad, 1990), designers and contractors (Al-Hammad & Assaf, 1992), contractors and subcontractors (Al-Hammad, 1993; Hinze & Tracey, 1994), maintenance contractors and owners (Al-Hammad, 1995), and owners and designers (Al-Hammad & Al-Hammad, 1996). In addition, a few studies have identified the interfaces among all project participants involved within the construction projects. One such study was conducted by Al-Hammad (2000) on the common interface problems among various construction participants. Moreover, new studies identified the same IM problems that Al-Hammad had identified and added more new IM problems (Chen et al., 2008; R. Huang, Huang, Lin, & Ku, 2008; Ku et al., 2010; Mortaheb & Rahimi, 2010).

In addition, some studies have identified the factors that lead to IM conflicts in construction projects by applying statistical tools; an example is the construction projects of a mass rapid transit system (MRTS) (R. Huang et al., 2008; Ku et al., 2010). Therefore, it is necessary to measure the impact of IM on project performance indicators.

Many researchers emphasized that project performance, in terms of quality, scope, time, schedule, and safety, will be improved by implementing IM at the early stages of the project (Caglar & Connolly, 2007; Chen, Reichard, & Beliveau, 2007; Shokri et al., 2012).

Although many researchers have discussed and reported different methods for project performance measurement, insufficient project performance measurement is one of the major problems affecting the construction industry (Costa, Formoso, Kagioglou, & Alarcon, 2004a; Costa, Lima, & Formoso, 2004b). Traditionally, in construction projects performance measurement is based on quality, time, and cost, which are defined as the iron-triangle (Belassi & Tukel, 1996; Walker, 1995). In the last two to three decades performance indicators have

changed and many new aspects of project performance have been included. These indicators are used primarily for benchmarking purposes and have been used for controlling the performance during the project lifecycle (Haponava & Al-Jibouri, 2009).

For instance, in 1992 performance measures were developed to measure project success among owners, designers, and contractors, and all were in agreement that successful projects need to meet the budget and the schedule, must have no legal claims, and need to meet the profit goals (Sanvido, Grobler, Parfitt, & Coyle, 1992). Weston & Gibson (1993) measured many project performance indicators in terms of value engineering savings, change-order cost, cost growth, schedule growth, and claims costs. Performance measurements have been established for benchmarking in different countries, namely the USA (Construction Industry Institute [CII], 2000), Chile (Corporación de Desarrollo Tecnológico [CDT], 2002), the UK (Key Performance Indicators Working Group [KPI], 2003), and Brazil (Costa et al., 2004b).

In Alberta's construction industry, there are insufficient studies for identification and enhancement of interface problems in construction projects. Using Alberta data collected by means of web questionnaires from a large group of experienced industry experts, this study covers different company types in the construction sector, including owner; engineering, procurement, and construction (EPC); engineering, procurement, and construction management (EPCM); construction contractor/sub-contractor; engineering consultant; architecture firms; architecture and engineering firms; and construction management companies, in order to have a strong understanding of the main interface problems causing interface conflicts and affecting IM in these companies. In addition, the study included different industry types, such as infrastructure, oil and gas, transportation, commercial and buildings, and manufacturing, as well as many job titles within these sectors.

Nowadays, with the increased complexity of projects, it is important to have a clear understanding of interface problems and of IM and to enhance the interfaces between different project participants to increase their performance in effectiveness and efficiency for large projects.

The objectives of this study are twofold: (a) enhancing the IM among different project participants involved in the construction projects and (b) increasing the effectiveness of IM throughout the project lifecycle, focusing specifically on the engineering/design phase. This research study has been approved by the Conjoint Faculties Ethics Board of the University of Calgary (No. 7281) as shown in Appendix I. The focus of this study is to (a) enhance the IM in construction by identifying the main interface problems and/or factors causing interface conflicts and affecting IM using Alberta as a case study; (b) investigate the relationships among IM factors and company types, industry types, and respondent's title/position and years of experience; (c) identify problems considered critical to IM; (d) enhance project performance by developing and applying multiple-regression analysis models among the identified interface problem factors and the project performance indicators (these models can be used to evaluate and predict project performance based on IM); and (e) develop conceptual framework (RIBA framework) and use case models to study the IM relationships among owner, designer, and construction contractor in order to identify the main responsibilities for each one, highlight the IM areas consider critical, and consequently provide suggestions for improving and enhancing IM that are adequate to all project participants engaged in different construction projects. To avoid conflicts and omissions, at the beginning of the project the responsibilities and interfaces among owner, designer, and construction contractors must be carefully defined.

The results of this study may help owners, construction contractors, engineers, architects, and others within the construction industry to study and inspect the interfaces and the project performance during the early stages of the project. This could influence project performance positively by minimizing project delay and cost overruns and reducing conflict among different project members engaged in the construction project.

1.3 Research Questions and Problem Statement

Many people are involved in construction projects, including engineers, architects, designers, procurement staff, construction workers, and those in charge of commissioning. This creates complex relationships that can lead to many interface problems (Al-Hammad & Al-Hammad, 1996; Al-Hammad & Assaf, 1992; Al-Hammad, 1990, 1993, 1995, 2000; Chen et al., 2008; R. Huang et al., 2008; Ku et al., 2010; Mortaheb & Rahimi, 2010). Interface problems can cause cost and time overruns, impact quality, and lead to contract termination, claims, arbitration, and legal actions (Chen et al., 2008; Morris, 1983; Mortaheb & Rahimi, 2010). Therefore, it is important to identify the IM problems and measure the impact of IM on project performance. However, few studies in the literature have specifically addressed the IM problems and their impact on project performance.

Through the use of Alberta data collected from a large group of experienced industry experts using two web questionnaires, this research study intends to address the following research question: how does one enhance the IM among different participants involved in construction projects and increase the effectiveness of IM throughout the project lifecycle, specifically during the engineering/design phase? This research question can be broken down into six sub-questions that examine IM throughout the project lifecycle, focusing specifically on the engineering/design phase:

1. What are the main interface problems and/or factors causing interface conflicts that affect IM of Alberta's construction projects throughout project lifecycle phases and in particular during the engineering/design phase?
2. What are the relationships between IM factors and company types, industry types, and respondent's title/position and years of experience, in particular during the engineering/design phase?
3. What are the top 10 IM problems affecting IM throughout project lifecycle phases, in particular during the engineering/design phase?
4. What are the relationships between IM factors (the underlying interface problem factors) and project performance indicators of construction projects throughout project lifecycle phases, in particular during the engineering/design phase?
5. Could we study the IM relationships among owner, designer, and construction contractor in commercial and buildings projects throughout project lifecycle phases and recommend solutions for management?
6. What are the procedures or areas for improving IM that are acceptable to all project participants engaged in construction projects throughout project lifecycle phases?

1.4 Research Objectives

The objectives of this study are twofold: enhancing the IM among different project participants involved in the construction projects and increasing the effectiveness of IM throughout the project lifecycle, focusing specifically on the engineering/design phase. This objective was accomplished through the following set of main tasks:

1. Investigate, identify, and classify the main IM factors that considerably impact IM and cause interface conflicts among the participating parties in construction projects throughout the project lifecycle phases and in particular during the engineering/design phase.
2. Investigate relationships among IM factors and company types, industry types, and respondent's title/position and years of experience throughout the project lifecycle phases and in particular during the engineering/design phase.
3. Identify problems considered critical to IM throughout the project lifecycle phases and in particular during the engineering/design phase.
4. Investigate the relationships between extracted IM factors and the project performance indicators quality management, schedule management, cost management, scope management, safety management, and teamwork throughout the project lifecycle phases and in particular during the engineering/design phase.
5. Develop a conceptual framework (RIBA framework) and use case models to study the interface management relationships among owner, designer, and construction contractor throughout the project lifecycle phases.
6. Provide suggestions for improving and enhancing IM that are adequate to all project participants engaged in different construction projects.

1.5 Scope of the Work and Limitations

The focus of this study is to enhance IM in construction by identifying the main interface problems and/or factors causing interface conflicts and affecting IM using Alberta as a case study. Research limitations are mostly related to methodological issues, which in turn are

associated with the constraints of applying qualitative and quantitative techniques. Consequently, the following limitations should be taken into consideration:

1. The companies' project profiles and availability of the data are considered some of the main complexities in the research process. Mainly, in construction projects, companies keep project data confidential because of the competitive nature of the work and other political matters.
2. As with any study using interview and questionnaire surveys, the data collection may be influenced by different factors. Those could be insufficient resources, time limitations, respondents' biases, and transparency.
3. This research study used statistical methods to analyze the collected data. Therefore, research findings are essentially vulnerable to the statistical limitations of the selected data analysis methods. However, the application of qualitative techniques may moderate the vulnerability of the results.
4. This study does not take into consideration the impact of different construction project sizes on IM.
5. The data are from Alberta only. Also, there are limitations for different types of construction sectors, such as transportation and manufacturing.

1.6 Research Methodology

This research study used both qualitative and quantitative statistical approaches (mixed methods) to examine, identify, and categorize interface problems in the construction projects of Alberta. A comprehensive literature review of journals papers, previous relevant studies, and conference proceedings was conducted. This was followed by industry pilot studies. This research study used structured methods (structured face-to-face interviews and web-page questionnaire), which is considered to be a good method to ensure understanding of the participants' points of view,

ideas, opinions, etc. In structured interviews “all respondents are asked the same questions with the same wording and in the same sequence” (Kajornboon, 2005). On the other hand, the web-page questionnaire method is used to answer the research questions and prove the hypothesis by asking the participants to answer a set of specific questions.

This study uses two web-page questionnaires to collect data from a large group of experienced industry experts in Alberta. Jick (1979) concluded that in research, survey technique is a chosen method to quantify observations because it provides greater confidence in the generalizability of the result findings. Different members of various associations and groups participated in this questionnaire, including the Project Management Focus Group (PMFG), Consulting Engineering for Alberta (CEA), Consulting Architects of Alberta (CAA), and the Alberta Construction Association (ACA). These members include project controllers, procurement staff, project engineers, engineers, architects, quality engineers, owners, general contractors, construction managers, subcontractors, safety leaders, construction managers, and planners. In addition, different industry sectors in the areas of commercial and buildings, infrastructure, oil and gas, and transportation participated in this study with a large sample of responses received from the oil and gas sector and the commercial and buildings sector.

Moreover, various companies types were involved in the data collection stage, such as owner, architecture, architecture and engineering, engineering procurement and construction, engineering procurement and construction management, engineering consultant, and construction management.

Statistical techniques, such as factor analysis, cross-tabulated analysis, and multiple regressions were used to analyze the data. This research project started with study of the interfaces

throughout project lifecycle phases and then narrowed them down to study interfaces during the engineering/design phase.

This study consists of the following steps: (1) a comprehensive literature review, (2) pilot studies, and (3) face-to-face interviews (structured interviews) (at this stage, data were gathered from all parties engaged in various types of construction projects in Alberta), (4) distribution of self-completion questionnaires (web-page questionnaires) to participants from industry and to members of different associations in Alberta, (5) identifying, studying, and categorizing of interface problem factors using factor analysis and Pearson's correlation matrix, (6) testing the correlation between IM factors and different construction data using the Multivariate Analysis of the Variance (MANOVA) analysis technique, (7) identifying the top 10 interface problems affecting IM performances through cross-tabulated analysis using SPSS software followed by the ranking process method, (8) developing and applying multiple-regression analysis models between the underlying interface problem factors and the project performance indicators, (9) developing conceptual framework (RIBA framework) and use case models to study the IM relationships among owner, contractor, and designer using the Unified Modeling Language (UML) use case diagrams, (10) identifying areas for improving IM, and (11) conducting in-depth interviews after questionnaires are completed to validate the final research findings.

In general, this methodology is applicable to other locations (other provinces in Canada) if the major industries and types of projects in each province are taken into consideration. In addition, this methodology can be applicable to other industrial sectors by conducting a dispersed study for each type of project.

1.7 Research Propositions and Hypotheses

The following research hypotheses have been established in this study to answer the research questions using Alberta's data:

1. Is there a correlation among all of the interface problems?
2. Is there a correlation between the identified IM factors (the underlying interface problem factors) contributing to interface conflicts in Alberta's construction projects and project performance indicators (quality management, schedule management, cost management, scope management, safety, and teamwork)?

Based on the research questions and the above research hypotheses, 10 null hypotheses were tested throughout project lifecycle phases and in particular during the design phase. These hypotheses were examined in this research study by using different statistical techniques, including a factor analysis tool and multiple regression models. These hypotheses are the following.

Hypotheses 1, 2, 3, and 4: there would be no significant difference in the means between the impact of the IM extracted factors (dependent variables) and

- Respondents' title groups as independent variables
- Company types as independent variables
- Industry types as independent variables
- Total years of experience groups as independent variables

Hypotheses 5, 6,7,8,9, and 10: there would be no significant relationships between the extracted factors and the project performance indicators:

- Quality
- Schedule
- Cost
- Scope

- Safety
- Teamwork

1.8 Structure of the Thesis

This thesis is a *manuscript-based thesis*, as shown in Figure 1.2. This section describes the outline of the thesis structure as follows:

Chapter 1: Introduction. This chapter gives an overview of the topic and areas of the research.

Chapter 2: Literature Review. This chapter highlights the related outcomes of the general literature review. Moreover, this chapter reviews the gaps in the previous studies.

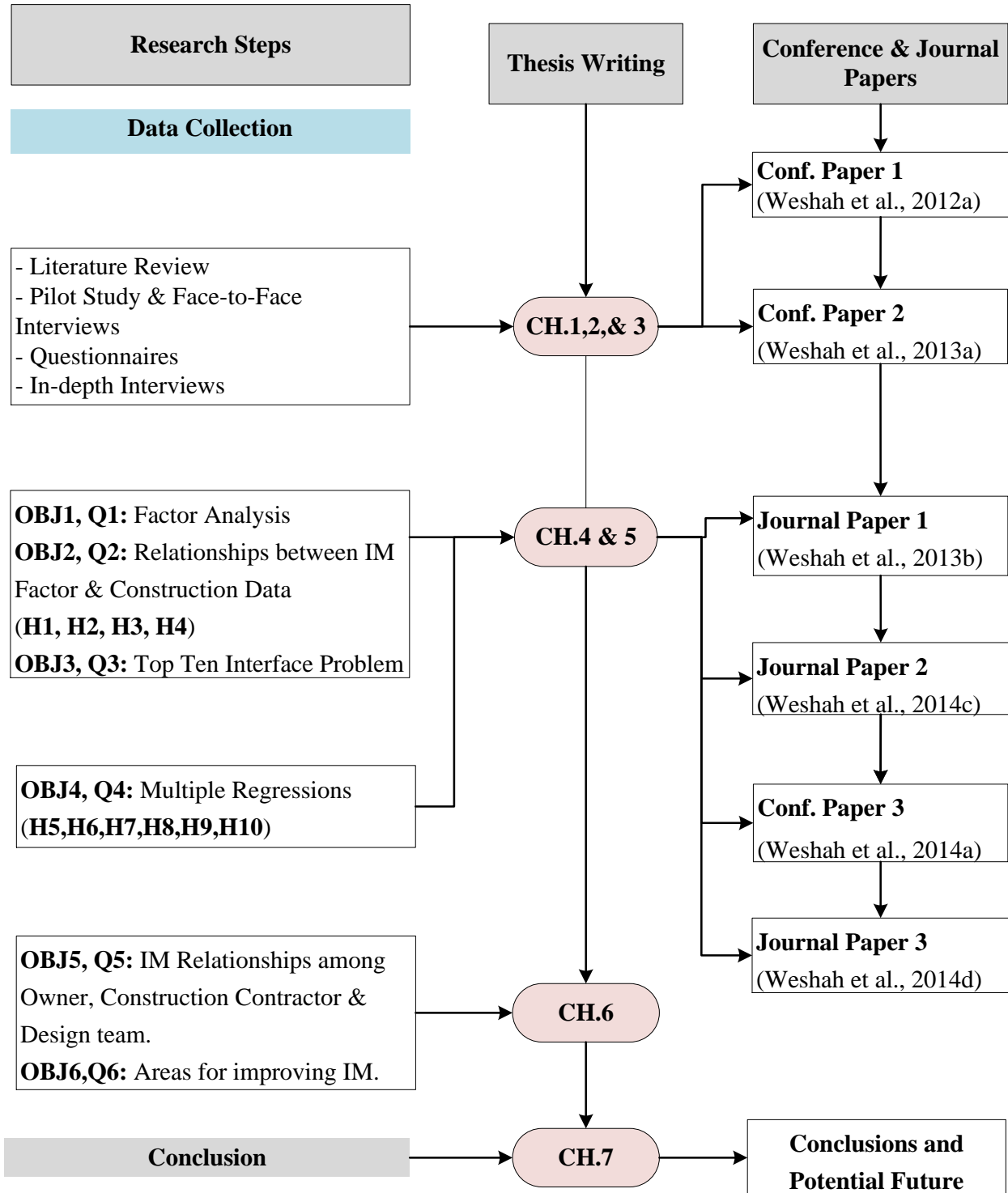
Chapter 3: Research Methodology. This chapter describes the research methodology and reviews the different research approaches (qualitative and quantitative). The approach chosen by the researcher was also discussed.

Chapter 4: Survey Number One. This chapter highlights the findings from the first survey that was conducted throughout project life-cycle phases. This chapter provides analysis of the survey results and discussion of the findings and conclusions. The material in this chapter was published as peer-reviewed journal articles (Weshah et al., 2014c, 2013b).

Chapter 5: Survey Number Two. This chapter highlights the findings from the second survey that was conducted during the engineering/design phase. This chapter provides analysis of the survey results and discussion of the findings and conclusions. The material in this chapter was submitted for publication.

Chapter 6: Relationships among Owner, Contractor, and Designer. This chapter provides a development of the conceptual framework (RIBA framework) and use case models for studying the IM relationships among owner, contractor, and designer (architect and engineer). The material in this chapter will be submitted for publication.

Chapter 7: Research Conclusions and Recommendations. This chapter integrates the findings of the individual chapters. It concludes the contributions of this research to the body of knowledge. As well, areas for future research are recommended.



Q: Question, OBJ: Objective, H: Hypothesis

Figure 1.2 Structure of the Thesis

Chapter Two: Literature Review

2.1 Chapter Overview

This chapter affords a wide review of the published research findings related to the interface management (IM) area. The previous studies in the areas of construction IM definitions, categorization of IM, IM problems among various construction parties, and project performance measurement are summarized. Useful information from previous studies and the methodologies that are used in those studies are reported and discussed. Parts of the materials in this chapter and in this thesis were included in Weshah et al. (2012a, 2012b, 2014a, 2014b, 2014c, 2014d, 2013a, 2013b).

The following section presents the main findings of the compilation of numerous academic journal papers, conference proceedings, and research reports published by various institutes on the subject area of the research. The areas covered in the literature review include construction interface definition, interface categorization, definitions and analysis of IM approaches to exploring IM problems and issues, project performance measurement, and areas for improving IM. The findings have been categorized into six main areas based on a careful study of the previous research studies, as shown in Figure 2.1.

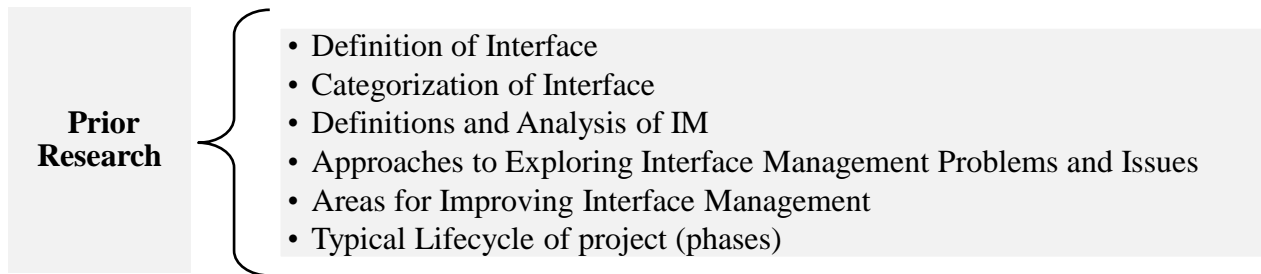


Figure 2.1 Six Categories from Prior Research

2.2 Definition of Interfaces

There is no agreement among different previous researchers about the definition of interfaces, although Shokri et al. (2012) say “interfaces are generally considered as the links between different construction elements, stakeholders, and project scope”. The identification and the engagement of the project stakeholders is very important concept in understanding the interfaces. Freeman (1984) defined the stakeholders as “A stakeholder is any group or individual who can be affected or is affected by the achievement of the organization’s objectives”. According to the Project Management Institute (PMI) Standards Committee, project stakeholders are “individuals and organizations who are actively involved in the project or whose interests may be affected by the execution of the project or by successful project completion” (Project Management Institute, 2004). The project management team should identify project stakeholders at the early stages of the project to ensure successful projects. It is important to identify the stakeholders and to understand the stakeholders’ engagement process to integrate them in the design and construction activities and to identify the interfaces among them and the IM problems in order to improve IM.

In construction projects, multiple interfaces appear among various contractors and project participants such as owner, engineering team, sub-contractors, and manufacturers. In addition, multiple interfaces appear among various disciplines such as civil, electrical, mechanical engineers (Mortaheb & Rahimi, 2010). Generally, interfaces occur from the division of work into parts that are executed by numerous organizations and people (Stuckenbruck, 1983).

The existence of interface concepts in project management (PM) followed the growth of the system approach. Both Wren (1967) and Morris (1983) define the factors included in this approach. Wren described the organization as “a system of mutually dependent variables” and

interface as “the meeting point between organizations”. Morris defined a system as a group (people, things or information) that comes together with a particular objective in mind. Both address the importance of project integration. Healy (1997) also provided a more-specific definition for interface, saying that it is a boundary across which interdependency exists and responsibility for interdependency can change. The interdependency is more technical, and the boundaries commonly are determined by the arrangement of organizations and people. Buede (1999) concluded that an interface can be extremely simple (a wire) or very complex (a worldwide communication system).

Asbjorn Rolstadas, Hetland, Jergeas, and Westney (2011) discussed the contractual interfaces and the Project ECO-System concept, which is defined as “the complete structure of the project owner and contracted suppliers”. They listed four alternatives of the Project ECO-System based on different contractual arrangements. These contractual arrangements may be among architects, engineering contractors, and general contractors and sub-contractors. As can be seen in Figure 2.2, vertical interfaces demonstrate agreements with a contract and horizontal interfaces those without a contract. In addition, Fellows and Liu (2012) discuss the vertical and horizontal “fragmentation among project participants”, the vertical among project participants such as designers, owners, commission client and horizontal among project participants such as sub-contractors.

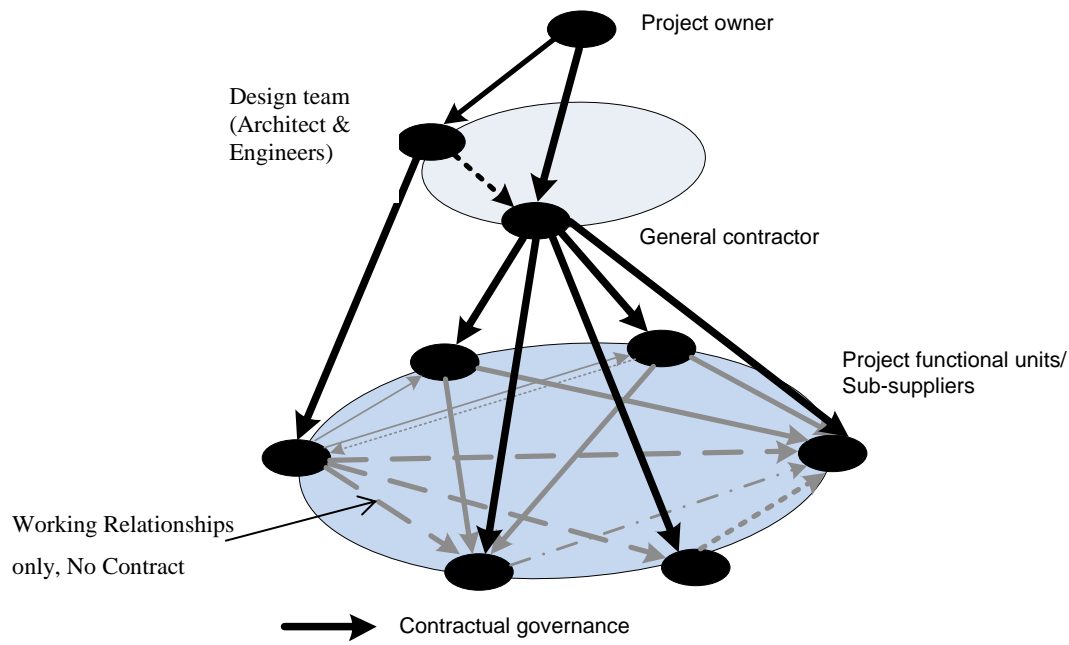


Figure 2.2: Vertical and Horizontal Ties in a General Contractor Concept, source Asbjorn Rolstadas et al. (2011) , with permission from the publisher.

The boundaries between project participants need to be carefully managed through communication and organization. Recently, many have discussed the boundary conditions among tools, phases, systems, physical elements/components, people, organization, occasions, processes, equipments, and others (Godinot, 2003; Wideman, 2002). R. Huang et al. (2008) defined the interfaces in mass rapid transit system (MRTS) construction projects as “the matters required to be physically and functionally coordinated or cooperated with among two or more subjects”. Collins, Durham, Fayek, and Zeid (2010) analyzed the interfaces in three levels: (1) inter-project interface: interfaces that may occur between the parties that participate in project execution and planning, (2) intra-project interface: interfaces that may occur inside the organization of each independent party participating in the project, (3) extra-project interface: interfaces that may occur between project parties that are involved in the project and external organizations/parties that do not engaged directly in the project execution. In summary, the

above-mentioned interface definitions give the boundaries and connections among phases, systems, tools, people, organization, physical elements, and others.

2.3 Categorization of Interfaces

In construction projects, interfaces occur from improper division of work, packaging design, and sub-contracting performed by various people and organizations (Stuckenbruck, 1983). The interfaces can be external if various organizations cooperate with each other or internal if one organization conducts the work (Awakul & Ogunlana, 2002; Healy, 1997).

Stuckenbruck (1983) grouped the interfaces into systematic interfaces, organizational interfaces, and personal interfaces. Healy (1997) classified the interfaces according to their level of compatibility between the things they separate as perfect match, partial match, and total mismatch. Korman, Fischer, and Tatum (2003) grouped the interfaces into actual, functional, extended, temporal, and future interfaces.

Pavitt and Gibb (2003) proposed three main interface types: physical, contractual, and organizational. Miles and Ballard (2002) discussed contractual interfaces. Al-Hammad (2000) categorized the interface problems into financial problems, environmental problems, inadequate contracts and specifications, and other problems. R. Huang et al. (2008) categorized the interface problems in six perspectives using factor analysis techniques, namely, experience, coordination, contract, regulation, management, and acts of God, whereas, Ku et al (2010) also used factor analysis techniques to classify the interface problems as negotiation, management, experience, contract, unavoidable, and law. In addition, experts from the construction industry in Alberta define another type of interface as information interfaces (B. Holmes, personal communication, June 5, 2012; D. Clarke, personal communication, June 13, 2012). They occur among project participants that do not have any physical, contractual, or organizational interactions within the

project. This happens when one party involved in the construction project has information that impacts the cost, schedule, safety, technical issues, or quality of the work of other parties. For instance, permit requirements by the regulatory group could have an impact on the module transportation of one of the construction contractors. Table 2.1 summarizes the categorization of interfaces and IM.

Table 2.1 List of the Interface Problems Categorization

Interface Categorization	References
Personal, organizational, systematic	Stuckenbruck (1983)
Static and dynamic	Morris (1983)
Attachment, spatial, transfer, control and communication, environmental, ambient, and user	Sanchez (1999)
Functional, physical, and organizational	Laan, Wildenburg, & Kleunen (2000)
Inadequate contract and specification, financial problems, environmental problems, and other problems	Al-Hammad (2000)
Product and project	Archibald (2003)
Physical, contractual, and organizational	Pavitt & Gibb (2003)
Actual, functional, extended, temporal, and future	Korman et al. (2003)
Management, experience, coordination, contract, acts of God, and regulation	R. Huang et al. (2008)
Physical, functional, contractual/organizational, and resource	Chen, Reichard, & Beliveau (2010)
Management, experience, negotiation, contract, unavoidable, and law	Ku et al. (2010)
Information interfaces	Expert from construction industry

Many studies outlined the interface problems between two parties or more, such as between contractors and owners (Al-Hammad, 1990), designers, and contractors (Al-Hammad & Assaf, 1992), contractors and subcontractors (Al-Hammad, 1993; Hinze & Tracey, 1994), maintenance contractors and owners (Al-Hammad, 1995), and owners and designers (Al-Hammad & Al-Hammad, 1996). These problems included such things as insufficient negotiation,

communication, and coordination among relevant project participants. Many researchers have noted that lack of communication and coordination among project participants involved in a construction project accounts for approximately 13% of the total delay causes in construction projects (Sweis, Sweis, Abu Hammad, & Shboul, 2008).

Also, Mortaheb & Rahimi (2010) identified the top 10 causes of interface problems in mega-oil refineries in Iran. They identified the main causes of interface problems and their effects on project completion of the Iranian ongoing oil refineries mega-projects through use of questionnaires. This study concluded with the identification of 65 major causes of interface problems within mega-projects in the Iranian sector. These were categorized into seven main groups, as causes of the interface problems related to (1) the owner, (2) the project, (3) engineering, (4) the contractor, (5) the consultant, (6) procurement, and (7) external issues (Mortaheb & Rahimi, 2010). The top 10 causes of interface problems based on all industry professionals' opinions were classified (Mortaheb & Rahimi, 2010) as (1) "owner late decision for dividing the program into the smaller projects", (2) "lack of key deliverables such as internal and external interface list, and IM plan within FEED package", (3) "owner late decision for hiring qualified project management consultant", (4) "change order issued by owner", (5) "incomplete and unclear scope definition", (6) "poor and slow owner's decision making process", (7) "owner's late in progress payment to contractor", (8) "poor contractor's communication and coordination with other project participants", (9) "contractors poor planning and scheduling", and (10) "consultants delay in reviewing and approving key engineering deliverables".

As well, Mortaheb and Rahimi (2010) identified the effects of the interface problems as (1) time overrun in terms of delay, (2) cost overrun, (3) quality impacts, (4) disputes, (5) arbitration,

(6) litigation, and (7) termination. While the study conducted by Mortaheb and Rahimi (2010) focused on the identification of the major causes of interface problems, the IM factors were not identified using a statistical tool such as factor analysis. Also, the relationships between interface problems and the seven main groups (owner, project, engineering, contractor, consultant, procurement, and external issues) were not examined using statistical tools. The relationships between interface problems and the project performance were not tested using statistical tools such as the multiple-regression model. The sample size in Mortaheb and Rahimi's (2010) research study was not large enough to conduct a statistical analysis, such as factor analysis, but the study concluded with the identification of 65 major causes of interface problems within mega-projects in the Iranian sector. While 70 experts from the Iranian sector participated in this research study, the sample was not sufficient to conduct factor analysis. A summary of the interface problems is shown in Table 2.2. Readers can refer to Appendix II for a detailed list of the collected IM problems and examples under each IM problem.

Many of the aforementioned studies of different types of construction projects outlined interface problems between two parties or more. However, very few studies in the literature have addressed the interfaces among all project participants involved within the construction project. Moreover, many researchers have discussed, reported, and listed one type of interface problems. In addition, few studies have identified the factors that lead to IM conflicts in construction projects by applying statistical tools such as factor analysis. In conclusion, management of interfaces is a necessary activity requiring intensive attention from all participants involved in the project. Consequently, the next section discusses the following question: How to manage the interfaces?

Table 2.2 List of the Collected IM Problems Based on Literature Review

No.	Interface problems	References
1	Insufficient negotiation, communication and coordination among relevant project participants involved in the project	Al-Hammad & Al-Hammad (1996); Al-Hammad (1993, 2000); Ayudhya (2011); Chen et al. (2008); Graumann & Schlei (1982); R. Huang et al. (2008); Ku et al. (2010)
2	Financial difficulties	Al-Hammad & Assaf (1992); Al-Hammad (1995, 2000); Ayudhya (2011); Chen et al. (2008); R. Huang et al. (2008); Ku et al. (2010)
3	Poor decision making	Al-Hammad (2000); Ayudhya (2011); Chen et al. (2008); R. Huang et al. (2008); Ku et al. (2010)
4	Limited skills for labour and engineering	Al-Hammad (1993, 1995, 2000); Ayudhya (2011); Chen et al. (2008); R. Huang et al. (2008); Ku et al. (2010).
5	Materials procurement problems	Al-Hammad (2000); Chen et al. (2008)
6	Construction process problems	Al-Hammad (1993, 2000); Ayudhya (2011); Chen et al. (2008)
7	Engineering process problems related to interfaces	Al-Hammad & Assaf (1992); Chen et al. (2008)
8	Project site issues	Chen et al. (2008)
9	Information problems	Chen et al. (2008)
10	Lack of project management	Chen et al. (2008); Mortaheb & Rahimi (2010)
11	Lack of IM	Chen et al. (2008)
12	Planning and scheduling problems	Chen et al. (2008); R. Huang et al. (2008); Ku et al. (2010)
13	Imprecise project cost estimate	Al-Hammad & Al-Hammad (1996); Al-Hammad (2000); Ayudhya (2011); R. Huang et al. (2008); Ku et al. (2010)
14	Discrepancies among the owners' expectations regarding project construction schedule, cost. and quality	Ku et al. (2010)
15	Lack of personal experience of the project teams	Al-Hammad & Al-Hammad (1996); R. Huang et al. (2008); Ku et al. (2010)
16	Inability to predict and resolve project's problems related to new technological techniques and materials	Ku et al. (2010)

Table 2.2 cont'd

No.	Interface problems	References
17	Contractor's unfamiliarity with the environmental circumstances and local weather	Al-Hammad (1995)
18	Lack of knowledge about site circumstances by the project team members	Al-Hammad & Assaf (1992)
19	Increase project interfaces conflicts when different contractors insist on their points of view	Ku et al. (2010)
20	Insufficient and inaccurate work drawings and specifications	Al-Hammad & Al-Hammad (1996); Al-Hammad (1993, 2000); Ayudhya (2011); Chen et al. (2008)
21	No proper work packaging design and subcontracting because of many reasons	Chen et al. (2008)
22	Slow submission and approval of change orders, permits, and shop drawings	Al-Hammad (1993, 2000); Ayudhya (2011); Chen et al. (2008); Ku et al. (2010)
23	Unclear contract details and badly written contract	Al-Hammad & Al-Hammad (1996); Al-Hammad (2000); Ayudhya (2011); R. Huang et al. (2008)
24	Delay in established schedule of engineering, procurement, and construction, and delay in owner approval of completed tasks	Al-Hammad (1995)
25	Application of fast-track engineering and construction techniques	Al-Hammad & Assaf (1992)
26	Weather and climate conditions problems	Al-Hammad (2000); Ayudhya (2011); Chen et al. (2008); R. Huang et al. (2008)
27	Unexpected changes in materials and labour availability and cost	Al-Hammad (1993, 2000); Ayudhya (2011); Chen et al. (2008); R. Huang et al. (2008); Ku et al. (2010).
28	Geotechnical circumstances problems	Al-Hammad (2000); Chen et al. (2008); R. Huang et al. (2008); Ku et al. (2010).
29	Inexperience with government auditing protocols and procedures	R. Huang et al. (2008); Ku et al. (2010)
30	Inexperience with local laws and other government regulations and modification in laws and regulations	Al-Hammad (2000); R. Huang et al. (2008); Ku et al. (2010)
31	Inexperience with building codes, and "trade union practices"	Al-Hammad & Assaf (1992); Chen et al. (2008)

2.4 Definition and Analysis of Interface Management

How to Manage Interfaces?

The rise of dynamism and complexity within construction projects has imposed many interfaces among various project participants engaged within these projects. Shokri et al. (2012) state that “industry leaders in mega construction projects believe that IM will improve alignment between parties and reduce project issues and conflicts”. (Therefore, the concept of IM becomes important. IM is a comparatively new topic in project management. It is not widely recognized what subjects are enclosed under this project management area (Chen et al., 2007).

Many researchers have reported many definitions of IM. The Project Management Institute describes IM as “the management of communication, coordination and responsibility across a common boundary between two organizations, phases, or physical entities which are interdependent” (Project Management Institute, 2003). A common boundary is the point where an two or more parties come together; these are usually set out in contracts (Bible et al., 2014). “In essence, interface management is the glue that holds a project together” (Crumrine et al., 2005). “IM as an effective method in recognizing and communicating interfaces between project parties and construction components, is an essential tool in successful execution” (Shokri et al., 2012). Healy (1997) defined IM as “the management of the interdependencies and responsibilities across the boundary of the interface”. Stuckenbruck (1983) mentioned that IM is part of project integration and involves “identifying, documenting, scheduling, communicating and monitoring interfaces related to both the product and the project”. IM is successful in dealing with complex projects (Chen et al., 2007).

Wideman (2002) provided two meanings of IM within construction projects: the first meaning is “the management of communication, coordination and responsibility across a common boundary

between two organizations, phases, or physical entities which are interdependent”. The second meaning is “managing the problems that often occur among people, departments, and disciplines rather than within the project team itself”. Mortaheb and Rahimi (2010) defined IM within oil refineries’ mega projects as “the management of borders and boundaries between different project players, including designers and contractors, contractors and sub-contractors, owners and licensors, owners and designers, owners and contractors, as well as common interface problems among various construction participants to enhance management of the resources, costs, schedules, safety, risks, contracts, and systems in order to create a dynamic, organized, and active environment during project execution of oil refineries mega projects”. Fellows and Liu (2012) use the term “boundary management” to discuss the business organizational boundaries/interfaces. This paper aims “to explore boundary management on engineering construction projects to address issues of fragmentation and of performance”. Generally, different perspectives have been used to define the organizational boundaries such as cross-system interfaces (Yan & Louis, 1999). The “cross-system interfaces” perspective focuses on “the interdependent relations and cross-boundary transaction between systems” (Yan & Louis, 1999) that matches the aforementioned definitions of interface management and projects’ interfaces.

On the other hand, IM must be continued through the life of a project; its objective is to keep all aspects of the project (scope, time, cost, quality, and resources) in balance (Crumrine et al., 2005). Many researchers emphasized that project performance, in terms of quality, scope, time, and schedule, safety, will be improved by implementing IM at the early stages of the project (Caglar & Connolly, 2007; Chen et al., 2007; Shokri et al., 2012). Failure to properly manage interfaces impacts project scope control, quality, schedule, cost, safety, and resources (Crumrine

et al., 2005; Mortaheb & Rahimi, 2010; Pavitt & Gibb, 2003). “The failure of IM may result in low productivity, low quality construction, problems, and increased cost” (Chen et al., 2008). Shokri et al. (2012) mentioned that “Poor management of interfaces may result in deficiencies in the project cost, time, and quality during the project life cycle execution, or may result in failures after the project has been delivered”.

Consequently, the critical relationship between project success and IM is expanded continuously in the literature (Morris, 1983; Pavitt & Gibb, 2003; Stuckenbruck, 1983). Chen et al. (2007) reported and listed the benefits of including IM in the construction process as follows: (1) deal with project difficulty by classifying and reporting the best IM practices that can be used and applied in future projects, (2) meet customer desires by improving design in terms of risk, cost, quality, etc., (3) facilitate a well-organized construction project delivery system, 4) decrease the uncertainties within the construction projects and regulate the work flow for different types of interfaces, (5) build good relationships among different project participants involved in construction projects to get effective communication, coordination, and cooperation among them, (6) minimize project complexity by improving subcontracting and work packaging, (7) identify the interfaces at an early stage of the project, which will minimize interface issues within the project phases, and (8) assist project participants to have a deep understanding of project difficulty.

Successful project management can be achieved through managing both internal and external interface problems.

Chen et al. (2008) outlined the causes of interface issues through six perspectives, namely, documentation, resources, processes/methods, people/participants, project management, and environment. In addition, five different domains have been proposed in order to analyze IM,

namely, technology interfaces, contract interfaces, monitor interfaces, execution integration interfaces, and the interacting behavior in the interface (R. Huang et al., 2008). “The execution integration interface is considered to be the most comprehensive and practical to understanding IM in construction projects” (R. Huang et al., 2008). Investigations and lessons learned concluded that poor IM and organization are the main factors causing major delay during the execution phase, which impact the relationships among a project’s scope, cost, quality, time, and resources (Mortaheb & Rahimi, 2010). During the execution phase, construction projects involved many participants that have contracts with each other, such as suppliers, executives, designers, and sub-contractors. While many parties that have contracts with one another are involved in construction projects, the main contractor possesses the power to control and combine the execution phase, as shown in Figure 2.3. Because of that, effective IM must integrate all the managerial and practical issues among engaged project members and manage their communication. If not, interfaces can happen, causing loss to all project members engaged in the construction projects (R. Huang et al., 2008).

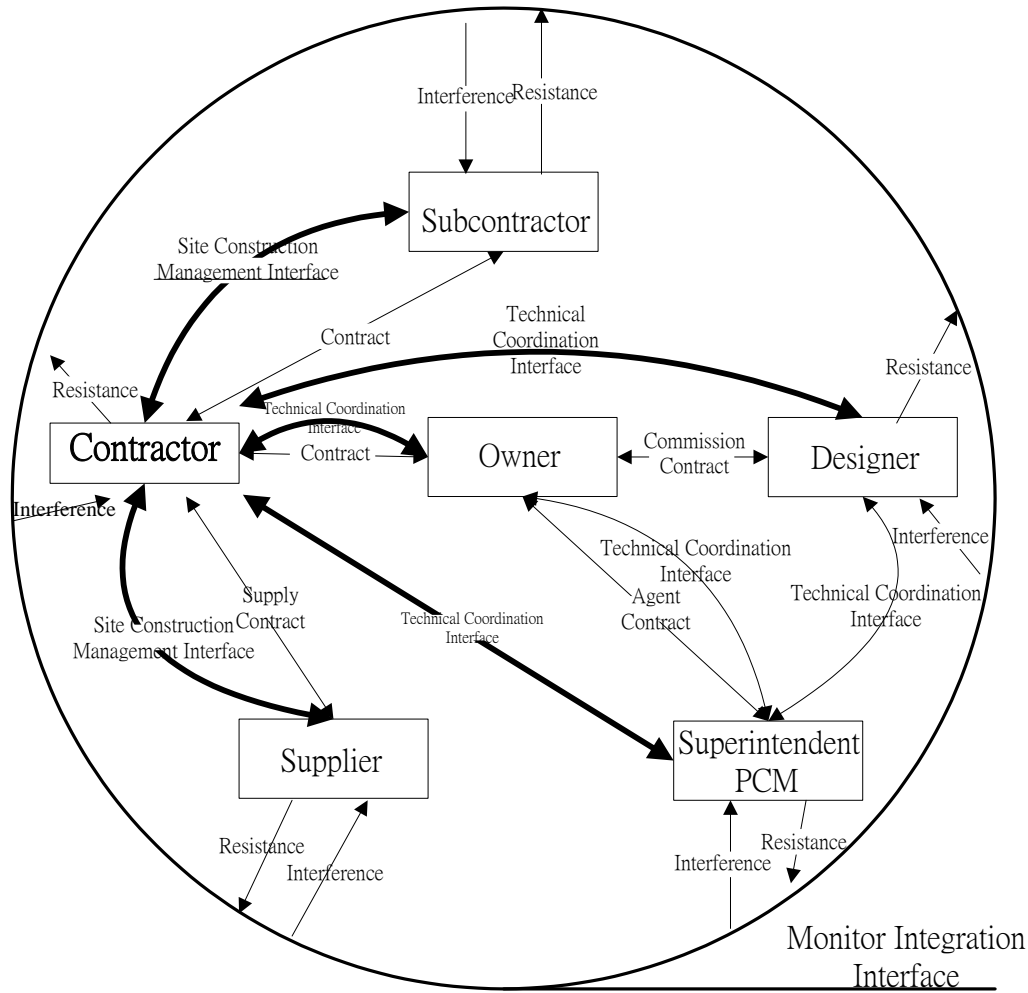


Figure 2.3 Execution of Construction Interface, source R. Huang et al. (2008), with permission from the authors

Lin (2009) proposed an IM procedure in five phases: interface finding, interface identifying, interface communicating, interface recording, and interface closing. Moreover, Caglar and Connolly (2007) identified the interface management process in six steps as follows: (1) identification and recording an interface, (2) creating an interface agreement, (3) agreeing/resolving conflict, (4) monitoring the status, (5) reporting the status, and (6) closing the interface agreement. Godinot (2003) identified five strategies to manage interfaces as follows: interface definitions, visibility, communication, control, and response to interface

issues. Finally, for efficient IM the project control is very important. Caron, Marchet, and Perego (1998) state that “the management of the interface between two successive phases is critical in guaranteeing the integration of the overall project”. Morris (1983) emphasized that the transitions from one phase to another one need to be managed carefully in terms of organization, planning, direction, and control. In conclusion, to address the complexity of interface problems, Mortaheb and Rahimi’s (2010) comprehensive definition for mega-oil refineries is adopted in this study. Therefore, interface management is defined as the management of borders and boundaries, relationships, and information transfer among different project actors including architects, engineers, construction contractors, sub-contractors, owners, and others. It also covers management of dual and multiple interface problems among the participants in various project life-cycle phases to enhance management of the costs, schedules, safety, quality, scope, and teamwork in order to create a dynamic, organized, and active environment during the project life cycle and in particular during the engineering/design phase.

2.5 Approaches to Exploring Interface Management Problems and Issues

Many researchers have provided various approaches to investigate, identify, and classify interface problems in different types of projects:

1. Many researchers have also identified, reviewed, and reported the interface problems in different countries within varying types of projects through a comprehensive literature review, pilot studies, and interviews with experts from industry and questionnaires in different countries without applying statistical techniques (Al-Hammad & Al-Hammad, 1996; Al-Hammad & Assaf, 1992; Al-Hammad, 1990, 1993, 1995, 2000). For instance, Mortaheb and Rahimi (2010) set up a research study of the Iranian ongoing oil refineries mega-projects to identify the main causes of the interface problems and their effects (impacts) on project

completion through questionnaires without applying statistical techniques such as factor analysis, multiple-regression model, etc.

2. Multi-perspective approach: Chen et al. (2008) presented the multi-perspective approach to investigate the causes of interface problems in different construction projects (residential construction, offshore construction, and commercial construction) by using “the Cause and Effect (C&E) diagram method”. The Cause and Effect (C&E) diagram method was proposed by Ishikawa in 1968 (Ishikawa, 1968). This method uses a hierarchical prepared approach to identify and categorize the level of implication of each cause of the problems as major causes, minor causes, and sub-factors, as shown in Figure 2.4 and Figure 2.5. Although this approach provided a holistic view of interface problems and a comprehensive cause of the interface issues, it is only a graphical tool and does not provide any numerical values, such as the impact or severity of each interface problem.

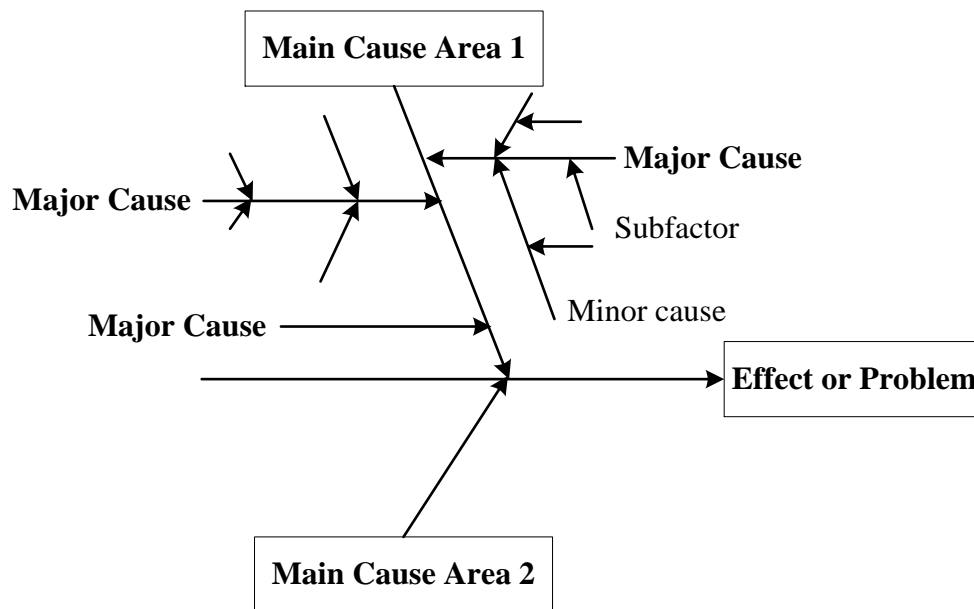


Figure 2.4 C&E Diagram Method, source Chen et al. (2008), with permission from ASCE.

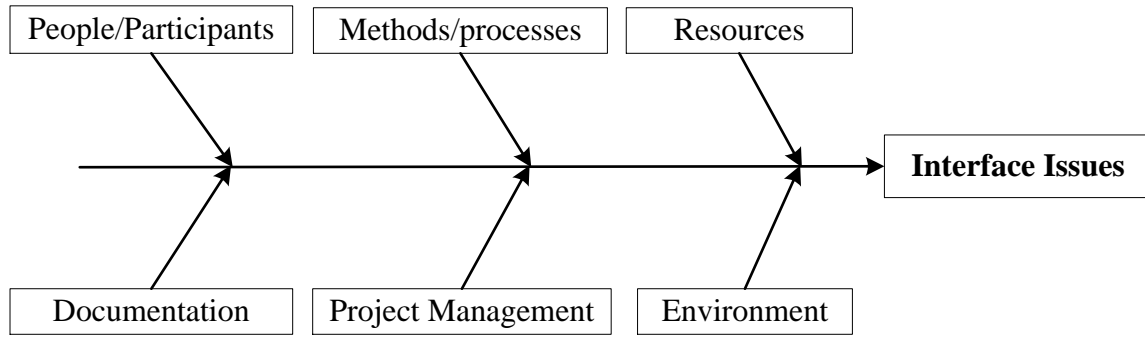


Figure 2.5 Research Method of C&E Diagram, source Chen et al. (2008), with permission from ASCE. Notice: “This material may be downloaded for personal use only. Any other use requires prior permission of the American Society of Civil Engineers”.

3. Other researchers identified the interface problem factors in different construction projects using both qualitative and quantitative statistical approaches using two statistical tools (factor analysis and multiple regression models). For instance, R. Huang et al. (2008) and Ku et al. (2010) have named the factors that cause IM conflicts in mass rapid transit system (MRTS) construction projects by applying statistical tools in two stages. The first stage consisted of a literature review, pilot studies, and face-to-face interviews with experts from industry to identify the interface problems. The second stage developed a questionnaire survey. This approach is considered to be appropriate for this research study because it combines both qualitative and quantitative methods. Combining both qualitative and quantitative methods increases the reliability of the results. Using both methods may result in the finding of unseen variances that otherwise might have been ignored through the use of a single method (Hewage, 2007). Pole (2007) stated that “mixed methods research can provide for stronger inferences because the data are looked at from multiple perspectives. One method can provide greater depth, the other greater breadth and together they confirm or complement each other”.

4. There are some other approaches, such as Work Breakdown Structure (WBS), to manage the interfaces between systems and activities (Chua & Godinot, 2006).

2.6 Project Performance Measurement

A brief summary of project performance measurement techniques and the relevant indicator has been outlined here to provide a better understanding of the impact of IM on project performance. Traditionally, in construction projects performance measurement is based on quality, time, and cost, which are defined as the iron-triangle (Walker, 1995). During the last two to three decades, performance indicators have changed and many new aspects of project performance have been included. These are primarily used for benchmarking purposes and have been used for controlling the performance during the project lifecycle (Haponava & Al-Jibouri, 2009). For instance, in 1992 performance measures were developed to measure project success among owners, designers, and contractors (Sanvido et al., 1992), based upon an agreement that successful projects have to meet the budget and the schedule, have no legal claims, and meet the profit goals. Weston and Gibson (1993) and Schmader and Gibson (1995) measured many project performance indicators in terms of value engineering savings, change-order cost, cost growth, schedule growth, and claims cost. Pocock, Hyun, Liu, and Kim (1996) presented an approach for measuring the relationship between the project participants' communication and project performance indicators in terms of cost growth, schedule growth, number of contract modifications, claims cost, value-engineering savings, and safety information. Performance measurements that have been established for benchmarking in different countries, namely the USA (CII, 2000), Chile (Corporación de Desarrollo Tecnológico [CDT], 2002), the UK (Key Performance Indicators Working Group [KPI], 2003), and Brazil (Costa et al., 2004b), are as described below.

A. Construction Industry Institute (CII) Benchmarking System

Although the CII Benchmarking and Metrics Program commenced in 1993, the first data collection was in 1996 (CII, 2000; Costa et al., 2004a) and included the following:

1. Cost: project cost growth, project budget factor (contractor data only), phase cost factor (owner data only), and phase cost growth (owner data only);
2. Schedule: project schedule growth, project schedule factor (contractor data only), phase duration factor (owner data only), total project duration, and construction phase duration;
3. Safety: recordable incident rate (RIR) and lost workday case incident rate (LWCIR);
4. Changes: change cost factor;
5. Rework: total field rework factor.

B. National Benchmarking System for the Chilean Construction Industry:

The National Benchmarking System for the Chilean Construction Industry was launched by the Corporation for Technical Development (Corporación de Desarrollo Tecnológico) of the Chilean Chamber of Construction (Camara Chilena de la Construcción) in 2001. This measurement system includes a group of performance indicators: deviation of cost, deviation of construction due date, change in amount contracted, accident rate, risk rate, efficiency of direct labour, productivity, rate of subcontracting, client cost complaints, urgent orders, and planning effectiveness” (CDT, 2002; Costa et al., 2004a). These performance indicators are differentiated for five sub-sectors of the construction industry: high-rise or low-rise buildings, heavy or light industrial construction, and civil works (CDT, 2002; Costa et al., 2004a).

C. Key Performance Indicators in the UK

The KPI Program was developed by the UK Best Practice Program in 1998. The aim of this program was to facilitate the measurement of project and organizational performance. In

November 2000 the first group of KPIs was created (Costa et al., 2004a; KPI, 2003) and are client satisfaction–product, client satisfaction–service, construction cost, construction time, defects, predictability-cost, predictability-time, profitability, productivity, and safety (Costa et al., 2004a; KPI, 2003).

D. Performance Measurements System for the Brazilian Construction Industry (SISIND)

The SISIND was launched in 1993 and consists of the following indicators: time deviation, non-conformity index for critical processes, percentage of plan completed (PPC), supplier performance, degree of user satisfaction (product), sale time, ratio between the number of accidents and total man-hour input, construction site best practice index, and degree of internal client (worker) satisfaction (Costa et al., 2004b).

The aforementioned studies measure project performance according to a few indicators. Insufficient project performance measurement is one of the major problems that affect the construction industry (Costa et al., 2004a; Costa et al., 2004b). In terms of quality of the built facilities and project performance, interface problems and issues have been recognized to considerably harm the construction industry (Chen et al., 2010). Despite project performance measurements being a very significant topic in the construction industry, the data on project performance measurements are very limited. The review revealed that there is no standard method for measuring project performance (Costa et al., 2004a; 2004b). Table 2.3 summarizes the most common indicators that have been used for the assessment of project performance in the literature review.

Therefore, it is necessary to measure the impact of the IM on project performance indicators. This study examine the relationships between the IM factors and the basic project performance

indicators (quality management, schedule management, cost management, scope management, safety management, and teamwork) using the multiple regression technique.

Table 2.3 The Common Used Project Performance Indicators by Previous Studies

Indicator	Definition	Reference
Field rework factor	The ratio of total direct cost of field rework to actual construction phase cost	CII (2000)
Schedule deviation (total duration, phase duration)	Percent difference between original and actual schedule	Alarcón & Ashley (1996); CDT (2002); CII (2000); Griffith, Gibson, & Hamilton (1999); KPI (2003); Pocock, Hyun, Liu, & Kim (1996); Sanvido, Grobler, Parfitt, & Coyle (1992); Weston & Gibson (1993)
Cost deviation (total cost, phase cost)	Percent difference between original and actual cost	
Change cost factor	Total cost impact of changes, which is a ratio of total cost of changes to actual total project cost	CII (2000)
Urgent orders	Number of urgent orders divided by total number of orders in procurement phase	CDT (2002)
Subcontracting	Subcontracted costs divided by total project cost	
Quality (defects)	The ratio of cost of repairing defects to total project cost	KPI (2003)
Safety (incident rate)	The number of incidents that a company experiences per a defined number of full-time employees in any given time	CDT (2002); KPI (2003)
Safety (lost workday incident rate)	The number of lost work days per a defined number of full-time employees in any given time frame	CII (2000)
Number of contract modifications	Number of contract modifications	CDT (2002); Pocock et al. (1996)

Table 2.3 cont'd

Indicator	Definition	Reference
Percent amount of contract modification	The percent ratio of total cost of contract modification to the contract value	CII (2000)
Number of claims	Number of claims	Weston & Gibson (1993)
Percent amount of claims	The percent ratio of total cost of claims to the contract value	Weston & Gibson (1993)
Value engineering savings	The percent ratio of total savings obtained by calculating the ratio of value engineering practices to the total project cost	Weston & Gibson (1993)
Client satisfaction	It is measured based on questionnaire survey and state of award	KPI (2003); Yu, Kim, Jung, & Chin (2005)
Productivity	The ratio of the output of a system to the inputs that are used to produce that output	KPI (2003); CDT (2002)

2.7 Areas for Improving Interface Management

Mortaheb and Rahimi (2010) provided a list of recommendations for each project party (owner, contractor, consultant, and engineering) to improve IM of oil refinery mega-projects. These areas can be summarized for each party (owner, contractor, consultant, and engineering), e.g., split the program of the project at the end of the front-end loading (FEL) phase by the engineering designer into sub-programs and prepare the internal and external interfaces list. A summary of areas for improving the IM is shown in Table 2.4. The areas for improving IM were divided into hard and soft by the researcher. The soft actions can be defined as the actions that need more discussion, communication, engagement, and coordination among different project participants. The hard actions can be defined as the actions that need a hard document to be circulated among the parties involved in a project. Mortaheb and Rahimi's (2010) research study provided a list of the areas for improving IM, but did not quantify these areas. In addition, this list of areas is specific to oil refinery mega-projects only and may not apply to all construction projects. The Center for Chemical Process Safety (CCPS) (2004) identified the application of management and communication techniques among different project participants involved in the projects to improve IM. Pavitt and Gibb (2003) identified areas for improving IM within construction projects, with specific reference to "building façade interface", using questionnaires as shown in Table 2.4. The areas for improvement are ranked from the highest to lowest as follows: (1) "identify the interface responsibility as early as possible", (2) "appoint the specialist contractor earlier", (3) "develop tools that identify and aid interface management", (4) "standardize interface designs", and (5) "improve programming and sequencing at site level". Hence, the identification of interface responsibilities as early as possible was ranked as the best area for improving the IM. This indicates that if the responsibilities of different project

participants are identified during the early stages of the project, the problems can be solved before construction. In addition, appointing a specialist contractor earlier ranked second. The response rate was 38%, which is considered to be a good response rate in statistics (Tabachnick & Fidell, 2001). Pavitt and Gibb's (2003) research study was with specific reference to building façade interface. Therefore, the findings of this research study cannot be generalized. In addition, Alarcón and Mardones (1998) identified three areas for improving IM, namely: (1) implementing engineering, procurement, and construction standards, (2) coordinating among multi-disciplines and specialties, (3) controlling the circulation of data within the project teams. In conclusion, it is important to note that research on areas for improving IM is very limited. Most have identified possible solutions, but no one attempted to quantify them and/or assess their impact on project performance. In addition, some researchers have reported the procedures or areas for improving IM in particular parts of the construction projects and/or in a specific sector. However, none of them list areas for improving IM among all project participants involved in a construction project. Table 2.4 provides a list of the areas for improving IM based on the literature review.

Table 2.4 List of the Areas for Improving the IM Based on Literature Review

No.	Procedures or Areas	Done by	Hard	Soft
1	Split the program of the project at the end of the front-end loading phase into sub-programs (Mortaheb & Rahimi, 2010)	Engineering designer	✓	
2	Prepare the internal and external interfaces list and IM plan (Mortaheb & Rahimi, 2010)	Engineering designer	✓	
3	Approve the design on time and pay the contractor on time (Mortaheb & Rahimi, 2010)	Owner	✓	
4	Clearly define the scope of project (Mortaheb & Rahimi, 2010)	Owner	✓	
5	Use appropriate tools for choice of contractors (Mortaheb & Rahimi, 2010)	Owner	✓	
6	Resolve any problem related to the interface issues (Mortaheb & Rahimi, 2010)	Owner		✓

Table 2.4 cont'd

No	Procedures or Areas	Done by	Hard	Soft
7	Strong understanding of the owner's requirements and the local law and regulations (Mortaheb & Rahimi, 2010)	Contractor		✓
8	Schedule, plan, and monitor the interface problems with other project participants (Mortaheb & Rahimi, 2010)	Contractor	✓	
9	Communicate and coordinate with other project participants (Mortaheb & Rahimi, 2010)	Contractor		✓
10	Accelerate the design events in terms of interface issues	Engineering designer		✓
11	Arrange for weekly, bi-weekly, and monthly meetings to discuss the interface issues (Mortaheb & Rahimi, 2010)	–		✓
12	Reduce disagreements or errors in engineering deliverables (Mortaheb & Rahimi, 2010)	Engineering designer	✓	
13	Use 3D computerized modeling software (Mortaheb & Rahimi, 2010)	–	✓	
14	Provide the project with an interface manager (Mortaheb & Rahimi, 2010)	–	✓	
15	Identify the interface responsibility as early as possible (Pavitt & Gibb, 2003)	–	✓	
16	Appoint the specialist contractor earlier (Pavitt & Gibb, 2003)	–	✓	
17	Develop tools that identify and aid interface management (Pavitt & Gibb, 2003)	–	✓	
18	Improve programming and sequencing at site level (Pavitt & Gibb, 2003)	–	✓	
19	Standardize interface designs (Pavitt & Gibb, 2003)	–	✓	
20	Implement engineering, procurement, and construction standards (Alarcón & Mardones, 1998)	–	✓	
21	Coordinate among multi-disciplines and specialties (Alarcón & Mardones, 1998)	–		✓
22	Control the circulation of data within the project teams (Alarcón & Mardones, 1998)	–	✓	

2.8 Typical Lifecycle Project (Phases)

This research study was applied to different sectors of construction, mainly: (1) oil and gas and (2) commercial and buildings. The following section provides example of only the construction projects research area, namely, commercial and building.

2.8.1 Commercial and building projects

Building projects were developed from inception to completion, as shown in Table 2.5, which illustrates five main phases and deliverables of a typical life cycle adopted from The Royal Institute of British Architects (RIBA, 2007) . These phases include (1) preparation, (2) design, (3) pre-construction, (4) construction, and (5) use, as shown in Table 2.5.

Table 2.5 Typical Life Cycle from the Royal Institute of British Architects (RIBA, 2007)

Phases	Phase 1 Preparation	Phase 2 Design	Phase 3 Pre-Construction	Phase 4 Construction	Phase 5 Use
Stages	A. Inception B. Feasibility.	C. Outline proposals D. Scheme design E. Detail design	F. Production information G. Bills of quantities H. Tender action	J. Project planning K. Operations on site	L. Completion M. Feedback
Deliverables	Identifications of clients' needs, objectives, and business case	Preparation of concept design	Preparation of final production information, i.e., drawings, schedules, and specifications	Appointing the contractor	Administration of the building contract after practical completion and making final inspections
	Preparation of feasibility studies and assessment of options	Development of concept design	Preparation of bills of quantities and tender documents	Issuing of information to the contractor	Assisting building user during initial occupation period
	Carry out studies of use requirements, site conditions, planning, design, and cost	Preparation of technical design(s) and specifications	Procedure for selective tendering	Arranging site handover to the contractor	Review of project performance in use
	Identification of procurement method; appoint architect	Full design of every part and component of the building; complete cost checking of design		Administration of the building contract to practical completion; Review of information provided by contractors and specialists	

Finally, this review of the literature revealed that the focus of previous studies has been on identification of the interface issues through different perspectives and domains and not on the identification of the IM factors. None of the previous studies develop models between underlying interface problem factors and project performance indicators. In addition, they do not develop a conceptual framework to study the IM relationships among owner, contractor, and designer using the UML use case diagrams.

The next section identifies the gaps and room for improvement in details and how this research study plans to address these gaps.

2.9 Project Delivery Methods (Systems)

Many organizations have identified and classified several project delivery methods (PDS), such as design-bid-build, design-negotiation-build, design-build (The Construction Specifications Institute [CSI], 2004).

The design-bid-build is the traditional delivery method for public sector. Based on the contract documents (drawings, specifications, and necessary information), the design-bid-build consists of the competitive bid and lump sum construction contracts. The contract documents are prepared by the architects and engineers. The design-bid-build consists of the following phases: 1) project conception, 2) design, 3) construction documents, 4) competitive bidding, and 5) construction. The owner secures competitive bids from contractors based on the contract documents that were developed by the design team (engineers, architects). Based on an accepted bid, the owner signs a contract with the selected contractor for construction of the project.

On the other hand, **Design-Negotiation-Build** is an informal process as only one contractor is involved in developing the cost and negotiating a contract in order to construct the project (CSI, 2004). In design-bid-build and design-negotiation build methods, the pricing stage has to be

started after the design has to be completed. The main reason behind the using of design-negotiation build method is to finalize the project in less time comparing to the design-bid-build method.

On other hand, **Design-Built** delivery method is process as the owner has single agreement/contract with only single party (designer-builder) to complete the design and the construction phases of the project (CSI, 2004). The main reason behind the using of the design-built delivery method is the owner's need only one single entity to be responsible to perform the design and the construction of the project.

2.10 Summary (Identified Gaps/Room for Improvement) and Connection with the Next Chapters

Although there is no consensus among researchers about the meaning and classifications of IM and the interfaces, many discuss the border and boundary conditions between physical elements/components, tools, equipments, phases, systems, people, organization, occasions, processes, and others.

The construction industry still has many things that we do not know, and this justifies more research, especially into the interface among project participants involved within construction projects. After review of the literature, the following gaps in knowledge and practices in the area of IM were identified.

1. Few studies have identified the IM problems among all project participants involved within the construction project lifecycle.
2. While several studies related interface problems and issues in different projects, few previous studies have identified the factors that contribute to IM conflicts in construction projects by applying statistical tools. In addition, none of previous studies have investigated the

relationships between IM factors and company types, industry types, and respondent's title/position and years of experience.

3. Previous studies have considered a limited number of the factors that contribute to IM conflicts in construction projects.
4. Some studies measure project performance according to a few indicators.
5. None of the previous studies list areas for improving IM among all project participants involved in construction project.

Overall, most of the previous studies focused on the identification of IM problems and not on the identification of the IM factors using statistical tools such as factor analysis. Previous studies have considered a limited number of the factors that contribute to IM conflicts in construction projects. This study adopts a comprehensive analytical approach to identify factors to be considered in the quantification model. Moreover, this research study aims to address the interface problems among all project participants involved within construction projects. In addition, relationships between IM factors and company type, industry types, experience types, and a participant's level of education were not examined in the previous studies using statistical tools. This research aims to investigate relationships between IM factors and company types, industry types, and respondent's title/position and years of experience and to identify the top 10 problems affecting each aspects of IM.

In sum up, this study attempts to bridge existing knowledge gaps in four areas: (1) focusing on the impact of IM factors on project performance indicators: quality management, schedule management, cost management, scope management, safety, and teamwork, (2) developing conceptual framework using The Royal Institute of British Architects (RIBA) structure to highlight the critical IM areas during different project phases, (3) developing use case models to

study the IM relationships among owner, contractor, and designer (architects, engineers) using UML use case diagrams, and (4) providing suggestions for improving and enhancing IM that are adequate to all project participants engaged in different construction projects.

The next chapter provides details of the research methodology.

Chapter Three: Research Methodology

3.1 Chapter Overview

The chapter defines the research methodology. It also explained the purpose for choosing the approach adopted. Parts of the material in this chapter and in this thesis were included in Weshah et al. (2012a, 2012b, 2014a, 2014b, 2014c, 2014d, 2013a, 2013b).

3.2 Research Design and Approach

This section provides and discusses the research design and approaches for this research study that was conducted throughout the project lifecycle and particularly during the engineering/design phase as shown in Figure 3.1. This research study used both qualitative and quantitative approaches (mixed methods) and had direct contact with practitioners to collect and analyze the research information. Using of mixed methods (combination of qualitative and quantitative methods) is more common, which increases the reliability of the results. The use of mixed methods may uncover the unseen variances that otherwise might have been ignored through the use of a single method (Hewage, 2007). Pole (2007) mentioned that “mixed methods research can provide for stronger inferences because the data are looked at from multiple perspectives. One method can provide greater depth, the other greater breadth and together they confirm or complement each other”.

This research study has been approved by the Conjoint Faculties Ethics Board of the University of Calgary (No. 7281); please see Appendix I. This study explored the interface management (IM) problems throughout project lifecycle and during the engineering/design phase and introduced a new approach for evaluating and analyzing the impact of IM on project performance indicators. For more details, a study was conducted to categorize the IM factors contributing to interface conflicts among project participants engaged in construction projects. A

comprehensive literature review followed by industry pilot studies was conducted through reviewing journals papers, previous relevant studies, and conference proceedings. In this study, structured interviews were conducted around a major question; what are the interface problems that may arise among different project participants involved in construction projects in Alberta? A complete literature review and pilot studies in industry were performed, as shown in Figure 3.1. While the pilot study concluded with the recognition of 16 major interface problems, the literature review concluded with the recognition of 31 major interface problems, as shown in Table 3.1. Therefore, the literature review (31 IM problems) and the pilot interviews (16 IM problems) concluded with the recognition of 47 major interface problems. Based on the 47 interface problems, two web-based online surveys were performed with participants from industry throughout the project lifecycle and during the engineering/design phase, as shown in Appendixes III and IV. While the first survey was conducted to study the interfaces throughout the project lifecycle phase with 47 interface problems, the second survey was conducted to enhance the IM during the engineering/design phase within construction projects with 22 interface problems, as shown in Figure 3.1. Out of 47 IM problems collected throughout the project lifecycle, 22 IM problems were found applicable to the engineering/design phase, as shown in Table 3.1.

In general, the research surveys questions were designed based on the interface problems and issues and on the following project performance indicators: quality management, schedule management, cost management, scope management, safety, and teamwork, as shown in Table 3.2. As can be seen in Table 3.2, the responses to the two questionnaires in this study were obtained to build a six-point Likert scale with the end points being 1 = negligible and 6 = disastrous and 1= unimportant and 7 = very important. The two likert scales (six-point Likert and

seven-point Likert scales) have the same effect in the analysis of the data. Therefore, this research adopted the six and the seven likert scales.

Using Alberta's data, this study was conducted in three phases (see Figure 3.2). Figure 3.2 shows the conceptual research framework (theoretical framework) for modeling the impact of IM on construction project performance throughout the project lifecycle phase and during the engineering/design phase.

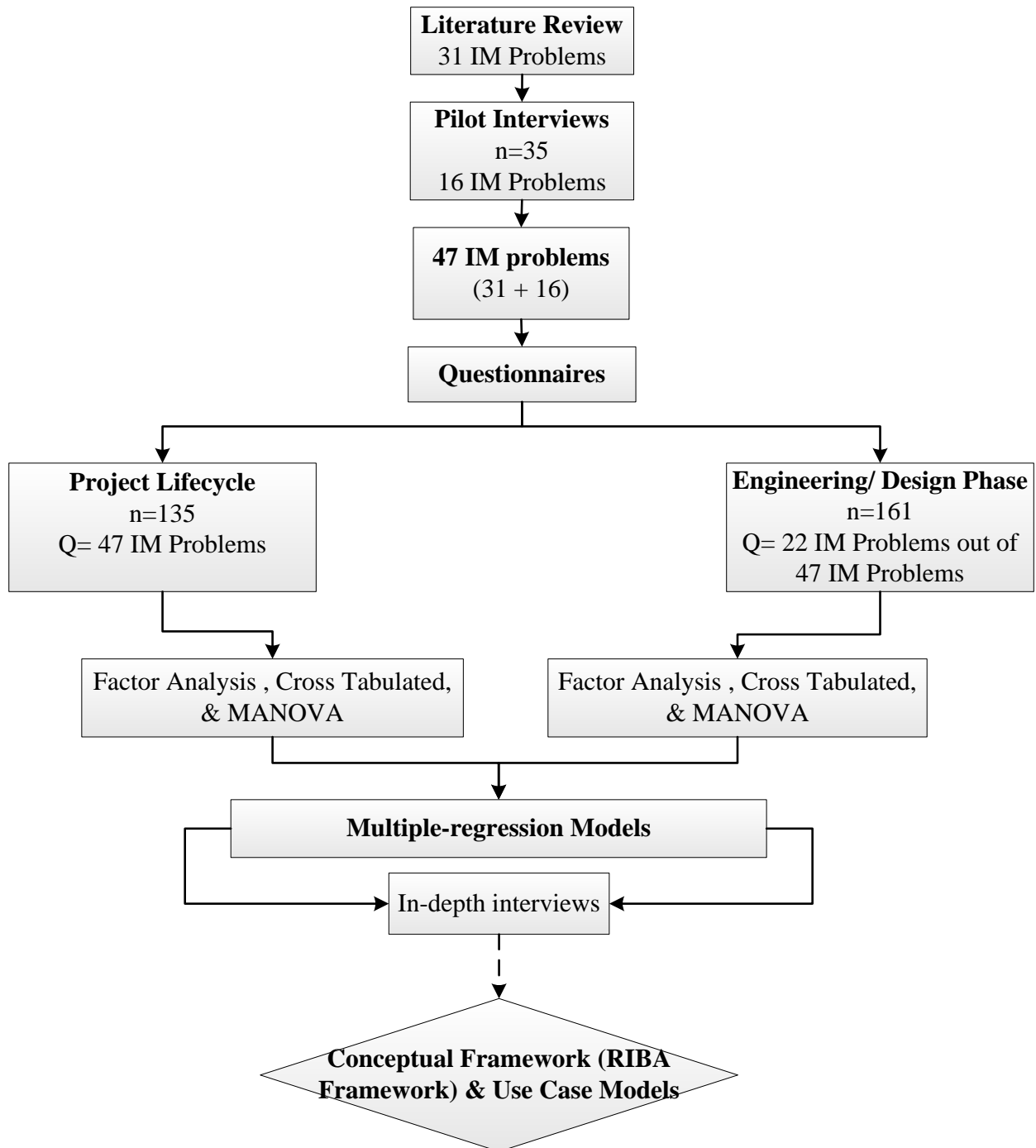


Figure 3.1 Overall Research Methodology

Table 3.1 List of the Collected IM Problems Based on Literature Review and Pilot Study (Project lifecycle and engineering design phase) (Unranked)

No.	Interface problems	Lit Rev. <i>n</i> = 31	Pilot <i>n</i> = 16	Project Lifecycle <i>n</i> = 47	Eng./ Design <i>n</i> = 22
1	Lack of enough negotiation and communication and coordination	✓		✓	✓
2	Financial difficulties	✓		✓	✓
3	Poor decision making	✓		✓	✓
4	Limited skills for labour and engineering	✓		✓	✓
5	Materials procurement problems	✓		✓	
6	Construction process problems	✓		✓	
7	Engineering process problems related to interfaces	✓		✓	✓
8	Project site issues	✓		✓	
9	Information problems	✓		✓	✓
10	Lack of project management	✓		✓	✓
11	Lack of IM system	✓		✓	✓
12	Planning and scheduling problems	✓		✓	✓
13	Type of organization structure		✓	✓	✓
14	Interfaces with other interdependent projects		✓	✓	✓
15	Undefined reporting structure and responsibilities		✓	✓	✓
16	Interfaces arise because of the application of the project development gating (or phases) system		✓	✓	
17	Insufficient or lack of alignment among WBS, CWBS, CBS, and OBS		✓	✓	✓
18	Imprecise project cost estimate	✓		✓	
19	Discrepancies between the owners' expectations regarding project construction schedule, cost, and quality	✓		✓	
20	Lack of personal experience of the project teams	✓		✓	✓
21	Inability to predict and resolve project's problems related to new technological techniques and materials	✓		✓	
22	Contractor's unfamiliarity with the environmental circumstances and local weather	✓		✓	
23	Project team members' lack of knowledge about site circumstances	✓		✓	
24	Increased project interfaces conflicts when different contractors insist on their points of view	✓		✓	

Table 3.1 cont'd

No.	Interface problems	Lit Rev. <i>n</i> = 31	Pilot <i>n</i> = 16	Project Lifecycle <i>n</i> = 47	Eng./ Design <i>n</i> = 22
25	Lack of trust among different project parties		✓	✓	✓
26	Insufficient and inaccurate work drawings and specifications	✓		✓	✓
27	No proper work packaging design and subcontracting	✓		✓	✓
28	Slow in change orders, permits and shop drawings submission and approval	✓		✓	
29	Unclear contract details and badly written contract	✓		✓	
30	Delay in established schedule of engineering, procurement, and construction, and delay in owner approval of completed tasks	✓		✓	✓
31	Type of the contract does not match the nature of the project.		✓	✓	✓
32	Application of fast-track engineering and construction techniques	✓		✓	
33	Lack of solid contracting strategy vision at early stage of the project		✓	✓	
34	Type of contracting strategy: EP, EPC, and EPCM		✓	✓	
35	In the invitation to tender, identify the interface problems		✓	✓	
36	Complete appraisal of bids to comprise an assessment of contractor's understanding of IM		✓	✓	
37	Weather climate conditions problems	✓		✓	
38	Unexpected changes in materials and labour availability and cost	✓		✓	
39	Geological circumstances problems	✓		✓	
40	Unclear company standard operating procedures		✓	✓	
41	Inexperience with the government auditing protocols and procedures	✓		✓	
42	Inexperience with local laws and other government regulations	✓		✓	✓
43	Inexperience with building codes and trade union practices	✓		✓	✓
44	Project extension versus greenfield (new) project type		✓	✓	
45	Free issue items		✓	✓	
46	Insufficient definition of projects boundaries at early stage of the project		✓	✓	
47	Unclear system completion requirements		✓	✓	✓

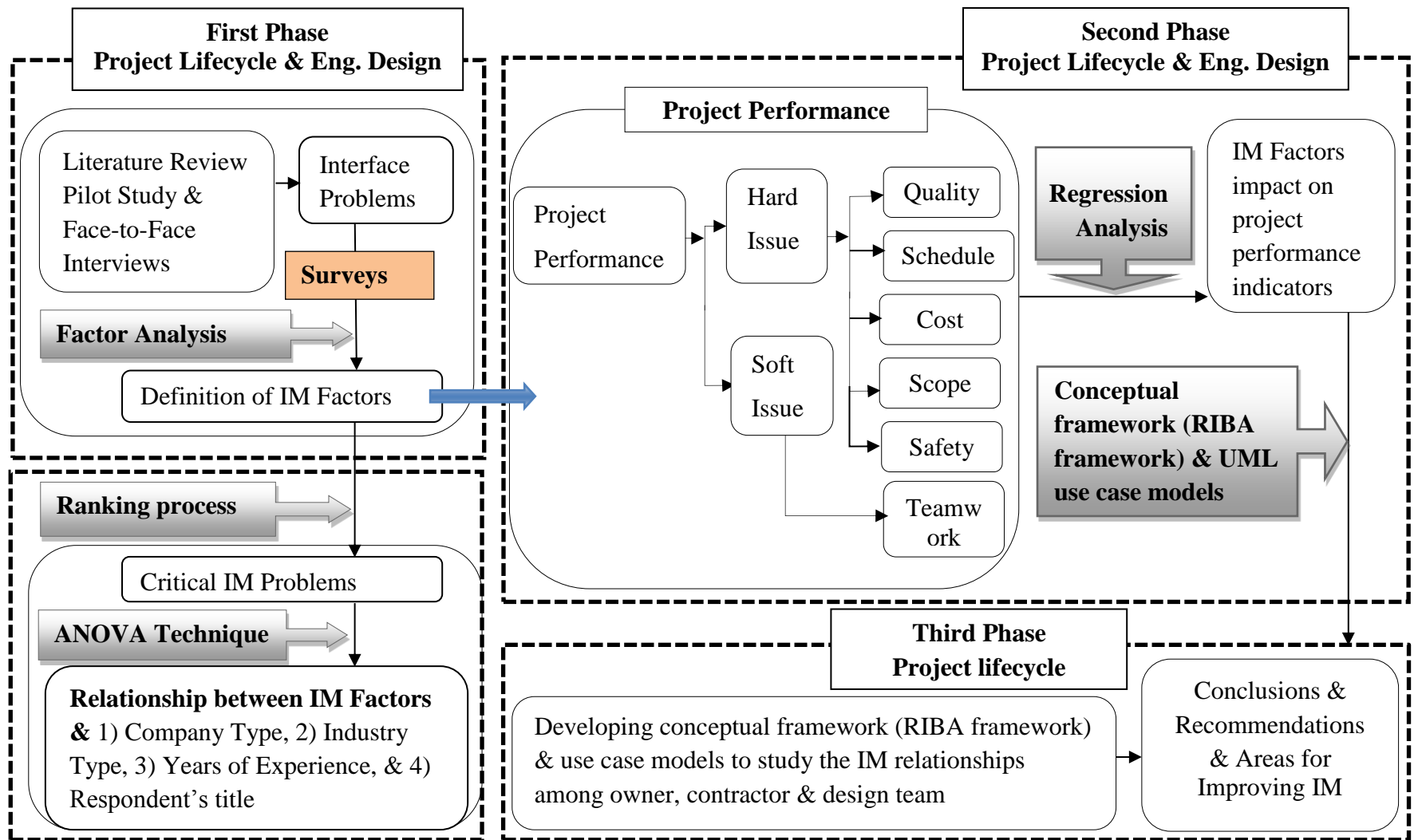




Figure 3.2 Conceptual Research Framework for Modeling the Impact of IM on Construction Project Performance (Project Lifecycle Phase and the Engineering/Design Phase)

	<div> <div>Negligible</div> <div>Disastrous</div> </div>						<div> <div>Unimportant</div> <div>Very Important</div> </div>						
	1	2	3	4	5	6	1	2	3	4	5	6	7
Interface Problems / Issues	Impact						Project Performance						
							Quality	Schedule	Cost	Scope	Safety	Team-work	
Lack of interface details within work drawings and specifications													



IM Factors (Phase One)



IM Factors Impact on Project Performance (Phase Two)

The first phase investigated, identified, and classified interface problems that impact IM and cause interface conflicts among the participating parties in construction projects. The first phase consists of (A) a complete literature review, followed by industry pilot studies and (B) two web-based questionnaires with participants from industry. Both qualitative and quantitative data were analyzed and interpreted using factor analysis. The findings of the first phase provided a comprehensive view of the main reasons and factors that contribute to IM conflicts in construction industry and provided the basis for the second phase.

Comprehensive literature reviews followed by industry pilot interviews were conducted.

Two web-based online questionnaires were conducted with participants from industry, as shown in Table 3.2. The research survey questions were designed based on the interface problems and

issues, as shown in Table 3.1, and project performance indicators: quality management, schedule management, cost management, scope management, safety, and teamwork. The participants were asked to assess the interface problems' impact on IM. Besides that, the impact of IM problems on project performance indicators was examined. Both qualitative and quantitative data were analyzed and interpreted using statistical techniques such as factor analysis and cross tabulated. The significant sample size was determined as shown in Appendix V. The relationships among IM factors and company types, industry types, respondents' titles/positions and years of experience were tested using statistical techniques.

C. Identifying the top 10 interface problems

This phase identifies the top ten interface problems affecting IM performances using the cross-tabulated analysis followed by the ranking factor process method. Cross-tabulation is a statistical technique that helps us to analyse the relationships among two or more variables.

3.2.2 The second phase.

Based on the results of the first phase, the second phase consists of enhancing project performance by developing a multiple-regression analysis model between the underlying interface problem factors and the project performance indicators.

A. Developing a Multiple-Regression Analysis Model

A multiple regression analysis model between the underlying interface problem factors and the project performance indicators (quality, cost, schedule, scope, teamwork, and safety) were developed. These indicators are further divided into soft and hard issues. The hard issues are quality management, schedule management, cost management, scope management, and safety management; the soft issue is teamwork. The regression model can provide a good method to examine how specific factors influence the outputs (Brace, Kemp, & Snelgar, 2006). As

regression analysis can assist in setting up a confidence interval of the results (Ng, 2006). However, there are many deficiencies in using this technique; it needs sufficient data to set up this model, which are not easy to obtain in the construction field. Also, if any new factor needs to be added to this model, the regression equation must be started over (Abdelgawad, 2011). This study adopted a comprehensive analytical approach to identify factors to be considered in the quantification model. The sample size in this research study was large enough to conduct a statistical analysis, such as multiple regressions and cross-tabulated analysis.

3.2.3 The third phase.

3.2.3.1 Developing conceptual framework and use case models.

Based on the previous phases, the last phase developed conceptual framework (RIBA framework) and use case models to study the IM relationships among owners, contractors, and designers (architect and engineer) using the UML use case diagrams. These models can be used to evaluate the IM relationships among owner, contractor, and designer based on IM and to provide suggestions for improving and enhancing IM, which are adequate to all participants engaged in construction projects.

3.2.3.2 Defining areas for improving IM.

The last step collected data regarding existing and proposed IM procedures and/or areas for improving and enhancing IM. Accordingly, suggestions for improving and enhancing the IM were provided by experts from Alberta's construction industry. These need to be adequate to all participants engaged in Alberta construction projects. The data were collected using the web-based online questionnaires. The last question in my survey was "from your experience, what do you suggest and recommend improving the interface management?"

Examples of the areas for improving the IM are shown in Table 3.3. Finally, in-depth interviews were conducted to validate the final research findings.

Table 3.3 Examples of the Areas for Improving IM

	Areas
1	Applying of management and communication techniques among different project participants involved in the projects
2	Engagement of the project teams (regulatory, engineering, procurement, construction, project controls, and planning) from the beginning of the project to the completion
3	Prepare plans and schedules at an early stage of the project
4	Clear definition of proper contracting strategy
5	Identify the site-wide services
6	Provide the project with a general construction manager or project manager contractor at the beginning of the project
7	Define a clear project organization structure
8	Define a clear work breakdown structure (WBS)
9	Define clear site access responsibilities
10	Define clear procedures for engineering review of construction design changes
11	Organize the regulatory and permit procedures
12	Minimize interfaces with other projects
13	Provide the owner's team with an interface manager
14	Application of management and communication techniques among different project participants

3.3 Data Collection

The following section provides full details for the data collection throughout project lifecycle and during the design phase. Quantitative and qualitative data were collected from different types of construction projects, including oil and gas, commercial and buildings, infrastructure, transportation, and manufacturing with the largest sample size of responses coming from the sectors oil and gas and commercial and buildings. In addition, different organizations were included in the data collection, such as EPC, owner, EPCM, construction management

companies, construction contractor/sub-contractor, engineering consultant, architecture, and architecture and engineering. Furthermore, surveys were sent to engineers, construction managers, procurement staff, quality engineers, safety leaders, architects, planners, project engineers, and project controllers. Two techniques were used to collect the data: (1) pilot studies and face-to-face interviews (structured interviews) and (2) questionnaires and in-depth interviews after the survey. The questionnaires were circulated through the members of the following associations and groups: Project Management Focus Group (PMFG), Consulting Engineering for Alberta (CEA), Consulting Architects of Alberta (CAA), and Alberta Construction Association (ACA). The next two sections explain these techniques in details.

3.3.1 Pilot studies and face-to-face interviews.

Structured interviews were conducted around a major question: what are the interface problems that may arise among different project participants involved in construction projects in Alberta? The survey instrument was also developed through the pilot study to ensure that the survey was comprehensible and comprehensive. Thirty-five experts from industry participated in the pilot studies and face-to-face interviews and identified 16 major interface problems, shown in Table 3.1.

3.3.2 Empirical surveys and data collection.

Data were collected to evaluate the impacts of the interface problems using two well-structured questionnaire instruments. Two web-based online surveys were performed with members from industry throughout the project lifecycle and during the engineering/design phase (see Appendixes III and IV). The survey questionnaires were designed based on the identified interface problems as shown in Table 3.1, and the format was recommended by experts in Alberta's industry. The two surveys include quantitative questions divided into two sections:

demographic information and interface problems. Both the rating scale and checklist techniques were used to design the questionnaire. The participants were asked to evaluate the impact of the interface problems on interface management performance. The study made use of the Likert scale, which is suitable for perception-oriented questions (Jugdev, Mathur, & Fung, 2007). The responses to the two questionnaires in this study were obtained to build a six-point Likert scale with the end points being 1 = negligible and 6 = disastrous.

The numerical values assigned to the selected choices were used in the statistical analysis using SPSS software by using two statistical tools (factor analysis and multiple-regression analysis). The questionnaires were distributed through the members of the PMFG, CEA, CAA, and ACA. Many parties engaged in the construction process participated in this survey questionnaire, including engineers (structural, mechanical, electrical), architects, leaders (safety, procurement, etc.), project controls, interface coordinators, contract administrators, project engineers, commissioning engineers, quality engineers, planning engineers, project managers, construction managers, construction planners, contractors/sub-contractors, project engineering managers. Participating parties were from different industry sectors, infrastructure, oil and gas, commercial and buildings, and transportation. In this research study, the large sample size of responses was received from the sectors oil and gas and commercial and buildings. Furthermore, in the data collection stage, various types of companies were included: owner, architecture, architecture and engineering, EPC, EPCM, construction contractor/sub-contractor, engineering consultant, and construction management company.

The collected data were analyzed using Pearson's Product-Moment Correlation (PPMT) matrix, factor analysis methods, cross-tabulated analysis, and multiple regressions. The Pearson's correlation is used to measure the strength of the relationships between variables (the identified

interface problems). Pearson's correlation matrix was created to study its use for factor analysis. Exploratory factor analysis was performed to extract the factors and the latent structure of independent variables (the identified interface problems) using the IBM SPSS Statistics 20. The one-way MANOVA was used to determine the relationships among the IM problems and different construction data in Alberta. Cross-tabulation is a statistical technique that helps us to analyse the relationships among two or more variables. For more details, the cross-tabulations provide a way of analysing how changes in the frequency of occurrence of one variable are related to changes in the frequency of occurrence of other variables (Tabachnick & Fidell, 2001). "Multiple regression is a statistical technique that allows us to predict someone's score on one variable on the basis of their scores on several other variables", where the researchers can predict one variable on the basis of a number of other variables (Brace et al., 2006). For the first survey that was conducted throughout the project lifecycle, the number of responses was 135 responses. The overall response rate was approximately 32%. This means that out of the 421 participants that completed the demographic questions, 135 completed the last survey question. In addition, out of the 421 participants that completed the demographic questions, 269 participants completed the first survey question (64%). To conduct factor analysis, the following scale guidelines were proposed in (Tabachnick & Fidell, 2001) to examine the sample size: (a) sample size of 50 as very poor, (b) 100 as poor, (c) 200 as fair to good, (d) 300 as good, and (e) 1000 as excellent.. Therefore, the sample size of this study is considered "fair to good" because the number of responses was 135. In addition, almost half of the participants (65 participants) provided the researcher with their email addresses, which indicated their agreement to participate in the in-depth interviews after the survey. This high percentage of the participants interested in

participating in the in-depth interviews after the survey shows the significance of IM in the construction industry sector of Alberta.

For the second survey that was conducted during the engineering/design phase, the number of responses was 162 responses. The overall response rate was approximately 46%. This means that out of the 354 participants that completed the demographic questions, 162 completed the last survey question. To conduct factor analysis, the following scale guidelines were proposed in (Tabachnick & Fidell, 2001) to examine the sample size: (a) sample size of 50 as very poor, (b) 100 as poor, (c) 200 as fair to good, (d) 300 as good, and (e) 1000 as excellent., Therefore, the sample size of this study is considered “fair to good” because the number of responses was 162.

3.3.3 In-depth interviews.

The primary advantage of in-depth interviews is that they provide much more detailed information than what is available through other data collection methods. A second round of in-depth interviews was conducted to validate the final research findings at the end of the study.

3.4 Data Analysis

Both quantitative and qualitative data were analyzed to address the research questions.

3.4.1 Qualitative data analysis.

The following steps were used to analyze the qualitative data collected of areas and procedures to improve IM (Creswell, 1998): (1) organizing: all data were organized using Microsoft Excel® or Word®, (2) scrutinizing: the entire data set was perused to get a sense of what it contains as a whole, (3) categorizing: all data were classified into categories or themes, and (4) synthesizing: conclusions will be drawn and theories offered..

3.4.2 Quantitative data analysis.

The main research hypotheses were tested to determine the correlation between IM problems in construction projects. Statistical tools such as factor analysis, one-way MANOVA, and multiple-regression analysis were used to analyze the data collected from the survey using SPSS software. Factor analysis is “a statistical technique used to identify a relatively small number of factors that can be used to represent the relationships among sets of many interrelated variables” (R. Huang et al., 2008). Exploratory factor analysis was performed to extract the factors and the latent structure of independent variables (interface problems/issues).

The one-way MANOVA test considered the relationships between identified IM factors and the company type, industry type, title type, and survey respondent’s years of experience. In addition, multiple-regression models were used to investigate the relationship between the extracted IM factors and project performance indicators (quality management, schedule management, cost management, scope management, safety management, and teamwork). This research study enhanced IM within construction projects by developing a conceptual framework (RIBA framework) and use case models to study the IM relationships among owner, contractor and designer using the Microsoft Visio® flowcharts and the UML use case diagrams. Based on the aforementioned discussion, regression techniques were used to examine the collected data at the first stage of the data analysis. Table 3.4 gives the research questions, research objectives, and potential methodologies and methods used throughout the project lifecycle and particularly during the design phase.

Table 3.4 Illustrates the Research Questions, Research Objectives, Potential Methodologies and Methods throughout Project Lifecycle and the Engineering/Design Phase

Research questions	Research objectives	Methodology	Data Collection	Data Analysis	Phases
1. What are the main interface problems and/or factors causing interface conflicts and affecting IM?	2. To investigate, identify, and classify the main IM factors that considerably impact IM and cause interface conflicts	Quantitative methodology	Web-page questionnaire #1 & #2	SPSS factor analysis tool	Project lifecycle and engineering/design phase
2. What are the relationships between IM factors and different construction data such as company types and industry types	3. To investigate the relationships between IM factors and different construction data such as: company types and industry types	Quantitative methodology	Web-page questionnaire #1 & #2	SPSS one-way MANOVA	Project lifecycle and engineering/design phase
3. What are the top 10 IM problems affecting each aspect of IM?	3. To list the top 10 IM problems affecting each aspect of IM	Quantitative methodology	Web-page questionnaire #1 & #2	SPSS cross-tabulated analysis followed by the ranking factor process	Project lifecycle and engineering/design phase

Table 3.4 cont'd

Research questions	Research objectives	Methodology	Data Collection	Data Analysis	Phases
4. What are the relationships between the identified IM factor and the project performance indicators of construction projects?	4. To investigate the relationship between the extracted IM factors and the project performance indicators	Quantitative methodology	Web-page questionnaire #1 & #2	SPSS multiple regression	Project lifecycle and engineering/design phase
5. Could we study the relationships among owner, contractor, and designer and recommend solutions for management?	5. To develop a conceptual framework and use case models to study the IM relationships among owner, contractor, and design team	Quantitative methodology	Web-page questionnaire #1 & #2	Microsoft Visio® flowcharts and the UML use case diagrams	Project lifecycle
6. What are the procedures or areas for improving IM?	6. To provide suggestions and recommendations for improving and enhancing IM	Qualitative methodology	In-depth interviews after the web-page questionnaire	Organizing, scrutinizing, categorizing, synthesizing	Project lifecycle

3.5 Research Reliability and Validity

In general, reliability measures and validity confirm and help data trustworthiness. In this study, a reliability statistical method is used to assess the stability and consistency in survey questions, to ensure that the questions are appropriately reliable, and to present a certain measurement. The

statistical method (Cronbach's α) was used for examining the reliability of extracted IM factors and six project performance indicators in order to ensure accuracy. A value of 0.7 reliability coefficient or higher is acceptable in the social sciences (Jugdev et al., 2007). Besides that, all the questions in this research study were established based on theoretical bases, expert consensuses and experience, and the empirical questionnaire.

The best validity test is to test the model on a real-life project; however, achieving access to real-life data may be a challenge owing to privacy and/or proprietary limits. In this study, the sample size had to be determined to fulfill statistical requirements. The validity can be achieved by requesting individuals external to the study to examine the credibility of the findings and involving participants in evaluating the accuracy of the interpretations of the collected data (Creswell & Miller, 2000).

In this study, participants in the pilot study prior to and after the web surveys provide an external review of the results. The participants found that the results of these two surveys were expected and make sense. The participants in the web-page questionnaires were also involved in assessing the accuracy of the interpretations, as they review the results of the two surveys.

Through in-depth interviews that were conducted to validate the final research findings at the end of the study. Experts from industry assisted in the review of the final research findings, specifically the final conceptual framework (RIBA framework) and the use case models that were developed. Many suggestions and actions from the industry experts were included in the proposed use case model packages for each project players (owner, design team, and construction contractor).

Moreover, "a good construct must explain why particular sets of variables are interconnected and are strong predictors of the results" (Sutton & Staw, 1995). The web-page questionnaires

developed in this study were constructed of groups of variables that were identified by a large group of experienced construction industry practitioners. Finally, the success of the multiple regression models when applied to the real world in statistics can be estimated using R squared (R^2) (Brace et al., 2006). An investigation of the survey's comprehensibility and comprehensiveness through a pilot study was conducted with experts from industry.

3.6 Summary and Connection with the Next Chapters

This chapter provided and discussed the research design and approaches for this research study in two sections: throughout the project lifecycle and during the engineering/design phase. This research study used both qualitative and quantitative approaches and had direct contact with practitioners to collect and analyze the research information. A complete literature review and pilot studies in industry were performed. After that, two web-based online surveys were performed with participants from industry, followed by in-depth interviews.

The next two chapters (4 and 5) provided full details of the two surveys that were conducted throughout the project lifecycle phases and during the engineering/design phase.

Chapter Four: Factor Analysis and Multiple Regression Analysis of Interface Management throughout the Project Lifecycle

4.1 Chapter Overview

Two web-based online surveys were performed with participants from industry throughout project lifecycle and during the engineering/design phase, as shown in Appendixes III and IV. This chapter provides full details of the *first* survey that was conducted throughout project lifecycle phases. This chapter provides analysis of the results and discussion of the findings and conclusions. Parts of the materials in this chapter and in this thesis were included in Weshah, El-Ghandour, Cowe Falls, and Jergeas (2014c) and Weshah, El-Ghandour, Jergeas, and Cowe Falls (2013b).

4.2 Analysis of Survey Results and Discussion of Findings

4.2.1 Respondents' profiles.

Out of the 135 valid questionnaires collected, the highest number of responses received were from the architect and project control group, followed by project manager and engineers (structural, mechanical, electrical), as shown in Table 4.1. In addition, in terms of the company types, the main responses were obtained from owners, engineering, procurement, and construction management (EPCM), engineering consultants, and engineering, procurement, and construction (EPC), as shown in Table 4.2. The participants are from different sectors in the industry in Alberta: Seventy-eight participants are working in the oil and gas industry, while 32 are working in commercial and buildings, as shown in Table 4.3.

Moreover, in terms of years involved in construction, the proportions of the respondents were as shown in Table 4.4; about half of the participants have at least 20 years of experience, which demonstrates the importance of interface management (IM) in the industry sectors of Alberta. Participants are well educated at the undergrad or higher levels, as shown in Table 4.5.

Table 4.1 Respondents' Job Profiles

Respondents' Job Profiles	Number of Responses	Percentage of Responses (%)
Lead (safety, procurement, etc.)	4	3
Project controls	20	15
Interface coordinator	7	5
Project engineer	8	6
Commissioning engineer	2	2
Quality engineer	2	1
Planning engineer	7	5
Project manager	16	12
Construction manager	3	2
Construction planner	3	2
Contractor/sub-contractor	2	1
Engineer (structural, mechanical, etc.)	13	10
Architect	30	22
Project Engineering Manager	5	4
Other	13	10

Table 4.2 Respondents' "Company" Types

Respondents' Company Types	Number of Responses	Percentage of Responses (%)
Owner	41	30
EPC	13	10
EPCM	18	13
Construction contractor/sub-contractor	6	5
Engineering consultant	15	11
Architecture firms	15	11
Architecture and engineering firms	10	7
Construction management company	4	3
Others	13	10

Table 4.3 Respondents' "Industry" Types

Respondents' Industry Types	Number of Responses	Percentage of Responses (%)
Infrastructure	13	10
Oil and Gas	78	58
Transportation	6	4
Commercial and buildings	32	24
Other Sectors	6	4

Table 4.4 Respondents’ “Years of Experience” Types

Respondents’ Years of Experience Types	Number of Responses	Percentage of Responses (%)
≤5 years	7	5
6–9 years	8	6
10–14 years	23	17
15–19 years	26	19
≥20 years	61	45
Others	10	8

Table 4.5 Respondents’ “Level of Education” Types

Respondents’ Level of Education Types	Number of Responses	Percentage of Responses (%)
Diploma	7	5
Post-diploma	10	7
BSc	55	41
MSc	44	33
PhD	14	10
Others	5	4

4.2.2 Pearson product-moment correlation.

The Pearson product-moment correlation (PPMC) matrix is considered to be the most common measure of dependence between two variables (Tabachnick & Fidell, 2001). “The Pearson product moment correlation coefficient is a measure of linear dependency between two variables in the range of -1 and 1 . A PPMC of 1 indicates an exact positive correlation, -1 indicates an exact negative correlation, while 0 indicates there is no linear relationship” (Phillips, Gauthier Dickey, & Thurimella, 2010). To interpret the correlation coefficient, the following scale guidelines have been proposed: correlations between 0 and 0.33 indicate a weak to low relationship, correlations between 0.33 and 0.66 reflect medium to high relationships, and correlations between 0.66 and 1 reflect very high and very strong relationships. The PPMC values shown in Appendix VI show that although 65% of the 47 interface problems correlate

positively and reflect medium relationships, 33% show low to weak relationships and 2% reflect high and very strong relationships. The correlation coefficients results show that our data are reasonable enough to apply factor analysis.

4.2.3 Factors influencing interface management.

Factor analysis is “a statistical technique used to identify a relatively small number of factors that can be used to represent the relationships among sets of many interrelated variables” (R. Huang et al., 2008). Exploratory factor analysis was performed to extract the factors and the latent structure of independent variables (in this case, the 47 interface problems) that reduce the 47 items into a small number of underlying factors. The extraction of the factors gives an apparent picture of what each factor stands for.

Through the use of the Kaiser’s normalization criterium results, nine factors were determined with eigenvalues greater than 1. Figure 4.1 is a scree plot showing the extracted factors plotted against an eigenvalue that may be less than nine factors. Different models from five to nine factors were reviewed and studied. The results show that the best factor solution is the six-factor results. The six factors were reasonable enough. Each extracted factor consists of its own interface problems that have common features that make them reasonable to be listed and categorized.

Six factors were extracted in this research study. According to the factor loading and item (interface problems) under each factor, the name for each of the factors was determined by studying the variables that loaded highly (>0.40) on all six factors. Based on the common features of their exact interface problems, each of the factors was given a specific name. Tables 4.6 – 4.11 show the components of the six extracted factors, namely: management, information, bidding and contracting, law and regulation, technical engineering and site issues,

and other interface problems. The reason behind the name of each of the interface problem factors is explained in the following section.

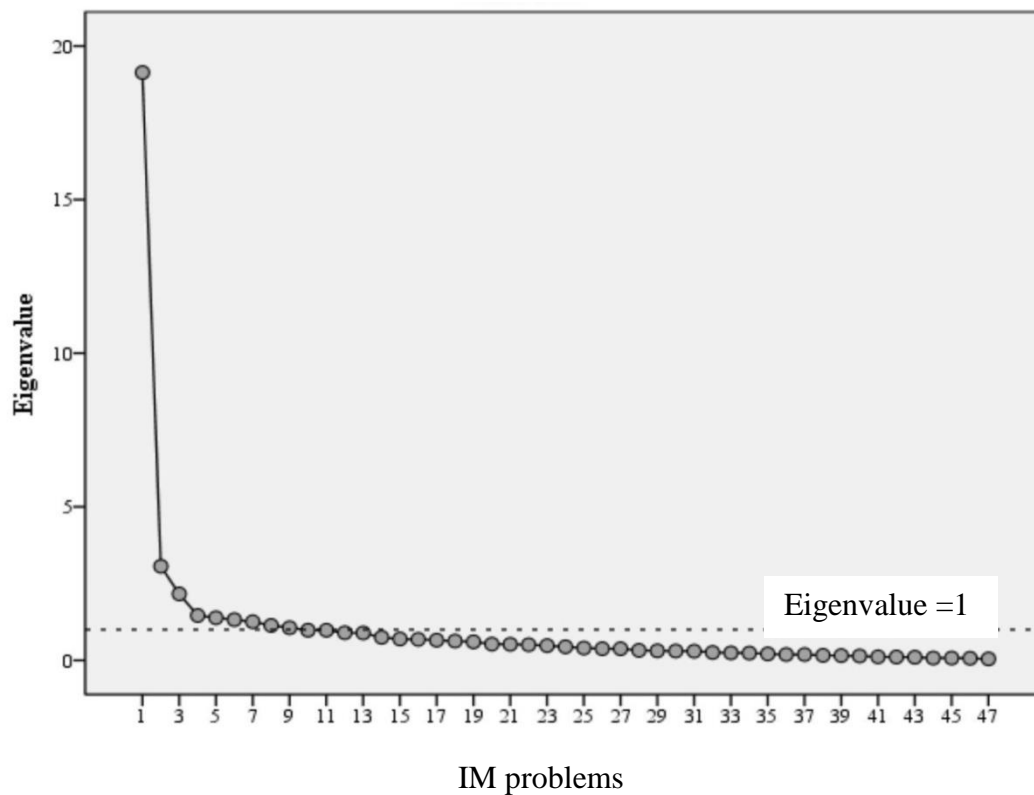


Figure 4.1 Scree Plot of 47 Interface Problems

1. Management factor (Mgt. factor)

This factor consists of 14 various IM problems related to management problems such as lack of enough negotiation, communication, and coordination among relevant parties involved in the project and lack of project management, as shown in Table 4.6. Therefore, this factor was named “management factor”. In addition, Table 4.6 shows the variables that loaded highly (>0.40) on all IM problems related to management problems.

2. Information factor (Inf. factor)

This factor includes seven IM problems related to information problems, for example inaccurate information and delays and undefined reporting structure and responsibilities, as shown in

Table 4.7. All of the interface problems under this factor are due to information issues leading to delay: missed, inaccurate, and insufficient information. Therefore, the name “information factor” was considered appropriate.

3. Bidding and contracting factor (Bid & contr. factor)

This factor consisted of 10 interface problems concerning the bid and contract that appear in the invitation to bid and contract execution, e.g., unclear contract details and poorly written contracts, and in the invitation to tender, identify the interface problems, as shown in Table 4.8. These problems may occur when different project parties are invited to bid or execute the contract. Therefore, the name “bidding and contracting factor” was considered to be suitable.

Table 4.6 Summary of Factor Analysis (Management Factor)

	IM Problems	Mgt. factor	Inf. factor	Bid & contr. factor	Law & reg. factor	Tech. engg. & site issues factor	Others factor
1	Lack of enough negotiation and communication and coordination	0.495	0.366	−0.066	0.235	0.118	0.368
2	Financial difficulties	0.552	0.188	0.035	0.196	0.213	−0.079
3	Poor decision making	0.565	0.165	0.12	0.02	0.369	0.23
10	Lack of project management	0.415	0.368	0.244	0.134	0.396	−0.067
12	Planning and scheduling problems	0.607	0.38	0.409	−0.019	0.135	−0.028
14	Interfaces with other interdependent projects	0.49	0.284	0.249	0.265	0.043	0.058
18	Imprecise project cost estimate	0.541	0.398	0.171	0.1	−0.044	0.005
19	Discrepancies among the owners’ expectations regarding project construction schedule, cost, and quality	0.502	0.429	0.016	0.173	0.191	−0.008
20	Lack of personal experience of the project teams	0.503	0.463	−0.061	0.181	0.136	0.289

Table 4.6 cont'd

	IM Problems	Mgt. factor	Inf. factor	Bid & contr. factor	Law & reg. factor	Tech. engg. & site issues factor	Others factor
21	Incapability to predict and resolve project's problems related to new technological techniques and materials	0.485	0.24	0.137	0.405	0.093	-0.249
25	Lack of trust among different project parties	0.512	0.334	0.294	0.238	0.326	-0.054
28	Slow in change orders, permits, and shop drawings submission and approval	0.385	0.239	0.345	0.174	0.347	0.265
30	Delay in established schedule of engineering, procurement, and construction	0.664	0.12	0.432	0.137	0.169	0.194
32	Application of fast-track engineering and construction techniques	0.556	0.196	0.281	0.061	0.294	0.116

Table 4.7 Summary of Factor Analysis (Information Factor)

	IM Problems	Mgt. factor	Inf. factor	Bid & contr. factor	Law & reg. factor	Tech. engg. & site issues factor	Other s factor
9	Information problems	0.413	0.515	0.118	0.139	0.362	0.183
11	Lack of IM system	0.345	0.586	0.218	0.227	0.145	0.156
13	Type of organization structure	0.169	0.68	0.264	0.064	0.166	0.124
15	Undefined reporting structure and responsibilities	0.299	0.617	0.14	0.224	0.178	-0.078
16	Interfaces arise because of the application of the project development gating (or phases) system	0.11	0.491	0.251	-0.021	0.278	0.001

Table 4.7 cont'd

	IM Problems	Mgt. factor	Inf. factor	Bid & contr. factor	Law & reg. factor	Tech. engg. & site issues factor	Others factor
17	Insufficient and lack of alignment among WBS, CWBS, CBS, and OBS	0.246	0.758	0.208	0.023	0.168	0.219
27	No proper work packaging design and subcontracting	0.291	0.416	0.37	0.304	0.366	0.116

Table 4.8 Summary of Factor Analysis (Bidding and Contracting)

	IM Problems	Mgt. factor	Inf. factor	Bid & contr. factor	Law & reg. factor	Tech. engg. & site issues factor	Others factor
24	Increase project interface conflicts when different contractors insist on their points of view	0.329	0.292	0.513	0.341	0.079	0.155
29	Unclear contract details and poorly written contract	0.353	0.224	0.459	0.343	0.272	0.059
31	Type of the contract does not match the nature of the project	0.447	0.106	0.622	0.145	0.134	-0.219
33	Lack of solid contracting strategy vision at early stage of the project	0.113	0.165	0.8	0.127	0.209	-0.095
34	Type of contracting strategy; EP, EPC, and EPCM	0.157	0.026	0.702	0.066	0.207	0.355
35	In the invitation to tender, identify the interface problems	0.122	0.269	0.44	0.318	0.271	0.284
36	Complete appraisal of bids to comprise an assessment of contractor's understanding of IM	0.109	0.217	0.521	0.409	0.124	0.227
45	Free issue items	0.082	0.378	0.444	0.186	0.082	0.333

Table 4.8 cont'd

	IM Problems	Mgt. factor	Inf. factor	Bid & contr. factor	Law & reg. factor	Tech. engg. & site issues factor	Others factor
46	Insufficient definition of projects boundaries at early stage of the project	– 0.074	0.269	0.612	0.315	–0.03	0.17
47	Unclear system completion requirements	0.157	0.354	0.623	0.352	–0.024	0.108

4. Technical engineering and site issues factor (Tech. engg. & site issues factor)

This factor consisted of 10 IM problems concerning the technical engineering and site issues that occur because of a lack of skills or the complexity of the process and (or) site problems. Some examples of this factor are limited skills for labour and engineering, contractor's unfamiliarity with the environmental circumstances and local weather, and project site issues such as excessive usage of heavy equipment and unclear site wide service responsibilities, as shown in Table 4.9. Therefore, the name “technical engineering and site issues factor” was considered to be appropriate. Also, the name “construction engineering and site issues factor” can be used as another name to this factor.

5. Law and regulation factor (Law & reg. factor)

This factor consisted of four IM problems regarding laws and regulations that occur when different project parties are unfamiliar with the government auditing protocols, local laws, and building codes. Examples of this factor are inexperience with the government auditing protocols and procedures and inexperience with building codes, by-laws, statutes, and other government regulations, as shown Table 4.10. Therefore, the name “law and regulation factor” was considered to be appropriate.

6. Other interface problems factor

This factor consisted of two IM problems that do not match up with the aforementioned factors, as shown in Table 4.11. The two IM problems are unexpected changes in materials and labour availability and cost and project extension of existing projects versus greenfield (new) project type. Therefore, the name “other interface problems factor” or “others factor” was found appropriate

Table 4.9 Summary of Factor Analysis (Technical and Site Issues)

		Mgt. factor	Inf. factor	Bid and contr. factor	Law & reg. factor	Tech. Eng. & site issues factor	Others factor
4	Limited skills for labour and engineering	0.391	0.393	-0.116	0.136	0.437	0.072
5	Materials procurement problems	0.474	0.225	0.183	0.039	0.559	-0.064
6	Construction processes and methods problems	0.149	0.211	0.139	0.133	0.715	0.193
7	Engineering process problems related to interfaces	0.404	0.307	0.209	0.142	0.631	0.141
8	Project site issues	0.056	0.471	0.086	0.314	0.513	0.019
22	Contractor's unfamiliarity with the environmental circumstances and local weather	0.204	0.153	0.231	0.402	0.61	0.012
23	Lack of knowledge about site circumstances by the project team members	0.268	0.215	0.233	0.415	0.607	0.037
26	Insufficient and inaccurate work drawings and specifications	0.308	0.257	0.199	0.232	0.648	0.084
37	Weather and climate conditions problems	0.344	-0.038	-0.042	0.298	0.403	-0.037
39	Geotechnical circumstances problems	0.381	-0.123	0.377	0.213	0.42	-0.10

Table 4.10 Summary of Factor Analysis (Law and Regulations)

		Mgt. factor	Inf. factor	Bid & contr. factor	Law & reg. factor	Tech. Eng. & site issues factor	Others factor
40	Unclear company standard operating procedures	0.111	0.334	0.457	0.532	0.11	0.023
41	Inexperience with the government auditing protocols and procedures	0.094	0.187	0.387	0.736	0.112	0.103
42	Inexperience with local laws and other government regulations and modification in laws and regulations	0.156	0.051	0.21	0.849	0.175	0.127
43	Inexperience with building codes and trade union practices	0.248	0.059	0.149	0.789	0.037	0.046

Table 4.11 Summary of Factor Analysis (Other Interface Problems Factor)

		Mgt. factor	Inf. factor	Bid & contr. factor	Law & reg. factor	Tech. Eng. & site issues factor	Others factor
38	Unexpected changes in materials and labour availability and cost	0.216	0.198	0.154	0.214	0.121	0.666
44	Project extension versus greenfield (new) project type	0.148	0.092	0.267	0.069	0.104	0.739

4.2.3.1 Correlation between emergent factors.

The Pearson product-moment correlation technique was used to examine the correlation between the six IM factors. The correlation coefficients among the six factors that emerged from the factor analysis test are shown in Table 4.12. Based on the previously proposed scale, the analysis

results confirm that the six interface management factors are highly and positively correlated. This means that the six extracted factors impact each other as well as presenting the IM performance.

Table 4.12 Correlation Coefficients between Six Extracted Factors

	Mgt. factor	Inf. factor	Bid & contr. factor	Law & reg. factor	Tech. engg. & site issues factor	Others factor
Mgt. factor	1					
Inf. Factor	.757	1				
Bid & contr. factor	.693	.689	1			
Law & reg. factor	.531	.492	.678	1		
Tech. engg. & site issues factor	.678	.700	.669	.642	1	
Others factor	.621	.583	.603	.405	.618	1

4.2.4 Analysis of the variance (MANOVA) between IM factor and different data.

The following two sections present the test of the normality and the performed hypotheses between IM factors and different data: company type, industry type, title type, and years of experience.

4.2.4.1 Normality.

Extracted IM factors were examined for normality and homogeneity of variance. If the data do not come from a random sample, normality and homogeneity of variance of the dependent variables within each group of the groups' variables, the researchers cannot apply the multivariate analysis of the variance (MANOVA) test. Normality tests are used to decide whether the research data collection is well-modeled by a normal distribution that consists of two elements: skewness and kurtosis (Tabachnick & Fidell, 2001). The skewness and kurtosis values need to be between -1 and $+1$ to be considered normal (Tabachnick & Fidell, 2001). The results

show that the variables are within the basic assumptions of the normality and homogeneity of variance and thus found to be satisfactory.

4.2.4.2 Research hypothesis between IM factors and different construction data.

To determine whether the six IM factors have a significant impact on IM among different groups type, MANOVA was applied. The multivariate variance analysis and the one-way MANOVA test considered the relationships between these variables and each of the following independent variables: company type, industry type, title type, and years of experience. The study tested four hypotheses. These hypotheses were examined in this research study by using the one-way MANOVA test. Because the one-way MANOVA test measures more than one dependent variable, this test can be chosen (Tabachnick & Fidell, 2001).

Tables 4.13, 4.15, 4.17, and 4.19 present the means, standard deviations, and the numbers of cases for the six dependent variables (IM extracted factors) that have been calculated per the independent variables (groups) of the title and company type. Tables 4.14, 4.16, 4.18, and 4.20 summarized the MANOVA results. Generally, the study used a significance level of 0.05. The following section provides full details regarding the tested hypotheses. The study concluded that the management factor is the factor most impacting IM performance.

1. Job title group related to factor group

The six extracted IM factors were analyzed by five job title groups: (1) project controls, planning engineer, construction planner, interface coordinator, and contract administrator; (2) project engineer, commissioning engineer, quality engineer, and lead (safety, procurement, etc.); (3) engineer (structural, mechanical, electrical) and project engineering manager; (4) project manager, construction manager, contractor and sub-contractor; (5) architect. The following hypothesis (Hypothesis 1) was examined; there would be no significant difference in the means

between the impact of the six IM extracted factors (dependent variables) and respondent's title groups as independent variables.

Based on the means (Table 4.13), the management factor is the factor most impacting the IM performance. The technical and site issues factor and the information factor ranked second and third, respectively. More conclusions could be summarized for each group, as shown in Table 4.13. For example, the project controls people do not consider the management factor among other groups as the highest factor impacting IM performance. This result was expected because the project controls people just support the project and other project participants provide them with information.

The overall MANOVA is statistically significant ($F_{24,402.39} = 2.01$; $p = 0.003$) as shown in Table 4.14. In addition, there is almost a significant difference between the five groups. Consequently, hypothesis 1 can be rejected. In more detail, the bidding and contracting factor ($F_{4,120} = 2.71$; $p = 0.033$) is statistically significant while the management factor ($F_{4,120} = 2.346$; $p = 0.058$) is almost statistically significant, as can be seen in Table 4.14. This indicates that these two factors are affected by different respondent's title groups. Under the management factor, there are statistically significant differences between group 3 (engineer (structural, mechanical, electrical) and project engineering manager) and group 5 (architect) with p -values 0.043. This means that the impact of this factor on IM performance is significantly different between these two groups.

In addition, under the bidding and contracting factor there is an statistically significant difference between group 3 (engineer group (structural, mechanical, electrical) and project engineering manager) and group 5 (architect), with $p = 0.037$. This result show that the impact of the management and bidding and contracting factors on IM performance are extremely different

between the engineer group ((structural, mechanical, electrical) and project engineering manager) and architect group. As can also be seen in Table 4.13, among the five groups the architect group views the management and bidding and contracting factors as having the highest impact on IM, while the engineer group (structural, mechanical, electrical) and project engineering manager views it as the lowest impact on IM performance. Other results could be concluded from Tables 4.13 and 4.14.

Table 4.13 Calculated Means (Title Type Groups and Extracted IM Factors)

Extracted IM Factors Title Type Group	Mgt. factor (X,SD,N)	Inf. factor (X,SD,N)	Bid & cont. factor (X,SD,N)	Law & reg. factor (X,SD,N)	Tech. & site issues factor (X,SD,N)	Others factor (X,SD,N)
1. Project controls, planning engineer, construction planner, interface coordinator, and contract administrator	(4.27, 0.77, 36)	(4.04, 0.10, 36)	(3.97, 0.85, 36)	(3.73, 1.12, 36)	(4.04, 0.89, 36)	(3.93, 1.05, 36)
2. Project engineer, commissioning engineer, quality engineer, and lead	(4.12, 0.66, 16)	(4.12, 0.60, 16)	(4.14, 0.64, 16)	(4.28, 0.84, 16)	(4.23, 0.74, 16)	(4.10, 0.84, 16)
3. Engineer and project engineering manager	(3.89, 0.60, 19)	(3.42, 0.90, 19)	(3.60, 0.76, 19)	(3.61, 0.10, 19)	(3.74, 0.74, 19)	(3.53, 0.96, 19)
4. Project manager, construction manager, contractor, and sub- contractor	(4.39, 0.51, 23)	(4.10, 0.75, 23)	(3.76, 0.76, 23)	(3.86, 1.06, 23)	(4.21, 0.53, 23)	(4.15, 0.81, 23)
5. Architect	(4.46, 0.71, 31)	(4.07, 0.87, 31)	(4.24, 0.68, 31)	(3.96, 0.10, 31)	(4.24, 0.65, 31)	(3.75, 0.77, 31)
Total	4.27	3.97	3.96	3.86	4.09	3.88

Table 4.14 MANOVA Results (Title Type Groups and Extracted IM Factors)

Source	<i>F</i>	Df1, df2	<i>P</i>
Overall	2.014	24, 402.397	0.003
Management factor	2.346	4, 120	0.058
Information factor	2.334	4, 120	0.059
Bidding and contracting factor	2.712	4, 120	0.033
Law factor	1.171	4, 120	0.327
Technical engineering and site issues factor	1.668	4, 120	0.162
Others factor	1.680	4, 120	0.159
*Management factor group comparison			
Group 3 (engineer and project engineering manager) and Group 5 (architect)			0.043
*Bidding and contracting factor group comparison			
Group 3 (engineer and project engineering manager) and Group 5 (architect)			0.037

*Included only the significant pairwise comparison

2. Company type

The six extracted IM factors were analyzed by five groups, which consist of owner, EPC/construction contractor, EPCM/construction management, engineering consultant, and architecture firms and architecture and engineering company. The following hypothesis (Hypothesis 2) was tested; there would be no significant difference in means between the impact of the six IM extracted factors (dependent variables) and different company types as independent variables. Based on the means in Table 4.15, the greatest difference among groups was observed in the management factor, indicating that the management factor is more important than other factors. The technical and site issues factor and the information factor ranked second and third, respectively. More conclusions could be summarized for each group as shown in Table 4.15.

The overall MANOVA is almost statistically significant ($F_{24,398.90} = 1.42$; $p = 0.09$), as shown in Table 4.16. Consequently, hypothesis 2 can be rejected. In more detail, the bidding and

contracting factor has a statistically significant effect on different company types with ($F_{4,119} = 2.86$; $p = 0.026$), as can be seen in Table 4.16. This indicates that this factor is affected by different respondents' company groups. Under the bidding and contracting factor there were statistically significant differences between company type group 4 (engineering consultant) and company type group 5 (architecture firms and architecture and engineering company) with p -values of 0.048. This means that the impact of this factor on IM performance is significantly different between these two groups. There were almost statistically significant differences between company type group 2 (EPC/construction contractor) and company type group 5 (architecture firms and architecture and engineering firms) with p -values of 0.089.

As can also be seen in Table 4.15, the architecture firms and architecture and engineering firms companies view the bidding and contracting factor as having the highest impact on IM, while the engineer consultant company views it as having the lowest impact on IM performance as the architect works with the engineers (electrical, mechanical, etc.) to finalize the work.

These results show that the impacts of the bidding and contracting factors on IM performance are extremely different between group 5 (architecture firms and architecture and engineering firms companies) and group 4 (engineer consultant company). This result shows that the IM factors are affected by the company type. Other results could be concluded from Tables 4.15 and 4.16.

Table 4.15 Calculated Means (Company Type Groups and Extracted IM Factors)

Company typeGroups \ Extracted IM Factors	Mgt. factor (X,SD,N)	Inf. factor (X,SD,N)	Bid & cont. factor (X,SD,N)	Law & reg. factor (X,SD,N)	Tech. and site. issues factor (X,SD,N)	Others factor (X,SD,N)
1. Owner	(4.40, 0.66, 41)	4.19, 0.79, 41)	4.06, 0.79, 41)	(4.10, 1.15, 41)	(4.25, 0.7, 41)	4.20, 0.10, 41
2. EPC/construction contractor	(4.09, 0.64, 18)	(3.74, 0.86, 18)	(3.67, 0.71, 81)	3.71, 0.94, 18	3.10, 0.54, 18	3.75, 1.03, 18
3. EPCM/construction management	4.17, 0.61, 22)	(4.03, 0.92, 22)	(4.03, 0.64, 22)	(3.57, 1.10, 22)	(4.09, 0.84, 22)	3.66, 0.76, 22
4. Engineering consultant	(4.12, 0.70, 17)	(3.67, 0.94, 17)	(3.61 , 0.82, 17)	(3.76, 0.93, 17)	(3.97, 0.63, 17)	(3.79, 1.03, 17)
5. Architecture firms and architecture and engineering company	(4.52 , 0.70, 26)	(4.16, 0.80, 26)	(4.25 , 0.69, 26)	(3.97, 0.94, 26)	(4.27, 0.72, 26)	(3.93, 0.68, 26)
Total	4.30	4.01	3.97	3.88	4.15	3.93

Table 4.16 MANOVA Results (Company Type Groups and Extracted IM Factors)

Source	<i>F</i>	df1, df2	<i>P</i>
Overall	1.425	24, 398,000	0.09
Management factor	1.871	4, 119	0.21
Information factor	1.776	4, 119	0.138
Bidding and contracting factor	2.861	4, 119	0.026
Law factor	1.100	4, 119	0.360
Technical engineering and site issues factor	0.947	4, 119	0.439
Others factor	1.633	4, 119	0.171
*Bid factor group comparison			
Group 2 (EPC/construction contractor) and Group 5 (architecture firms and architecture and engineering company)			0.089
Group 4 (engineering consultant) and Group 5 (architecture firms and architecture and engineering company)			0.048

*Included only the significant pairwise comparison

3. Industry type

The six extracted IM factors were analyzed by three industry type groups, which include (1) infrastructure, (2) oil and gas, and (3) commercial and building. The following hypothesis (Hypothesis 3) was tested; there would be no significant difference in means between the impact of the six IM extracted factors (dependent variables) and different industry types as independent variables. Based on the means in Table 4.17, the greatest difference among groups was observed in the management factor, indicating that the management factor is more important than other factors. While the commercial and buildings industry type considered the management factor as the factor with the highest impact on IM followed by technical and site issues factor and bidding and contracting factor, the oil and gas industry type also considered the management factor as the factor with the highest impact on IM followed by technical and site issues factor and information factor. The overall MANOVA is not statistically significant ($F_{12,250} = 1.41$; $p = 0.157$), as shown in Table 4.18.

Consequently, hypothesis 3 can be accepted. There was not a statistically significant difference between the IM factors and the industry type. Consistent with these findings, a follow up univariate test showed no significant results among groups. This result shows that the interface management factors are not affected by the industry type.

Table 4.17 Calculated Means (Industry Type Groups and Extracted IM Factors)

Industry Type Group \ Extracted IM Factors	Mgt. factor (X,SD,N)	Inf. factor (X,SD,N)	Bid & cont. factor (X,SD,N)	Law & reg. factor (X,SD,N)	Tech. and site issues factor (X,SD,N)	Others factor (X,SD,N)
1. Infrastructure	(4.30, 0.67,13)	(3.84, 0.85, 13)	(3.80, 0.56,13)	(3.96, 0.80, 13)	(4.27, 0.66, 13)	(3.69, 0.95, 13)
2. Oil and gas	(4.21, 0.69,79)	(4.03, 0.85, 79)	(3.95, 0.79,79)	(3.78, 1.20, 79)	(4.06, 0.77, 79)	(3.99, 0.97, 79)
3. Commercial building	(4.33, 0.71,41)	(3.87, 0.91, 41)	(3.95, 0.83, 41)	(3.88, 0.83, 41)	(4.11, 0.69, 41)	(3.79, 0.77, 41)
Total	4.26	3.96	3.94	3.83	4.10	3.90

Table 4.18 MANOVA Results Table (Industry Type Groups and Extracted IM Factors)

Source	<i>F</i>	df1, df2	<i>P</i>
Overall	1.419	12, 250	0.157
Management factor	0.446	2, 130	0.641
Information factor	0.602	2, 130	0.549
Bidding and contracting factor	0.240	2, 130	0.787
Law factor	0.233	2, 130	0.792
Technical engineering and site issues factor	0.446	2, 130	0.641
Others factor	0.991	2, 130	0.374

4. Years of experience

The six extracted IM factors were analyzed by four groups, based on years of experience, which includes: (1) ≤ 9 years, (2) 10–14 years, (3) 15–19 years, and (4) ≥ 20 years. The following hypothesis (**Hypothesis 4**) was tested: there would be no significant difference in means between the impact of the six IM extracted factors (dependent variables) and total years of experience groups as independent variables. Based on the means in Table 4.19, the greatest difference among groups was observed in the management factor, indicating that the management factor is more important than other factors. The technical and site issues factor ranked second. The overall

MANOVA is almost statistically significant ($F_{18,334.24} = 1.55$; $p = 0.070$). Consequently, hypothesis 4 can be rejected. In more detail, the management factor has a statistically significant effect on different years of experience types ($F_{3,123} = 3.37$; $p = 0.021$). This indicates that this factor is affected by different respondents' years of experience groups. As can be seen in Table 4.20, under the management factor there were almost statistical significant differences between group 2 (10 to 14 years) and group 3 (15 to 19 years). This means that the impact of this factor on IM performance is significantly different between these two groups. As can be seen also in Table 4.19, group 3 (15 to 19 years) views the management factor as having the highest impact on IM, group 2 (10 to 14 years) views it as having the lowest impact on IM performance. Finally, regardless of the years of experience, the highest years of experience group (≥ 20 years) and the lowest years of experience group (≤ 9 years) ranked the factors affecting IM performance in the same order. Both groups considered the management factor as the factor most affecting IM performance followed by technical and site issues, information, bidding and contracting, and law and regulation factors, respectively. This ranking of factors was not expected and was surprising.

Table 4.19 Calculated Means (Years of Experience Groups and Extracted IM Factors)

Years of Experience Group \ Extracted IM Factors	Mgt. factor (X,SD,N)	Inf. factor (X,SD,N)	Bid & cont. factor (X,SD,N)	Law & reg. factor (X,SD,N)	Tech. and site. issue factor (X,SD,N)	Others factor (X,SD,N)
1. ≤ 9 years	(4.10, 0.53, 16)	(3.80, 0.52, 16)	(3.69, 0.60, 16)	(3.67, 0.78, 16)	(3.96, 0.49, 16)	(3.72, 0.63, 16)
2. 10–14 years	(3.94, 0.99, 24)	(3.70, 1.01, 24)	(3.71, 0.94, 24)	(3.87, 1.06, 24)	(3.87, 1.06, 24)	(3.69, 1.14, 24)
3. 15–19 years	(4.48, 0.77, 26)	(4.27, 0.89, 26)	(4.11, 0.82, 26)	(4.08, 1.11, 26)	(4.17, 0.70, 26)	(3.92, 0.98, 26)
4. ≥ 20 years	(4.30, 0.60, 61)	(3.94, 0.89, 61)	(3.93, 0.84, 61)	(3.68, 1.19, 61)	(4.17, 0.60, 61)	(4.00, 0.87, 61)
Total	4.23	3.93	3.93	3.80	4.08	3.89

Table 4.20 MANOVA Results (Years of Experience Groups and Extracted IM Factors)

Source	<i>F</i>	df1, df2	<i>P</i>
Overall	1.553	18, 334.240	0.070
Management factor	3.376	3, 123	.021
Information factor	2.223	3, 123	0.089
Bidding and contracting factor	0.976	3, 123	0.407
Law factor	0.97	3, 123	0.440
Technical engineering and site issues factor	1.508	3, 123	0.216
Others factor	0.869	3, 123	0.459
*Management factor group comparison			
Group 2 and Group 3			0.05

*Included only the significant pairwise comparison

4.2.5 Top 10 interface problems that affect IM.

What are the most critical problems affecting each aspect of IM? The frequency of the 47 IM problems was examined using the cross-tabulated analysis followed by the ranking factor process method. The ranking process is defined in a way that puts more focus and value on aspects of the data according to the contribution that leads to the final outputs, so that the aspects that have more contribution get more focus in the analysis. That is, rather than each variable in the data contributing equally to the final result, some data are adjusted to contribute more than others. The 47 IM problems were studied within four areas: company types, industry types, years of experience, and respondent's title. The five company types reported and discussed are (1) owner, (2) EPC and construction contractor, (3) EPCM and construction management companies, (4) engineering consultant, and (5) architecture firms and architecture and engineering firms. The 47 IM problems were studied and summarized in 47 tables that show the rating average for each company type. As an example, Table 4.21 shows an example of the rating average for the problem of "lack of a solid contracting strategy vision at the early stage of the project". This table describes the steps used to calculate the rating average for five company types of the interface problem "lack of a solid contracting strategy vision at the early stage of the project". The columns through company type 1 to company type five listed the number of participants in the questionnaire for each scale from 1 (negligible) to 6 (disastrous) linked scale. As can be seen, the weighting scale is from x_1 through x_6 ; where x_1 is the weighting scale corresponding to the lowest linked scale of the ranking process. Consequently, x_6 is the weighting scale of the highest linked scale given to the IM problem through the ranking process. The weighting columns

represent the multiplication of each company's number of responses column by the weighting scale. For instance, the column "Weighting 1" represents the multiplication of company 1's number of responses by the weighting scale. The following equation is used to calculate the rating average Y_j :

$$Y_j(\%) = \frac{\sum_i a_{ij}}{\sum_i b_{ij} \times n} 100 \quad (1)$$

where a_{ij} is the weighting scale of the linked scale i for company j , b_{ij} is the number of responses of linked scale i for company j , and n is the number of responses in the survey. For example, using equation 2, the rating average company type 1 is equal to $(197 / (44 \times 128)) \times 100 = 3.50$.

Based on equation 1, the rating averages of the five company types are 3.50, 2.95, 3.62, 3.08, and 3.91, respectively. This means that the participants from company type five (architecture firms and architecture and engineering firms) acknowledged the importance of this IM problem (lack of a solid contracting strategy vision at the early stage of the project) more than other companies. Consequently, the remaining 47 tables were constructed to find the company type that considers each of the 47 IM problems the most critical. Based on the data from the 47 tables, the top 10 IM problems for each company type were ranked and summarized as shown in Table 4.22. Table 4.22 summarized the rating average of the highest IM problems for each company type.

It should be noted that the five company types are almost in agreement over the 10 general IM problems with the exception of company type 4 (engineering consultants), as they reported different IM problems, such as lack of personal experience of the project teams. In addition, EPCM and construction management companies reported different IM problems, such as

(1) complete appraisal of bids to comprise an assessment of contractor's understanding of interface management and (2) no proper work packaging design and subcontracting.

Table 4.21 Example of Ranking Process of IM Problems Based on Five Company Types

IM Problems	6 likert scale	Weighting scale	Company 1 number of responses	Weighting 1	Company 2 number of responses	Weighting 2	Company 3 number of responses	Weighting 3	Company 4 number of responses	Weighting 4	Company 5 number of responses	Weighting 5	Total number of responses
Lack of a solid contracting strategy vision at the early stage of the project	1 Negligible	x1	0	0	1	1	0	0	0	0	0	0	1
	2 Marginal	x2	1	2	2	4	0	0	2	4	1	2	6
	3 Moderate	x3	6	18	2	6	2	6	4	12	1	3	15
	4 Substantial	x4	16	64	8	32	7	28	6	24	5	20	42
	5 Severe	x5	13	65	5	25	10	50	5	25	9	45	42
	6 Disastrous	x6	8	48	0	0	3	18	1	6	10	60	22
	Total (<i>n</i>)		44	197	18	68	22	102	18	71	26	130	128
	Rating Average		3.50		2.95		3.62		3.08		3.91		

The top 10 frequent sources of IM problems were also studied according to the area of *industry types* in the same way as for the area of company types. Three industry groups resulted from the classification: (1) infrastructure, (2) oil and gas, and (3) commercial and building. Using equation 1, the 47 IM problems were studied and summarized in 47 tables that show the rating average for each industry type. After that, the 47 tables were examined to determine the most critical problems for each industry type.

Based on that, the top 10 IM problems for each industry type were ranked and summarized. Table 4.23 summarized the rating average of the highest IM problems for each industry type. As a general conclusion, the different industry types are almost in agreement as to the top 10 problems. For more detail, the oil and gas industry reported different IM problems, such as (1) unexpected changes in materials and labour availability and cost, (2) project extension versus greenfield (new) project type, and (3) type of the contract does not match the nature of the project. In addition, the commercial and buildings reported different IM problems, such as insufficient and inaccurate work drawings and specifications.

Table 4.22 A Summary of the Rating Average of the Highest IM Problems for each Company Type

IM Problem		Owner	EPC and Construction Contractor	EPCM and Construction Management Companies	Engineering Consultant	Architecture and Architecture and Engineering firms
1	Unclear system completion requirements	3.63	3.15	3.52	-	3.73
2	Inexperience with local laws and other government regulations and modification in laws and regulations	3.52	3.28	-	3.33	-
3	Lack of solid contracting strategy vision at an early stage of the project	3.50	-	3.62	-	3.91
4	Geotechnical circumstances problems	3.47	3.46	-	3.51	3.69
5	Type of the contract does not match the nature of the project	3.40	3.26	3.17	-	3.37
6	Project extension versus greenfield (new) project type	3.36	-	-	3.13	-
7	Unclear company standard operating procedures	3.36	-	-	-	-
8	Increase project interfaces conflicts when different contractors insist on their points of view	3.35	-	-	-	-
9	Insufficient definition of projects boundaries at an early stage of the project	3.35	-	3.75	3.17	3.57

Table 4.22 cont'd

IM Problem		Owner	EPC and Construction Contractor	EPCM and Construction Management Companies	Engineering Consultant	Architecture and Architecture and Engineering firms
10	Delay in established schedule of engineering, procurement, and construction, and delay in owner approval of completed tasks	3.34	3.07	3.18	3.16	3.48
11	Inexperience with building codes and trade union practices	-	3.47	-	3.39	3.67
12	Discrepancies between the owners' expectations regarding project construction schedule, cost, and quality	-	3.26	3.15	3.13	3.50
13	Weather and climate conditions problems	-	3.25	-	3.16	-
14	Unclear contract details and poorly written contract	-	3.19	3.19	-	3.54
15	Insufficient and inaccurate work drawings and specifications	-	3.11	-	-	-
17	Lack of solid contracting strategy vision at an early stage of the project	-	-	-	-	-
18	Application of fast-track engineering and construction techniques	-	-	3.42	3.28	-

Table 4.22 cont'd

IM Problem		Owner	EPC and Construction Contractor	EPCM and Construction Management Companies	Engineering Consultant	Architecture and Architecture and Engineering firms
19	Complete appraisal of bids to comprise an assessment of contractor's understanding of IM	-	-	3.21	-	-
20	No proper work packaging design and subcontracting	-	-	3.16	-	-
21	Lack of personal experience of the project teams	-	-	-	3.12	-
22	Lack of trust among different project parties	-	-	-	-	3.49

Table 4.23 A Summary of the Rating Average of the Highest IM Problems/Industry Type

	IM problems	Infrastructure	Oil & gas	Commercial & building
1	Inexperience with building codes and trade union practices	3.33	-	3.35
2	Insufficient definition of projects boundaries at an early stage of the project	3.30	3.17	3.21
3	Application of fast-track engineering and construction techniques	3.29	-	-
4	Geotechnical circumstances problems	3.28	3.05	3.40
5	Inexperience with local laws and other government regulations and modification in laws and regulations	3.26	3.03	3.09
6	Discrepancies between the owners' expectations regarding project construction schedule, cost, and quality	3.20	-	3.24
7	Unclear system completion requirements	3.15	3.32	3.25
8	Imprecise project cost estimate	3.07	-	-
9	Lack of solid contracting strategy vision at early stage of the project	3.05	3.17	3.34
10	Complete appraisal of bids to comprise an assessment of contractor's understanding of IM	3.00	-	-
11	Unexpected changes in materials and labour availability and cost		3.14	-
13	Project extension versus greenfield (new) project type		3.00	-
14	Delay in established schedule of engineering, procurement, and construction, and delay in owner approval of completed tasks		2.99	3.10
15	Type of the contract does not match the nature of the project		2.97	-
16	Unclear contract details and poorly written contract		2.97	3.09
18	Insufficient and inaccurate work drawings and specifications		-	3.01

Additionally, the top 10 frequent sources of IM problems were also studied according to the five independent job title groups: (1) project controls, planning engineer, construction planner, interface coordinator, and contract administrator, (2) project engineer, commissioning engineer, quality engineer, and lead (safety, procurement, etc.), (3) engineer (structural, mechanical, electrical), and project engineering manager, (4) project manager, construction manager, contractor and sub-contractor, (5) and architect. Based on equation 1, the 47 IM problems were studied and summarized in 47 tables that show the rating average for each respondent's title. After that, the 47 tables were examined to determine the most critical problems for each respondent's title. Based on that, the top 10 IM problems for each respondent's title type were ranked and summarized. As an example, Table 4.24 summarized the rating average of the highest IM problems for each respondent's title type.

Generally, the different respondent's title types are in agreement as to the top 10 problems. As well, engineer and project engineering manager reported different IM problems, such as (1) lack of knowledge about site circumstances by the project team members, (2) insufficient and inaccurate work drawings and specifications, and (3) interfaces with other interdependent projects.

In addition, the top 10 frequent sources of IM problems were further divided into four groups, according to years of experience, as follows: (1) ≤ 9 years, (2) 10–14 years, (3) 15–19 years, and (4) ≥ 20 years. Using equation 1, the 47 IM problems were studied and summarized in 47 tables that show the rating average for each type of years of experience. After that, the 47 tables were examined to determine the most critical problems for each years of experience type. Based on

that, the top 10 IM problems for each years of experience type were ranked and summarized. Table 4.25 summarized the rating average of the highest IM problems for each years of experience type. Generally, the different years of experience types are in agreement concerning the top 10 problems.

Table 4.24 A Summary of the Rating Average of the Highest IM Problems for each Job Title

	IM Problems	1. Project controls, planning engineer, construction planner, interface coordinator	2. Project engineer, commissioning engineer, quality engineer, and lead	3. Engineer and project engineering manager	4. Project manager, construction manager, contractor	5. Architect
1	Inexperience with building codes and trade union practices	3.60	3.50	3.15	3.25	3.65
2	Slow in change orders, permits, and shop drawings submission and approval	3.57	3.59	-	-	3.88
3	Lack of solid contracting strategy vision at early stage of the project	3.33	-	3.02	3.30	-
4	Type of contracting strategy; EP, EPC, and EPCM	3.28	3.28	3.28	3.55	3.62
5	Inexperience with the government auditing protocols and procedures	3.26	3.61	3.19	-	3.58
6	Lack of knowledge about site circumstances by the project team members	3.20	-	-	-	-
7	Lack of trust among different project parties	3.19	-	-	3.36	
8	In the invitation to tender, identify the interface problems	3.18	-	-	-	-
9	Type of organization structure, e.g., matrix organization increases interface points	3.17	-	-	-	-
10	Incapability to predict and resolve project's problems related to new technological techniques and materials	3.17	-	-	-	3.40
11	Weather and climate conditions problems	-	3.75	3.18	-	-

Table 4.24 cont'd

	IM Problems	1.Project controls, planning engineer, construction planner, interface coordinator	2.Project engineer, commissioning engineer, quality engineer, and lead	3) Engineer & project engineering manager	4.Project manager, construction manager, contractor	5.Architect
12	Application of fast-track engineering and construction techniques	-	3.66	-	3.42	3.48
13	Unexpected changes in materials and labour availability and cost	-	3.52	3.12	3.51	3.66
14	Geotechnical circumstances problems, e.g., lack of information on the geotechnical examination	-	3.52	-	3.36	-
15	Complete appraisal of bids to comprise an assessment of contractor's understanding of interface management	-	3.43	-	-	-
16	Unclear contract details and poorly written contract	-	3.33		-	-
17	No proper work packaging design and subcontracting	-	-	3.07	3.23	
18	Lack of knowledge about site circumstances by the project team members	-	-	3.07	-	-
19	Insufficient and inaccurate work drawings and specifications	-	-	3.02	-	3.40
20	Interfaces with other interdependent projects	-	-	3.00		
21	Increase project interfaces conflicts when different contractors insist on their points of view	-	-	-	3.30	3.47
22	Lack of personal experience of the project teams	-	-	-	-	3.41

Table 4.25 A Summary of the Rating Average of the Highest IM Problems for each Year of Experience

	IM Problems	≤9 years	10–14 years	15–19 years	≥20 years
1	Lack of solid contracting strategy vision at early stage of the project	3.62	3.19	3.60	3.26
2	Unclear system completion requirements	3.58	3.18	3.50	3.28
3	Insufficient definition of projects boundaries at an early stage of the project	3.40	3.06	3.31	3.40
4	Type of the contract does not match the nature of the project.	3.26	-	-	-
5	Inexperience with building codes and trade union practices	3.23	3.29	3.26	3.23
6	Weather climate conditions problems	3.20	3.12	-	3.15
7	Geotechnical circumstances problems	3.10	3.08	3.25	3.46
8	Project extension versus greenfield (new) project type	3.04	3.06	-	-
9	Type of contracting strategy; EP, EPC, and EPCM	3.01	-	-	-
10	Inexperience with local laws and other government regulations and modification in laws and regulations	3.01	3.39	3.31	-
11	Unclear contract details and poorly written contract	-	3.09	-	-
12	Inexperience with the government auditing protocols and procedures	-	3.08	-	-
13	Unclear company standard operating procedures	-	-	3.36	-
14	Delay in established schedule of engineering, procurement, and construction	-	-	3.25	3.17
15	Lack of trust among different project parties	-	-	3.24	-
16	Unexpected changes in materials and labour availability and cost	-	-	3.22	3.22
17	Application of fast-track engineering and construction techniques	-	-	-	3.21
18	Insufficient and inaccurate work drawings and specifications	-	-	-	3.20

4.2.6 Multiple regression models.

In this study, the number of participants is 135 and there are six interface management factors (six predictors), which indicates that this study has 22 times as many participants as predictor variables (approximately 22 participants for each predictor variable); this exceeds the required ratio of 5:1 (Brace et al., 2006). The following null hypotheses were proposed and examined under this section. To examine the hypotheses, six multiple regression models were conducted between the six different construction performance indicators (quality management, schedule management, cost management, scope management, and safety management, and team work) as dependent variables and six underlying interface problem factors as independent variables, using IBM SPSS® Statistics version 20. The six multiple regression models can be used to predict the factors that affecting each project performance indicator. Consequently, these models can be used to predict overall project performance at the early stages of the projects. **Hypothesis 5, 6, 7, 8, 9, and 10:** There would be no significant relationships between the extracted factors and the project performance indicators:

- Quality
- Schedule
- Cost
- Scope
- Safety
- Teamwork

The multiple regression analyses results indicated that the interface problem factor had a major impact on the project performances. Appendix VII shows the results of the multiple-regression analysis. The results of the multiple-regression models indicate that the interface problems caused by the technical engineering and site issues factor, the information factor, the bidding and

contracting factor, and law and regulation factor were the strongest in influencing the schedule project performance indicator as shown in Table 4.26, whereas the interface problems caused by the technical engineering and site issues factor, the bidding and contracting factor, and the information factor were the strongest to influence the cost project performance indicator. On the other hand the problems caused by the management factor and the law and regulation factor had the most influence on the rest of the project performance indicators, which are quality, scope, safety, and teamwork. Readers can refer to Weshah et al., (2013b) for more details about the IM problems listed under each IM factor. In summary, based on all the multiple regression results, Table 4.26 shows that the management factor, law and regulation factor, and technical and site issues factor are the most important factors affecting overall project performance. Many results can be concluded out of Table 4.26, for example under the quality project performance indicator the β for the management factor and the law and regulation factor were 0.487 and 0.285, respectively, which indicated that the law and regulation factor influences the quality management less than the management factor.

Table 4.26 Standard Deviation of Responses for Overall Project Performance

Factors	Quality	Schedule	Cost	Scope	Safety	Teamwork	Overall Performance
Mgt.	0.487			0.521	0.477	0.455	1.94
Inf.		0.225	0.218				0.443
Bid & cont.		0.181	0.259				0.44
Law & reg.	0.285	0.152		0.207		0.388	1.032
Tech. & site issues		0.354	0.399				0.753

“One way of developing multiple correlation is to obtain the prediction equation for Y' in order to compare the prediction value of the dependent variables with obtained Y' ” (Tabachnick & Fidell, 2001).

$$Y' = A + B_1X_1 + B_2X_2 + \dots + B_KX_K \quad (2)$$

where

Y' is the predicted value of Y , A is the value of Y' when all X are zero, B_1 to B_K represent regression coefficients, and X_1 to X_K represent the independent variables” (Tabachnick & Fidell, 2001).

Based on equation (2) and Appendix VII, the predication equations for the:

- ***Project quality performance is***

$$Y' = 0.529 + 0.621 X_1 + 0.248 X_2 \quad (3)$$

where Y' is the project quality performance predicted value

X_1 is the management factor

X_2 is the law and regulation factor

An example of calculations of the project quality performance predicted value is as follows:

$$Y' = 0.529 + 0.621(4.18) + 0.248(3.78) = 4.06$$

X_1 is equal to 4.18, which is the mean of the data under the management factor collected using the questionnaire.

X_2 is equal to 3.78, which is the mean of the data under the law and regulation factor collected using the questionnaire.

- ***Project schedule performance is***

$$Y' = 0.824 + 0.434X_1 + 0.231X_2 + 0.199X_3 + 0.132X_4 \quad (4)$$

where

Y' is the project schedule performance predicted value

X_1 is the technical engineering and site issues factor

X_2 is the information factor

X_3 is the bidding and contracting factor

X_4 is the law and regulation factor

▪ ***Project cost performance is***

$$Y' = 0.547 + 0.514X_1 + 0.301X_2 + 0.236X_3 \quad (5)$$

where

Y' is the project cost performance predicted value

X_1 is the technical engineering and site issues factor

X_2 is the bidding and contracting factor

X_3 is the information factor

▪ ***Project scope performance is***

$$Y' = 0.532 + 0.684X_1 + 0.183X_2 \quad (6)$$

where

Y' is the project scope performance predicted value

X_1 is the management factor

X_2 is the law and regulation factor

▪ ***Project safety performance is***

$$Y' = 0.407 + 0.724X_1 \quad (7)$$

where

Y' is the project safety performance predicted value

X_1 is the management factor

▪ ***Project teamwork performance is***

$$Y' = 0.294 + 0.633X_1 + 0.321X_2 \quad (8)$$

where

Y' is the project teamwork performance predicted value

X_1 is the management factor

X_2 is the law and regulation factor

Based on the results of the aforementioned regression analysis, all the null hypotheses were rejected.

4.2.7 Reliability.

The reliability statistical tool is usually used to assess the stability and consistency in survey questions, to ensure that the questions are appropriately reliable and to present a certain measurement by using Cronbach's alpha. "Cronbach's alpha measures how well a set of items measures a single unidimensional latent construct" (Nunnally, 1978). In this research study, the reliability analysis was conducted for examining the reliability of the six extracted IM factors to ensure the correctness (accuracy) of the extracted factors. A value of 0.7 reliability coefficient or higher is acceptable in the social sciences (Nunnally, 1978). Most of the Cronbach's α values in this study are greater than 0.85 except for the other interface problems factor, which is lower

than 0.70 with a value of 0.415, as shown in Table 4.27. Therefore, the variables in this research study are considered reliable.

As discussed in the previous sections, the other interface problems factor consists of only two IM problems, which will not impact the reliability of overall data including the 47 IM problems. In addition, all the Cronbach's α values of the reliability test of the six project performance indicators are greater than 0.95, as shown in Table 4.28.

Table 4.27 Reliability Test of Interface Problem Factor

Factor Categories	Mgt. factor	Inf. factor	Bid & contr. factor	Law & reg. factor	Tech. Eng. & site issues factor	Others factor
Cronbach's α	0.902	0.865	0.899	0.875	0.881	0.416

Table 4.28 Reliability Test of Project Performance Indicators

Indicator Name	Quality Mgt.	Schedule Mgt.	Cost Mgt.	Scope Mgt.	Safety Mgt.	Teamwork Mgt.
Cronbach's α	0.97	.97	.974	.968	.978	.97

4.3 Conclusions

This research began a comprehensive investigation to identify and classify interface problem factors in Alberta's construction projects through structured face-to-face interviews and empirical questionnaires. The collected data were analyzed using factor analysis, Pearson's correlation matrix, and the one-way MANOVA test. Exploratory factor analysis was performed to extract the factors and the latent structure of independent variables (interface problems). Correlation between IM factors and different construction data was tested. The data analysis

results provided a comprehensive view of the main causes behind IM conflicts in Alberta's construction industry. The results identified six IM factors affecting construction project performance in Alberta. The study concluded that the management factor is the factor most impacting IM performance. Although there are strong relationships between the six extracted factors and the company type, job title type, and years of experience, there are no relationships between the six extracted IM factors and the industry type.

Based on the aforementioned conclusions that identified major interface management factors impacting construction project performance, a new integrated IM model was introduced to enhance project performance by developing multiple regression models. These models were used to evaluate and predict project performance based on IM at a project's early stages.

The results of the multiple regression models indicate that the interface problems caused by the technical engineering and site issues factor, the information factor, the bidding and contracting factor, and the law and regulation factor had the strongest influence on the schedule project performance indicator. The interface problems caused by the technical engineering and site issues factor, the bidding and contracting factor, and the information factor had the strongest influence on the cost project performance indicator. On the other hand, the problems caused by the management factor and the law and regulation factor had the most influence on the rest of the project performance indicators, i.e., quality, scope, safety, and teamwork. Readers can refer to Weshah et al. (2013) for more details about the IM problems listed under each IM factor.

4.4 Summary and Connection with the Next Chapters

The findings of this chapter present a basis for enhancing overall project performance and the interfaces by (a) reviewing the interfaces in depth during the engineering/design phase of construction projects (Chapter 5), (b) developing a conceptual framework (RIBA framework) in order to highlight the IM areas consider critical and use case models to study the IM relationships among owner, contractor and designer throughout project lifecycle using the Microsoft Visio® flowcharts and UML use case diagrams (Chapter 6), and (c) developing suggestions for improving and enhancing IM that are adequate to all participants engaged in construction projects (Chapter 6).

Chapter Five: Factor Analysis and Multiple Regression Analysis of Interface Management during Engineering/Design Phase

5.1 Chapter Overview

Two web-based online surveys were performed with participants from industry throughout the project lifecycle and during the engineering/design phase, as shown in Appendix III and IV. This chapter provides full details of the *second survey* that was conducted during the engineering/design phase. This part of the research study consists of deeply studying the interfaces during the engineering/design phase of projects using a web-based questionnaire with participants from industry. This chapter provides analysis of the *second survey* results and discussion of the findings and conclusions. The contents of this chapter will be submitted to the *Journal of Construction Engineering*.

5.2 Analysis of Survey Results and Discussion of Findings

5.2.1 Respondent's profile.

The number of valid responses is 161. The highest number of responses was received from project manager and engineers (structural, mechanical, electrical), followed by project control, project engineer, and architect, as shown in Table 5.1. In addition, in terms of the company types, the highest number of responses was obtained from owners, EPC, EPCM, and engineering consultants, as shown in Table 5.2. The questionnaire participants are in different fields and include 99 participants working in the oil and gas industry and 29 working in commercial and buildings, as shown in Table 5.3. Finally, more than half of the questionnaires' contributors have ≥ 20 years of experience, as shown in Table 5.4. The participants in this study are well-educated,

as shown in Table 5.5. Finally, most of the participants' current projects are high-complexity projects, as shown in Table 5.6.

Table 5.1 Respondents' Job Profiles

Respondents' Job Profiles	Number of Responses	Percentage of Responses (%)
Lead (safety, procurement, etc.)	7	4
Project controls	18	11
Interface coordinator	12	8
Project engineer	18	11
Quality engineer	2	1
Planning engineer	2	1
Project Manager	36	22
Contractor/sub-contractor	3	2
Engineer (structural, mechanical, electrical)	22	14
Architect	16	10
Project engineering manager	11	7
Other	14	9

Table 5.2 Respondents' Company Types

Respondents' Company Types	Number of Responses	Percentage of Responses (%)
Owner	47	29
EPC	34	21
EPCM	19	12
Engineering consultant	18	11
Architecture firms	3	2
Architecture and engineering firms	11	7
Construction management company	7	4
Others	22	14

Table 5.3 Respondents' Industry Types

Respondents' Industry Types	Number of Responses	Percentage of Responses (%)
Infrastructure	18	11
Oil and gas	99	61
Transportation	6	4
Commercial and buildings	29	18
Other sectors	9	6

Table 5.4 Respondents' Years of Experience Types

Respondents' Years of Experience Types	Number of Responses	Percentage of Responses (%)
≤5 years	11	7
6–9 years	18	11
10–14 years	31	19
15–19 years	15	9
≥20 years	86	54

Table 5.5 Respondents' Level of Education Types

Respondents' Level of Education Types	Number of Responses	Percentage of Responses (%)
Diploma	10	6
Post diploma	9	6
BSc	74	46
MSc	49	30
PhD	13	8
Others	6	4

Table 5.6 Respondents' Level of Complexity Types

Respondents' Level of Complexity Types	Number of Responses	Percentage of Responses (%)
High complexity	88	55
Medium complexity	59	36
Low complexity	14	9

5.2.2 Pearson product-moment correlation.

One of the requirements to get a reasonable factor analysis technique is to have a significant correlation between the 22 identified interface management (IM) problems. Pearson product-moment correlation (PPMC) values, given in Appendix VIII, show that although 67% of the 22 interface problems show medium to high relations and are correlated positively, 30% show low to weak relations, and 2% show high and very strong relations. Therefore, the collected data are reasonable to use in the factor analysis technique. The reader can refer to Chapter four to get more information about the PPMC.

5.2.3 Factor influencing interface management.

Factor analysis is “a statistical technique used to identify a relatively small number of factors that can be used to represent the relationships among sets of many interrelated variables” (R. Huang et al., 2008). Chapter four has information about the factor analysis technique. With eigenvalues greater than 1, results show that four factors can be extracted and identified during the engineering/design phase, as shown in the Kaiser’s normalization criterium results in Figure 5.1. Tables 5.7–5.10 provide the list of the four extracted factors, namely management, information, law and regulation, and other interface problems.

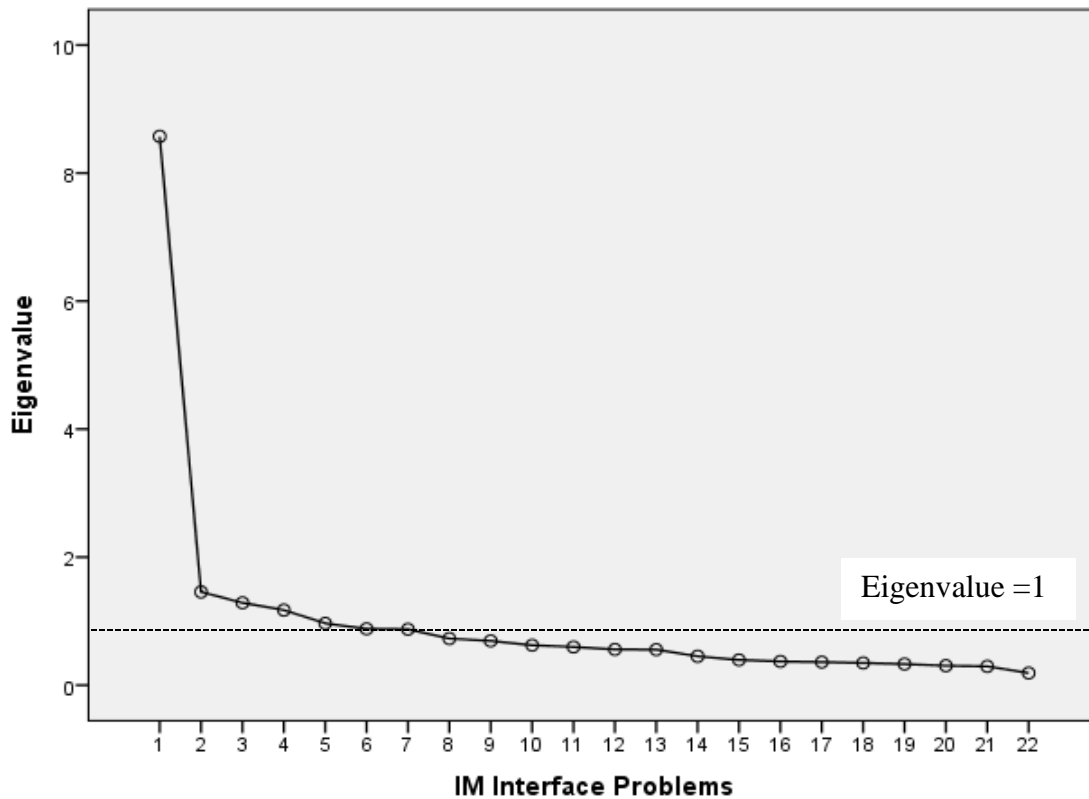


Figure 5.1 Scree Plot of 22 Interface Problems

Table 5.7 Summary of Factor Analysis (Management Factor)

No	IM Problem	Mgt. factor	Inf. factor	Law & reg. factor	Others factor
1	Lack of enough negotiation and communication and coordination	.601	.155	.202	.189
2	Financial difficulties	.615	.020	.090	.330
3	Poor decision making	.700	.330	.111	-.002
4	Limited skills for labour & engineering	.480	.164	.414	.107
5	Engineering process problems related to interfaces	.629	.345	.168	.032
7	Lack of project management	.573	.477	.022	.103
9	Planning and scheduling problems	.511	.113	-.040	.424
18	Delay in established schedule of engineering, procurement, and construction, and delay in owner approval of completed tasks	.552	.196	.342	.198

Table 5.8 Summary of Factor Analysis (Information Factor)

No	IM Problem	Mgt. factor	Inf. factor	Law & reg. factor	Others factor
6	Information problems	.478	.627	.159	.007
8	Lack of interface management system	.267	.685	.001	.251
10	Type of organization structure	-.104	.395	-.021	.255
12	Undefined reporting structure and responsibilities	.247	.669	.123	.147
13	Insufficient and lack of alignment among WBS, CWBS, CBS, and OBS	.248	.472	.092	.513
16	Insufficient and inaccurate work drawings and specifications	.177	.719	.307	.121
17	No proper work packaging design and subcontracting	.200	.699	.341	.100

Table 5.9 Summary of Factor Analysis (Law and Regulation Factor)

No.	IM Problem	Mgt. factor	Inf. factor	Law & reg. factor	Others factor
20	Inexperience with local laws and other government regulations and modifications in laws and regulations	.141	.254	.841	.140
21	Inexperience with building codes; trade union practices	.265	.285	.795	.111

Table 5.10 Summary of Factor Analysis (Others Factor)

No.	IM Problem	Mgt. factor	Inf. factor	Law & reg. factor	Others factor
11	Interfaces with other interdependent projects	.157	.165	.372	.585
14	Lack of personal experience of the project teams	0.080	.180	.113	0.653
15	Lack of trust among different project parties	0.126	.045	.220	.625
19	Type of the contract does not match the nature of the project	.304	-.031	.150	.669
22	Unclear system completion requirements	.325	.088	.206	.599

5.2.3.1 Correlation between emergent factors.

The correlation coefficients among the four extracted factors, calculated using the factor analysis technique, are shown in Table 5.11. The results show that these factors are significantly and positively correlated.

Table 5.11 Correlation Coefficients between Four Extracted Factors

	Mgt. factor	Inf. factor	Law & reg. factor	Others factor
Mgt. factor	1			
Inf. factor	.737	1		
Law & reg. factor	.554	.540	1	
Others factor	.731	.779	.562	1

5.2.4 Analysis of the variance (MANOVA) between IM factor and different data.

This section provides results of the test of normality and research hypothesis between IM factors and different construction data. For more details, these hypotheses examine the relationships between the IM factors and different construction data: company type, industry type, title type, and years of experience.

5.2.4.1 Normality.

The test of normality shows that all the variables are consistent with the normality assumptions and homogeneity of variance.

5.2.4.2 Research hypothesis between IM factors and different construction data.

The MANOVA technique was applied to decide whether the four factors (variables) have an important impact on IM among different groups type (independent variables: company type, industry type, title type, and years of experience). Four hypotheses were presented and examined

in this research study using the one-way MANOVA test. Tables 5.12, 5.14, 5.16, 5.18, and 5.20 show the means, standard deviations, and the numbers of cases for the four dependent variables (IM extracted factors) and the independent variables (groups) of the company type, industry type, title type, and years of experience, complexity of the projects. Tables 5.13, 5.15, 5.17, 5.19, and 5.21 summarize the MANOVA results. Results show that the information factor and law and regulation factor impact IM most during the engineering/design phase. These results are expected and make sense during this phase. The following section provides full details regarding the tested hypotheses.

1. Job title group related to factor group

Based on five groups, the four IM factors were examined. Five independent job title groups were included in the respondent's title type: (1) project controls, planning engineer, interface coordinator; (2) project engineer, quality engineer, and lead (safety, procurement, etc.); (3) engineer (structural, mechanical, electrical) and project engineering manager; (4) project manager, contractor, and sub-contractor; (5) architect. The following hypothesis (Hypothesis 1) was presented and examined; there would be no significant difference in the means between the impact of the four IM extracted factors (dependent variables) and respondent's title groups as independent variables.

Table 5.12 shows that for the calculated means, the information and the law and regulation factors are the factors that most impact IM, followed by the management factor. More results could be listed for each group, as shown in Table 5.12. For example, the project controls people, planning engineer, and interface coordinator consider the information factor among other groups

as the highest factor impacting IM performance. This result was expected because they merely support the project and other project participants provide them with the information. On the other hand, the project engineer, quality engineer, and lead consider the law and regulation factor as the factor impacting IM the most. Moreover, Table 5.13 shows that the overall MANOVA is statistically significant ($F_{16,400.849} = 2.720$; $p = 0.000$). In addition, there is almost a significant difference between the five groups. Therefore, hypothesis 1 can be rejected. For more details, three out of four factors are statistically significant: the management factor ($F_{4,134} = 2.449$; $p = 0.049$), the information factor ($F_{4,134} = 3.126$; $p = 0.017$), and the law and regulation factor ($F_{4,134} = 2.578$; $p = 0.040$), as shown in Table 5.13. Therefore, this result specifies that these three factors are affected by different respondent's title groups. There are major differences between group 4 and group 5 under the management factor with p -values equal to 0.076. This indicates that between group 4 and group 5 the impact of this factor on IM performance is significantly different. Other findings could be summarized from Tables 5.12 and 5.13.

Table 5.12 Calculated Means (Title Type Groups and Extracted IM Factors)

Extracted IM Factors Title Type Group	Mgt. factor (X,SD,N)	Inf. factor (X,SD,N)	Law & reg. factor (X,SD,N)	Others factor (X,SD,N)
1. Project controls, planning engineer, interface coordinator	4.54, 0.68, 31	5.56 , 0.94, 31	4.66, 1.13, 31	4.01, 0.88, 31
2. Project engineer, quality engineer, and lead	4.57, 0.68, 27	5.02, 0.75, 27	5.11 , 0.91, 27	4.41, 0.73, 27
3. Engineer (structural, mechanical, etc.) and project eng. manager	4.32, 0.54, 28	4.44, 0.82, 28	4.63, 0.95, 28	4.16, 0.75, 28
4. Project manager, contractor, and sub-contractor	4.58, 0.54, 39	4.82, 0.68, 39	4.64, 1.18, 39	4.46, 0.66, 39
5. Architect	4.08, 0.62, 14	4.35 , 0.46, 14	4.00, 1.04, 14	4.27, 0.63, 14
Total	4.47	4.67	4.67	4.26

Table 5.13 MANOVA Results (Title Type Groups and Extracted IM Factors)

Source	<i>F</i>	df1,df2	<i>P</i>
Overall	2.720	16,400.849	0.000
Management factor	2.449	4,134	0.049
Information factor	3.126	4,134	0.017
Law factor	2.578	4,134	0.040
Other factors	1.981	4,134	0.101
*Management factor group comparison			
Group 4 and Group 5			0.076
*Information factor group comparison			
Group 2 and Group 3			0.049
*Law and fequlation factor group comparison			
Group 5 and Group 2			0.016

*Included only the significant pairwise comparison

2. Company type

Based on five company types, the four IM factors were examined. The five company types reported and discussed are (1) owner, (2) EPC, (3) EPCM and construction management companies, (4) engineering consultant, and (5) architecture firms and architecture and engineering firms. The following hypothesis (Hypothesis 2) was tested; there would be no significant difference in means between the impact of the four IM extracted factors (dependent variables) and different company types as independent variables. Table 5.14 shows that for the calculated means, the information and the law and regulation factors are the factors most impacting IM, followed by the management factor. That indicates that these two factors are more important than other factors. Moreover, among all groups, the engineering consultant company considered these two factors as the factor most impacting IM. Moreover, Table 5.15 shows that the overall MANOVA is statistically significant ($F_{16,403.904} = 2.001$; $p = 0.012$). In addition, there is almost a significant difference between the five groups. Therefore, hypothesis 1 can be rejected. For more details, three factors out of four factors are statistically significant: the management factor ($F_{4,135} = 2.853$; $p = 0.026$), the information factor ($F_{4,135} = 2.588$; $p = 0.040$), and the law and regulation factor ($F_{4,135} = 2.406$; $p = 0.053$), as shown in Table 5.15. Therefore, this result specifies that these three factors are affected by different company types. There are major differences between group 1 and group 5 under the management factor and the law and regulation factor with p -values equal to 0.020 and 0.042, respectively. This indicates that between group 1 and group 5 the impacts of these factors on IM performance are significantly different. Other findings could be summarized from Tables 5.14 and 5.15.

Table 5.14 Calculated Means (Company Type Groups and Extracted IM Factors)

Company type Groups \ Extracted IM Factors	Mgt. factor (X,SD,N)	Inf. factor (X,SD,N)	Law & reg. factor (X,SD, N)	Others factor (X,SD,N)
1. Owner	4.64, 0.62, 47	4.78, 0.85, 47	4.90, 1.01, 47	4.28, 0.83, 47
2. EPC	4.38, 0.54, 34	4.47, 0.73, 34	4.59, 1.14, 34	4.04, 0.68, 34
3. EPCM and construction management companies	4.52, 0.57, 27	4.78, 0.75, 27	4.59, 1.00, 27	4.31, 0.71, 27
4. Engineering consultant	4.58, 0.55, 18	5.03 , 0.73, 18	4.94 , 1.06, 18	4.54, 0.61, 18
5. Architecture firms and architecture and engineering firms	4.09, 0.62, 14	4.35, 0.46, 14	4.00, 1.04, 14	4.27, 0.63, 14
Total	4.49	<u>4.69</u>	<u>4.69</u>	4.26

Table 5.15 MANOVA Results Table (Company Type Groups and Extracted IM Factors)

Source	<i>F</i>	df1,df2	<i>p</i>
Overall	2.001	16, 403.904	0.012
Management factor	2.853	4, 135	0.026
Information factor	2.588	4, 135	0.040
Law factor	2.406	4, 135	0.053
Others factor	1.482	4, 135	0.211
*Management factor group comparison			
Group 1 and Group 5			0.020
*Regulation factor group comparison			
Group 1 and Group 5			0.042

*Included only the significant pairwise comparison

3. Industry type

Based on three industry types, the four IM factors were examined. The three industry types reported and discussed are (1) infrastructure, (2) oil and gas, and (3) commercial and building. The following hypothesis (Hypothesis 3) was tested; there would be no significant difference in means between the impact of the four IM extracted factors (dependent variables) and different industry types as independent variables.

Table 5.16 shows the calculated means; the information factor impacts IM the most, followed by the information and the law and regulation factors. That indicates that this factor is more important than other factors. Moreover, Table 5.17 shows that the overall MANOVA is statistically significant ($F_{8,284.00} = 2.182$; $p = 0.029$). In addition, there is almost a significant difference between the three groups. Therefore, hypothesis 1 can be rejected. For more details, two factors out of four factors are statistically significant: the management factor ($F_{2,145} = 4.572$; $p = 0.012$) and the information factor ($F_{2,145} = 4.020$; $p = 0.020$), as shown in Table 5.17. Therefore, this result specifies that these two factors are affected by different industry types. The oil and gas industry and commercial and building industry considered the law and regulation factor as the most important factor affecting IM followed by the information factor. There are major differences between group 1 and group 3 under the management factor with p -values equal to 0.008. This indicates that between group 1 and group 3 the impacts of these factors on IM performance are significantly different. There are major differences between group 1 and group 2 under the information factor with p -values equal to 0.024. This indicates that between group 1

and group 2 the impacts of these factors on IM performance are significantly different. Other findings could be summarized from Tables 5.16 and 5.17.

Table 5.16 Calculated Means (Industry Type Groups and Extracted IM Factors)

Industry Type Group \ Extracted IM Factors	Mg. factor (X,SD,N)	Inf. factor (X,SD,N)	Law & reg. factor (X,SD,N)	Others factor (X,SD,N)
1. Infrastructure	4.83, 0.50, 17	5.21 , 0.44, 17	4.85, 0.82, 17	4.62, 0.52, 17
2. Oil and gas	4.50, 0.60, 107	4.69, 0.81, 107	4.75 , 1.07, 107	4.26, 0.75, 107
3. Commercial and building	4.27, 0.53, 24	4.60, 0.61, 24	4.33, 1.13, 24	4.28, 0.58, 24
Total	4.51	4.73	4.69	4.30

Table 5.17 MANOVA Results Table (Industry Type Groups and Extracted IM Factors)

Source	<i>F</i>	df1, df2	<i>p</i>
Overall	2.182	8, 284.00	0.029
Management factor	4.572	2, 145	0.012
Information factor	4.020	2, 145	0.020
Law factor	1.723	2, 145	0.182
Other factors	1.905	2, 145	0.153
*Management factor group comparison			
Group 1 and Group 3			0.008
*Information factor group comparison			
Group 1 and Group 2			0.024
Group 1 and Group 3			0.028

*Included only the significant pairwise comparison

4. Years of experience

The four extracted IM factors were analyzed by four groups. Years of experience includes the four groups (1) ≤ 9 years, (2) 10–14 years, (3) 15–19 years, and (4) ≥ 20 years.

The following hypothesis (Hypothesis 4) was proposed and examined; there would be no significant difference in means between the impact of the four IM extracted factors (dependent variables) and total years of experience groups as independent variables. Table 5.18 shows that for the calculated means, the information and the law and regulation factors are the factors most impacting IM, followed by the management factor. That indicates that these two factors more important than other factors. Moreover, regardless of the years of experience, the highest years of experience group (≥ 20 years) and the lowest years of experience group (≤ 9 years) ranked the factors affecting IM performance in the same order. Both groups considered the law and regulation and information factors as the factors most affecting IM performance, followed by the management factor. Moreover, Table 5.19 shows that the overall MANOVA is statistically significant ($F_{12,402.440} = 1.730$; $p = 0.058$). In addition, there is almost a significant difference between the five groups. Therefore, hypothesis 1 can be rejected. For more details, four factors are statistically significant: the management factor ($F_{3,155} = 3.914$; $p = 0.010$), the information factor ($F_{3,155} = 4.674$; $p = 0.040$), the law and regulation factor ($F_{3,155} = 2.226$; $p = 0.087$), and others factor ($F_{3,155} = 2.299$; $p = 0.080$), as shown in Table 5.19. Therefore, this result specifies that these four factors are affected by different years of experience groups. There are major differences between group 1 and group 4 under the management factor, the information factor, and the law and regulation factor with p -values equal to 0.044, 0.011, and 0.052, respectively.

This indicates that between group 1 and group 4, the impacts of these factors on IM performance are significantly different. Other findings could be summarized from Tables 5.18 and 5.19.

Table 5.18 Calculated Means (Years of Experience Groups and Extracted IM Factors)

Years of Experience Group \ Extracted IM Factors	Mgt. factor (X,SD,N)	Inf. factor (X,SD,N)	Law & reg. factor (X,SD,N)	Others factor (X,SD,N)
1. ≤9 years	4.24, 0.53, 27	4.36, 0.69, 27	4.24, 1.14, 27	4.01, 0.68, 27
2. 10–14 years	4.37, 0.69, 31	4.49, 1.00, 31	4.69, 0.92, 31	4.19, 0.94, 31
3. 15–19 years	4.76, 0.58, 15	4.87, 0.59, 15	4.73, 1.34, 15	4.30, 0.61, 15
4. ≥20 years	4.57, 0.55, 86	4.90 , 0.66, 86	4.84 , 1.01, 86	4.40, 0.65, 86
Total	4.49	4.72	4.72	4.28

Table 5.19 MANOVA Results Table (Years of Experience Groups and IM Factors)

Source	<i>F</i>	df1,df2	<i>p</i>
Overall	1.730	12,402.440	0.058
Management factor	3.914	3,155	0.010
Information factor	4.674	3,155	0.040
Law factor	2.226	3,155	0.087
Others factor	2.299	3,155	0.080
*Management factor group comparison			
Group 1 and Group 3			0.027
Group 1 and Group 4			0.044
*Information factor group comparison			
Group 1 and Group 4			0.011
*Regualtion factor group comparison			
Group 1 and Group 4			0.052

*Included only the significant pairwise comparison

5. Project complexity

The four extracted IM factors were analyzed by three levels of project complexity: (1) high, (2) medium, and (3) low. The following hypothesis (Hypothesis 5) was proposed and examined; there would be no significant difference in means between the impact of the four IM extracted factors (dependent variables) and level of project complexity groups as independent variables. Table 5.20 shows that for the calculated means, the information and the law and regulation factors are the factors most impacting IM, followed by the management factor. That indicates that these two factors are more important than other factors. Table 5.21 shows that, the overall MANOVA is not statistically significant ($F_{8,300.000} = 0.630$; $p = 0.753$). Consequently, hypothesis 3 can be accepted. There was no statistically significant difference between the IM factors and the level of project complexity. Consistent with these results, a follow up univariate test presented no significant results among level of project complexity types. Therefore, the conclusion is that the IM factors are not affected by the level of project complexity types. This result was not expected and needs to be studied more in future research.

Table 5.20 Calculated Means (Level of Complexity Groups and Extracted IM Factors)

Extracted IM Factors Years of Experience Group	Mgt. factor (X,SD,N)	Inf. factor (X,SD,N)	Law & reg. factor (X,SD,N)	Others factor (X,SD,N)
1. High complexity	4.56, 0.63, 88	4.77 , 0.80, 88	4.76 , 1.03, 88	4.33, 0.76, 88
2. Medium complexity	4.42, 0.54, 60	4.67, 0.73, 60	4.70, 1.05, 60	4.26, 0.59, 60
3. Low complexity	4.49, 0.57, 8	4.48, 0.78, 8	4.31, 0.96, 8	3.98, 1.10, 8
Total	4.51	4.72	4.72	4.28

Table 5.21 MANOVA Results Table (Level of Complexity Groups and IM Factors)

Source	<i>F</i>	df1, df2	<i>p</i>
Overall	0.630	8, 300.000	0.753
Management factor	0.958	2, 153	0.386
Information factor	0.731	2, 153	0.483
Law factor	0.701	2, 153	0.498
Others-factor	0.911	2, 153	0.404

5.2.5 Top 10 interface problems that affect IM.

What are the most critical problems affecting each aspect of IM during the engineering/design phase of EPC projects? The cross-tabulated analysis and the ranking factor process method were used to examine the frequency of the 22 IM problems. Four areas were studied with the 22 IM problems, including company types, industry types, years of experience, and respondent's title.

The five company types listed and discussed are (1) owner, (2) EPC, (3) EPCM and construction management companies, (4) engineering consultant, and (5) architecture firms and architecture and engineering firms. The 22 IM problems were studied and summarized in 22 tables that show the rating average for each company type. The following equation is used to calculate the rating average Y_j :

$$Y_j(\%) = \frac{\sum_i a_{ij}}{\sum_i b_{ij} \times n} 100 \quad (1)$$

where a_{ij} is the weighting scale of the linked scale i for company j , b_{ij} is the number of responses of linked scale i for company j , and n is the number of responses in the survey. The reader can refer to Chapter 4 to get more information about the application of this equation.

Accordingly, the 22 tables were created to find the company type that considers each of the 22 IM problems the most critical. Based on the data from the 22 tables, the top 10 IM problems for each company type were ranked and summarized, as shown in Table 5.22. It should be realized that the five company types are in agreement over the 10 general IM problems (not necessary, in the same rank) with the exception of company type 5 (architecture firms and architecture and engineering firms), as they reported different IM problems, such as type of the contract does not match the nature of the project. In addition, the following three companies, EPCM and construction management companies, engineering consultant, and architecture firms and architecture and engineering firms considered the lack of personal experience of the project teams as one of the top 10 IM problems.

Table 5.22 A Summary of the Rating Average of the Highest IM Problems for each Company Type

No.	IM Problem	1. Owner	2. EPC and Construction Contractor	3. EPCM and Construction Management Companies	4. Engineering Consultant	5. Architecture firms and Architecture and Engineering
1	Insufficient and inaccurate work drawings and specifications	3.61	3.22	3.60	3.79	3.05
2	Lack of project management	3.54	3.40	3.27	3.47	-
3	Inexperience with building codes; trade union practices	3.53	3.32	3.31	3.61	2.96
4	Inexperience with local laws and other government regulations and modification in laws and regulations	3.48	3.24	3.25	3.45	-

Table 5.22 cont'd

No.	IM Problem	1. Owner	2. EPC and Construction Contractor	3. EPCM and Construction Management Companies	4. Engineering Consultant	5. Architecture firms and Architecture and Engineering
5	Unclear system completion requirements	3.38	3.32	3.29	3.36	2.93
6	No proper work packaging design and subcontracting	3.32	3.11	3.44	3.66	3.19
7	Undefined reporting structure and responsibilities	3.32	3.12	3.29	3.34	2.99
8	Lack of trust among different project parties	3.32	3.14	3.33	3.85	-
9	Delay in established schedule of engineering, procurement, and construction, and delay in owner approval of completed tasks	3.29	3.32	3.31	3.31	2.99
10	Insufficient and lack of alignment among WBS, CWBS, CBS, and OBS	3.18	2.98	-	-	-
11	Lack of personal experience of the project teams	-	-	3.29	3.35	3.20
12	Type of the contract does not match the nature of the project	-	-	-	-	3.24
13	Planning and scheduling problems	-	-	-	-	3.00

In the same steps aforementioned for the area of company types, the top 10 frequent sources of IM problems were also evaluated and summarized based on the area of industry types. Three industry groups were included: (1) infrastructure, (2) oil and gas, and (3) commercial and building and transportation. Based on equation 1, the 22 IM problems were studied and

summarized in 22 tables that show the rating average for each industry type. After that, the 22 tables were studied to determine the most critical problems for each industry type. Based on that, the top 10 IM problems for each industry type were ranked and summarized as shown in Table 5.23. Table 5.23 summarized the rating average of the highest IM problems for each industry type. Generally, the top 10 problems based on the three industry types are similar but not necessarily in the same rank and order.

Table 5.23 A Summary of the Rating Average of the Highest IM Problems for each Industry Type

IM problems		Infrastructure	Oil and gas	Commercial and building
1	Insufficient and inaccurate work drawings and specifications	3.62	3.28	3.31
2	No proper work packaging design and subcontracting	3.58	3.12	3.24
3	Lack of project management	3.48	3.20	2.86
4	Undefined reporting structure and responsibilities	3.47	2.99	3.09
5	Unclear system completion requirements	3.44	3.20	2.83
6	Lack of trust among different project parties	3.43	3.14	3.07
7	Delay in established schedule of engineering, procurement, and construction, and delay in owner approval of completed tasks	3.36	3.15	2.96
8	Inexperience with building codes, by-laws, statutes and other government regulations	3.30	3.24	3.04
9	Insufficient and lack of alignment among WBS, CWBS, CBS, and OBS	3.29	-	2.92
10	Inexperience with local laws and other government regulations and modification in laws and regulations	3.26	3.18	-
11	Lack of personal experience of the project teams	-	2.92	3.11

Furthermore, the top 10 frequent sources of IM problems were also examined based on the area of respondent's title. Five independent job title groups were included in the respondent's title type: (1) project controls, planning engineer, interface coordinator; (2) project engineer, quality engineer, and lead (safety, procurement, etc.); (3) engineer (structural, mechanical, electrical) and project engineering manager; (4) project manager, contractor and sub-contractor; (5) architect. Using equation number 1, the 22 IM problems were studied and listed in 22 tables that display the rating average for each respondent's title. After that, the 22 tables were evaluated to determine the most critical problems for each respondent's title. Table 5.24 shows the top 10 IM problems for the five respondent's title types. It should be realized that the five respondent's title types are in agreement over the 10 general IM problems (not necessarily in the same rank) with the exception of respondent's title type 5 (architect), as they reported different IM problems, such as (1) type of the contract does not match the nature of the project and (2) planning and scheduling problems.

Table 5.24 A Summary of the Rating Average of the Highest IM Problems for each Job

Title

	IM Problems	Project controls, planning engineer, interface coordinator	Project engineer, quality engineer, and lead	Engineer and project engineering manager	Project manager, contractor	Architect
1	Lack of project management	3.54	3.39	3.21	3.48	-
2	Inexperience with building codes; trade union practices	3.43	3.65	3.31	3.39	2.98
3	Insufficient and inaccurate work drawings and specifications	3.43	3.78	3.29	3.61	3.07
4	Delay in established schedule of engineering, procurement, and construction	3.37	3.36	3.21	3.47	3.03
5	Unclear system completion requirements	3.36	3.62	3.21	3.34	2.95
6	Lack of trust among different project parties	3.29	3.49	3.43	3.46	-
7	Inexperience with local laws and other government regulations and modification in laws and regulations	3.27	3.70	3.34	3.28	-
8	No proper work packaging design and subcontracting.	3.23	3.76	3.26	3.38	3.24
9	Undefined reporting structure and responsibilities	3.14	3.43	3.07	3.47	3.01
10	Insufficient and lack of alignment among WBS, CWBS, CBS, and OBS	3.04	-	3.10	-	2.97
11	Lack of personal experience of the project teams	-	3.21	-	3.30	3.22
12	Type of the contract does not match the nature of the project	-	-	-	-	3.29
13	Planning and scheduling problems	-	-	-	-	3.01

In addition, the top 10 frequent sources of IM problems were further divided into four groups according to years of experience as follows: (1) ≤ 9 years, (2) 10–14 years, (3) 15–19 years, and (4) ≥ 20 years. Based on equation 1, the 22 IM problems were studied and summarized in 22 tables that show the rating average for each type of years of experience. After that, the 22 tables were examined to determine the most critical problems for each years of experience type. Based on that, the top 10 IM problems for each years of experience type were ranked and summarized. Table 5.25 summarized the rating average of the highest IM problems for each years of experience type. Generally, the top 10 problems based on the years of experience types are similar but not necessarily in the same rank and order. Group 3 (15–19 years) and group 1 (≤ 9 years experience) considered the planning and scheduling problems as one of the top 10 IM problems.

In addition, the top 10 frequent sources of IM problems were further divided into three groups, according to level of project complexity, as follows: (1) high complexity, (2) medium complexity, and (3) low complexity. Based on equation 1, the 22 IM problems were studied and summarized in 22 tables that show the rating average for each type of level of project complexity. After that, the 22 tables were studied to determine the most critical problems for each level of complexity type. Based on that, the top 10 IM problems for each level of project complexity type were ranked and summarized, as shown in Table 5.26. Table 5.26 summarized the rating average of the highest IM problems for each level of complexity type. Generally, the top 10 problems based on the level of project complexity types are similar but not necessarily in the same rank and order.

Table 5.25 A Summary of the Rating Average of the Highest IM Problems for each Years of Experience Group

	IM Problem Experience group 1	≤9 years	10–14 years	15–19 years	≥20 years
1	Lack of project management	2.84	2.95	3.11	2.96
2	Insufficient and inaccurate work drawings and specifications	2.79	2.85	3.28	3.18
3	No proper work packaging design and subcontracting	2.78	2.70	3.09	3.09
4	Unclear system completion requirements	2.73	2.70	2.95	3.01
5	Inexperience with building codes; trade union practices	2.70	2.94	2.98	3.11
6	Undefined reporting structure and responsibilities	2.68	2.89	2.91	2.92
7	Inexperience with local laws and other government regulations and modification in laws and regulations	2.63	2.96	2.98	2.98
8	Lack of trust among different project parties	2.61	2.81	3.05	3.05
9	Delay in established schedule of engineering, procurement, and construction, and delay in owner approval of completed tasks	2.59	2.80	3.09	3.00
10	Lack of personal experience of the project teams	2.59	2.75	-	2.86
10	Planning and scheduling problems	2.84	-	2.84	-

Table 5.26 A Summary of the Rating Average of the Highest IM Problems for each Project Complexity Level

IM Problems		1. High complexity	2. Medium complexity	3. Low complexity
1	Inexperience with building codes; trade union practices	3.13	3.00	2.80
2	Insufficient and inaccurate work drawings and specifications, e.g., lack of interface details within work drawings and specifications	3.11	3.15	2.81
3	Lack of project management	3.06	2.97	2.89
4	Unclear system completion requirements	3.06	2.92	2.98
5	No proper work packaging design and subcontracting	3.04	3.01	2.95
6	Delay in established schedule of engineering, procurement, and construction, and delay in owner approval of completed tasks	3.03	2.87	2.79
7	Lack of trust among different project parties	2.98	3.02	2.83
8	Inexperience with local laws and other government regulations and modification in laws and regulations	2.98	3.02	2.72
9	Undefined reporting structure and responsibilities	2.90	2.92	3.03
10	Insufficient and lack of alignment among WBS, CWBS, CBS, and OBS	2.85	-	-
11	Lack of personal experience of the project teams	-	2.91	2.66

5.2.6 Multiple regression models.

The findings show that the collected data are reasonable for building multiple-regression models. The number of valid responses in this research study is 162 responses. On the other hand, there are four interface management factors (four predictors). Brace et al. (2006) proposed the 5:1 ratio for the number of response to number of predictor variables. In this research study, there are approximately 40 participants for each predictor variables, which exceeds the required ratio. A multiple-regression technique was used, with the six different construction performance

indicators (quality management, schedule management, cost management, scope management, and safety management, and team work) as dependent variables and the four extracted interface problem factors as independent variables, to examine the following hypotheses:

Hypothesis 5, 6, 7, 8, 9, and 10: There would be no significant relationships between the extracted factors and the project performance indicators:

- Quality
- Schedule
- Cost
- Scope
- Safety
- Teamwork

Appendix IX summarizes the results of the multiple-regression analysis. The overall results show that the IM factors have a significant impact at the project performance. Therefore, the six hypotheses were rejected. Moreover, the information factor had the strongest influence on the six project performance indicators.

The results of the multiple regression models show that the interface problems caused by the information factor and management factor and the law and regulation factor had the strongest influence on the quality project performance indicator. The interface problems caused by the information factor and others factor were the strongest and positively influence the cost and safety project performance indicators. The problems caused by the management factor and the information factor were the most positive influences on the rest of the project performance indicators. In summary, based on the multiple regression results, Table 5.27 shows that the information factor is the most important factor affecting overall project performance.

Table 5.27 Multiple-Regression Results for Overall Project Performance

Factors	Quality	Schedule	Cost	Scope	Safety	Teamwork	Overall Performance
Mgt. factor	0.200	0.170		0.211		0.235	0.816
Inf. factor	0.548	0.428	0.493	0.562	0.284	0.470	2.785
Law & reg. factor	0.129						0.129
Others factor		0.332	0.379		0.302		1.013

“One way of developing multiple correlation is to obtain the prediction equation for Y' in order to compare the prediction value of the dependent variables with obtained Y ” (Tabachnick & Fidell, 2001) is as follows:

$$Y' = A + B_1X_1 + B_2X_2 + \cdots + B_KX_K \quad (1)$$

“where Y' is the predicted value of Y , A is the value of Y' when all X_S are zero, B_1 to B_K represent regression coefficients, and X_1 to X_K represent the independent variables” (Tabachnick & Fidell, 2001). For instance, based on equation number one and Appendix IX, the predication equation for the project quality performance is

$$Y' = -0.400 + 0.662X_1 + 0.303X_2 + 0.117X_3 \quad (2)$$

where Y' is the project quality performance predicted value

X_1 is the information factor

X_2 is the management factor

X_3 is the law and regulation factor

Based on equation number one and Appendix IX, the predication equations for the project performance indicators can be performed.

5.2.7 Reliability.

All the Cronbach's α value for the IM factors are greater than 0.75 except for the other interface problems factor, which is a little lower than 0.70 with a value of 0.649, as shown in Table 5.28. All the Cronbach's α values of the reliability test of the six project performance indicators are greater than 0.90, as shown in Table 5.29.

Table 5.28 Reliability Test of Interface Problem Factor

Factor Categories	Mgt. factor	Inf. factor	Law & reg. factor	Others factor
Cronbach's α	.794	.858	.844	.649

Table 5.29 Reliability test of project performance indicators

Indicator Name	Quality Mgt.	Schedule Mgt.	Cost Mgt.	Scope Mgt.	Safety Mgt.	Teamwork Mgt.
Cronbach's α	0.920	.923	.927	.931	.951	.944

5.3 Conclusions

This part consists of intensely studying the interfaces during the engineering/design phase of projects using a web-based questionnaire with participants from industry. This web-based questionnaire was distributed inside Alberta. Out of 47 IM problems that were collected throughout the project lifecycle, 22 IM problems were found applicable to the engineering/design phase. The questionnaire questions were designed based on the 22 interface management problems. The collected data were analyzed using factor analysis, Pearson's correlation matrix, and the one-way MANOVA test followed by Tukey's HSD post hoc tests. Exploratory factor analysis was performed to extract the factors and the latent structure of

independent variables (interface problems). Correlation between IM factors during the engineering/design phase and different construction data was tested. The results identified four IM factors affecting construction project performance in Alberta during the engineering/design phase.

The study concluded that while the management factor is the factor most impacting IM performance throughout project lifecycle, the information factor and the law and regulation factor impact IM performance the most during the engineering/design phase. These results are different from some previous studies, for example (Ku et al. (2010) concluded that negotiation and experience factors are the most important factors affecting IM. In addition, R. Huang et al. (2008) indicated that, the interface management problems caused by the experience and coordination factors are the most significant factors affecting IM. Therefore, some future investigation is required to clarify this issue.

Although there are strong relationships between the four extracted factors and the company type, industry type, job title type, and years of experiences, there are no relationships between the four extracted IM factors and the level of project complexity. Therefore, it was concluded that the four IM factors are not affected by the level of project complexity types. The results of the multiple regression models indicate that the interface problems caused by the information factor, management factor, and the law and regulation factor had the strongest influence on the quality project performance indicator. The interface problems caused by the information factor and the others factor were the strongest and positively influenced the schedule and cost and safety project performance indicators. The problems caused by the management factor and the information factor most positively influenced the rest of the project performance indicators.

5.4 Summary and Connection with the Next Chapters

The findings of this chapter present a basis for enhancing overall project performance and the interfaces by (a) developing conceptual framework to study the IM relationships among owner, contractor, and designer throughout project lifecycle using the Microsoft Visio® flowcharts and UML use case Diagrams (Chapter 6) and (b) developing practical guidelines and suggestions for improving and enhancing IM that are adequate to all participants engaged in construction projects as well as beneficial to management practices at early stages of the project (Chapter 7).

Chapter Six: Proposed Interface Management Framework Applying RIBA Structure and Use Case Models throughout Project Phases

6.1 Chapter Overview

As discussed in detail in Chapters 4 and 5, a comprehensive investigation was conducted through structured face-to-face interviews and questionnaires with participants from industry throughout the project lifecycle and during the engineering/design phase. The data analysis results provided a comprehensive view of the main causes behind IM conflicts in Alberta's construction industry. Throughout the project lifecycle, factors affecting interface management (IM) were identified and classified, namely, management, information, bidding and contracting, law and regulation, technical engineering and site issues, and other interface problems. In addition, during the engineering/design phases, factors affecting IM were identified and classified, namely, management, information, law and regulation, and other interface problems.

Moreover, the correlations between IM factors and different respondents' profiles (company type, industry type, title type, and years of experience) were examined and tested. The most critical problems affecting each aspect of IM were examined and discussed in detail. Finally, based on the identified major IM factors impacting construction project performance, a new integrated IM model was introduced to enhance project performance by developing *12 multiple regression models*. The reader can refer to Chapters 4 and 5 for more details.

Based on insights and results gained from the analysis and discussions described in previous chapters and interviews with specialists from industry, this chapter consists of the following.

(1) Develop conceptual framework using The Royal Institute of British Architects (RIBA) structure to highlight the critical IM areas during different project phases (2) Develop use case models to study the IM relationships among owner, contractor, and designer (architects,

engineers) using UML use case diagrams. Also, identify the main responsibilities for each one throughout project lifecycle phases in commercial and building projects. (3) Accordingly, provide suggestions for improving and enhancing IM that are adequate to all project participants engaged in different construction projects, as shown in Figure 6.1.

As mentioned before in chapter two (literature review chapter), many organizations have identified and classified several project delivery methods. This research study is using RIBA structure that considers the design-bid-built project delivery method. Consequently, this research study focuses on the design-bid-built project delivery method (traditional project delivery approach).

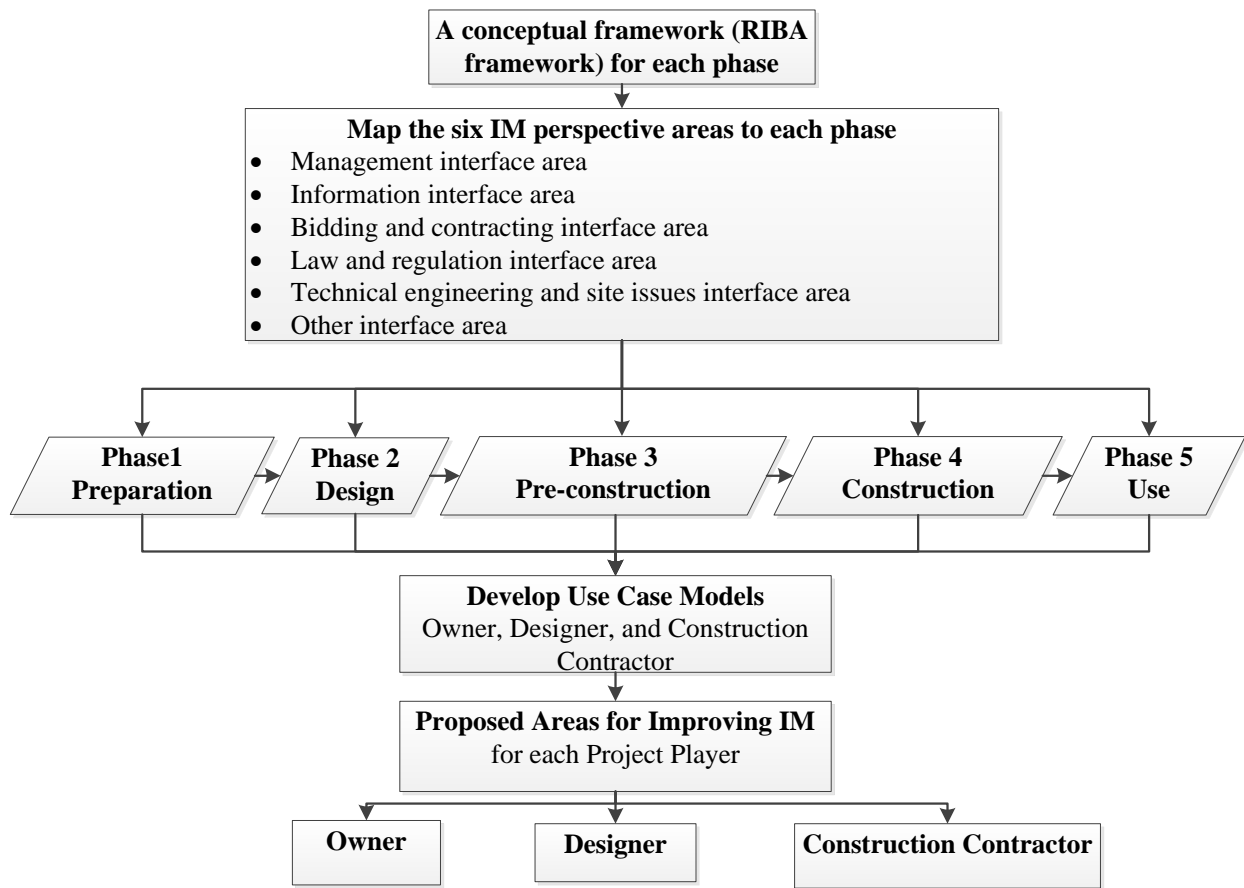


Figure 6.1 Overall Structure for this Chapter

6.2 Relationships among Owner, Contractor, and Designer

Construction projects involve a variety of parties having contracts with each other, such as owners, designers, constructors, and suppliers. This research study identified six different IM areas/factors to analyze interface management improvement opportunities. Those areas/factors are “management interface problems area”, “information interface problems area”, “bidding and contracting interface problems area”, “law and regulation interface problems area”, “technical engineering and site issues interface problems area”, and “other interface problems area”, as

shown in Figure 6.2. Under each area or factor there are a number of IM problems that were discussed and presented in the previous chapters.

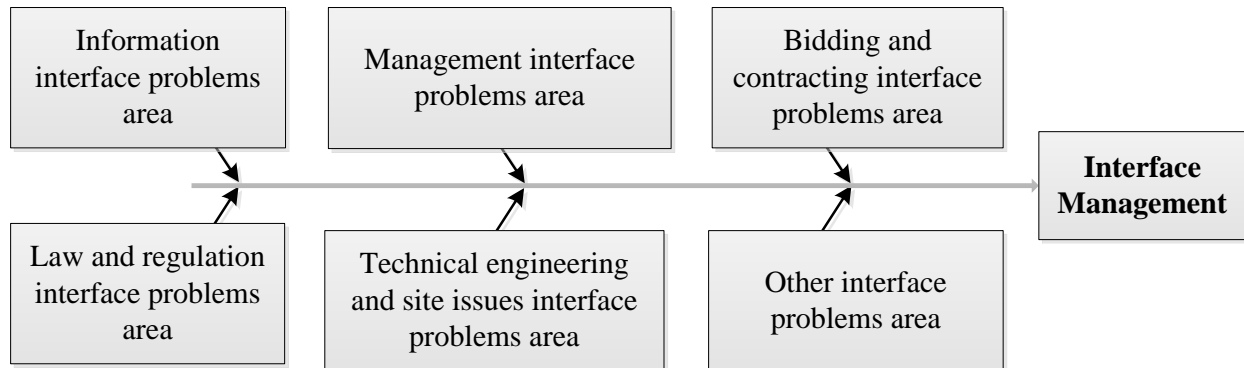


Figure 6.2 Six Factors or Areas Affecting IM throughout Project Lifecycle

6.2.1 Project lifecycle phases in commercial and building projects.

Building project developed from inception to completion, as shown in Figure 6.3, which illustrates five main phases and deliverables of a typical lifecycle adopted from (RIBA 2007). These phases are: (1) preparation, (2) design, (3) pre-construction, (4) construction, and (5) use. It should be noted that the operation phase and the close-out phase, known in the industry, are included in the construction and use phases of RIBA respectively. Under each phase different stages must be done. Figure 6.3 describes the phases and activities from appraising the client's requirements through to post-construction. For example, the design phase consists of the following steps: (a) prepare the concept design, (b) develop the concept design, (c) prepare the technical design(s) and specifications, (d) prepare the full design for each part of the project, and finally, (e) check the cost of the design (RIBA 2007).

Because the RIBA process consists of the tasks and the responsibilities is considered an architecture-based work-plan, using RIBA in this research study may create a bias towards

architects more than engineers. This can lead to some limitation in the application of this IM framework.

Alternatively, *A Guide to the Project Management Body of Knowledge* (Project Management Institute, 2004) illustrates four main phases and deliverables of a typical lifecycle, as shown in Figure 6.4. The phases include (1) starting the project, (2) organizing and preparing, (3) carrying out the project work, and (4) closing the project.

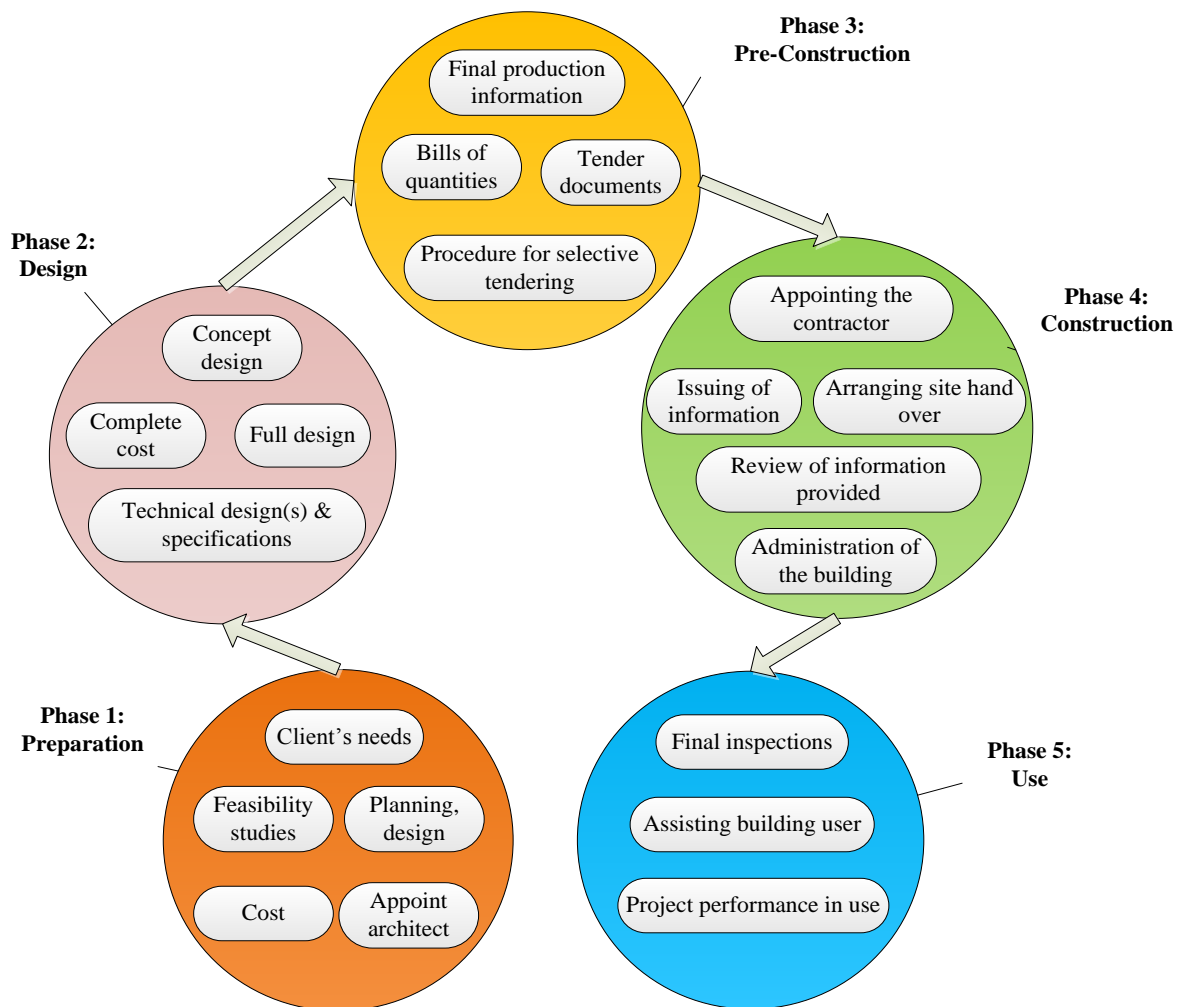


Figure 6.3 Project Lifecycle General Phases (RIBA, 2007)

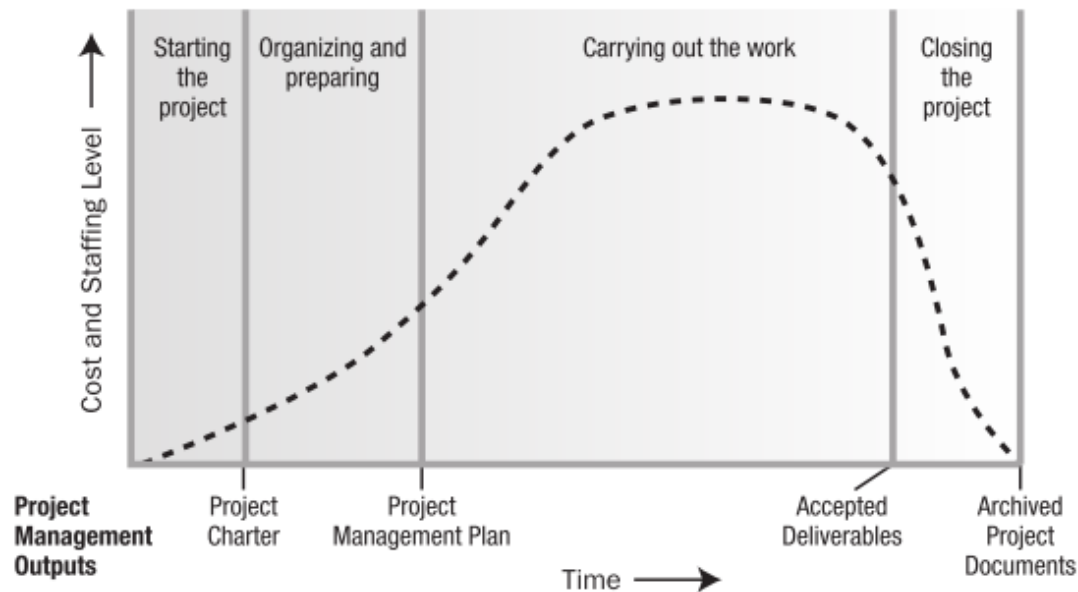


Figure 6.4 Project Lifecycle General Phases and Deliverables (Project Management Institute, 2004)

Results of the analysis and discussion described in the previous chapters and information provided by industry experts during their interview sessions were used to map the IM areas considered critical to different phases, as shown in Figures 6.5 through 6.9.

Based on the opinion of experts from industry, the following three areas were mapped to all phases: (1) management interface problems area, (2) information interface problems area, and (3) law and regulation problems areas. In addition, the technical interface problems area and other interface problems area were mapped to the design phase, pre-construction phase, and construction phase. As well, the bidding and contracting interface problems area was mapped to the phases pre-construction, construction, and use.

For example, Figure 6.5 shows a conceptual framework (RIBA framework) of the *preparation* phase that consists of two stages, (A) inception and (B) feasibility. During the inception stage, it

is important that the project teams understand, establish, and determine the project vision and the project management body. Therefore, the management interface problems area was mapped during this stage. There are some examples of the problems under this area. In addition, the information interface problems area was mapped during this stage. It must be taken into consideration to circulate the general outline of requirements and plan for future action (responsibilities of the client to the design and construction process) among people involved in the project and to ensure information transfer, i.e., what documents are shared, with whom, and when. Moreover, some interfaces arise between stages and phases. Also, the law and regulation area is one of the critical IM areas that have to be taken into consideration to carry out studies about user requirements, site conditions, and planning design and cost.

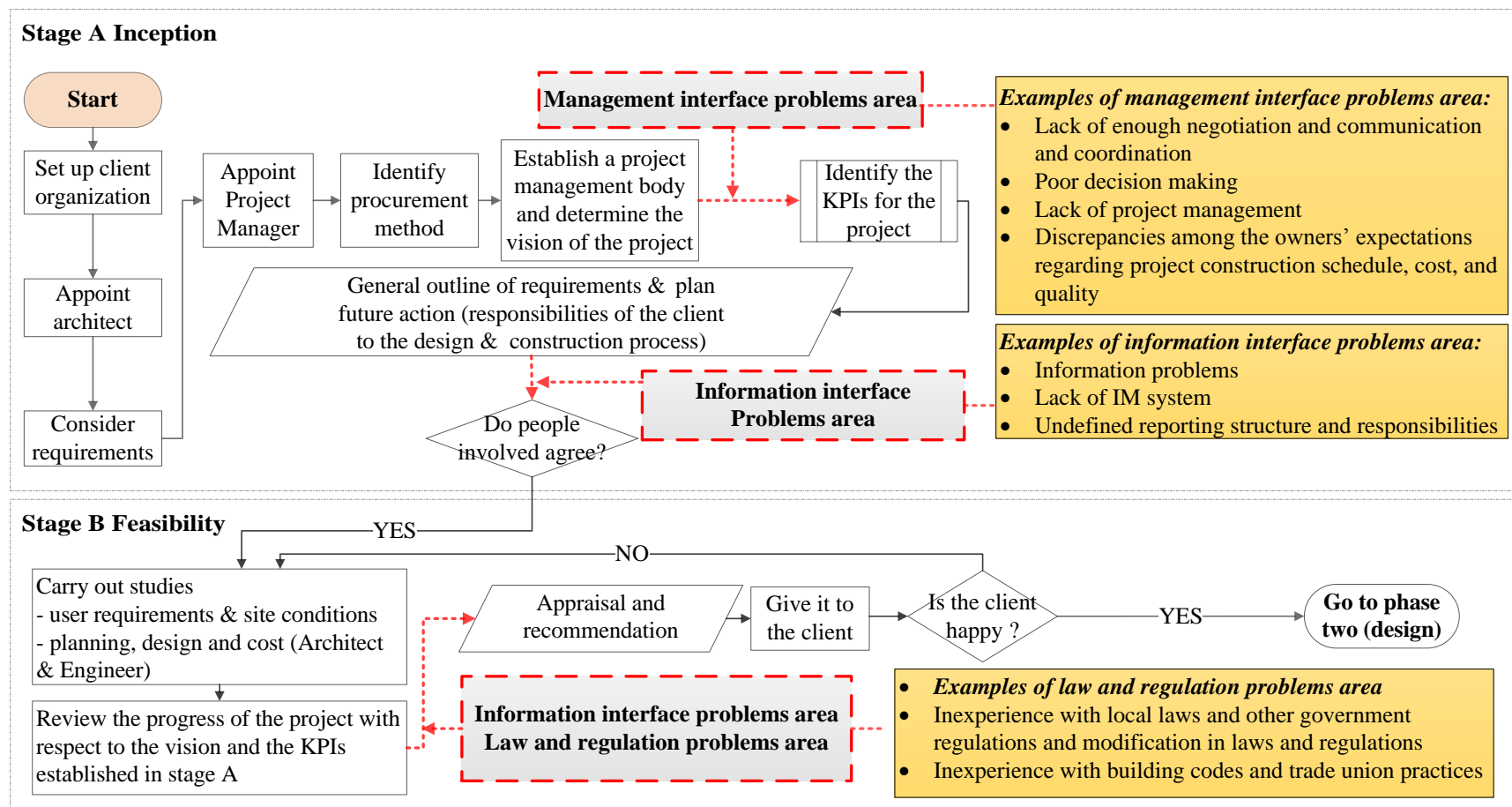


Figure 6.5 A Conceptual Framework of Phase One (Preparation) Including IM Interface Areas

Another example during the *design phase* that consists of three stages is shown in Figure 6.6: (1) outline proposal, (2) scheme design, and (3) detail design. The most critical areas during this phase are the law and regulation area, technical and engineering and site issues problems area, management interface problems area, and information interface problems area. During the outline proposal stage, it is important that the project team carries out studies on user requirements, technical problems, etc. Therefore, the project team has to be familiar with local laws and other government regulations, with modification in laws and regulations, and with building codes and trade union practices. At the same time, during the detailed design stage, full information must be circulated among the design team's members to finalize the working drawings related to design, specifications, construction, and cost. Besides that, the technical engineering and site issues problems have to be taken into consideration to properly complete the detail design.

Also, the IM areas considered critical were mapped to the pre-construction phase, as shown in Figure 6.7.

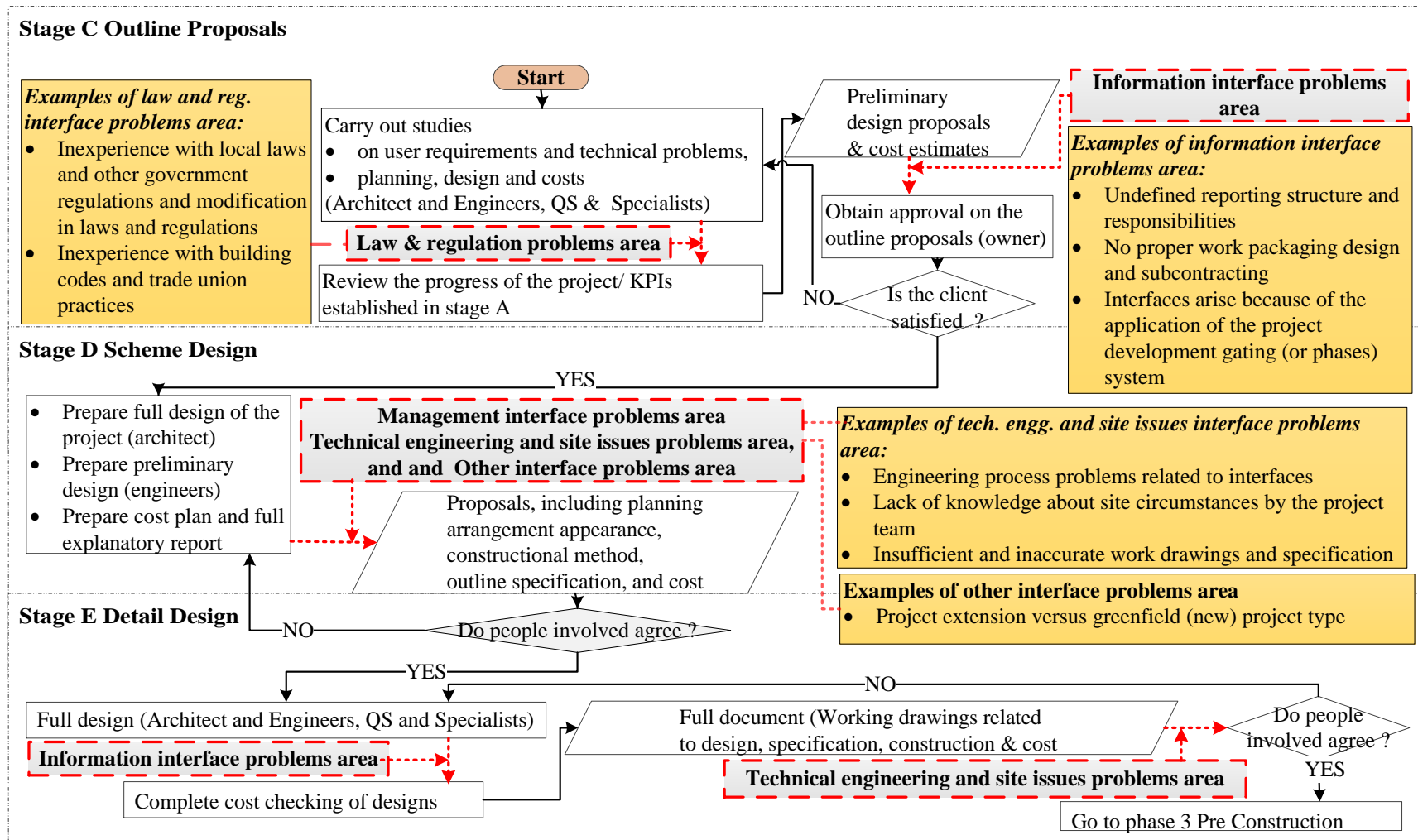


Figure 6.6 A Conceptual Framework of Phase Two (Design) Including IM Interface Areas

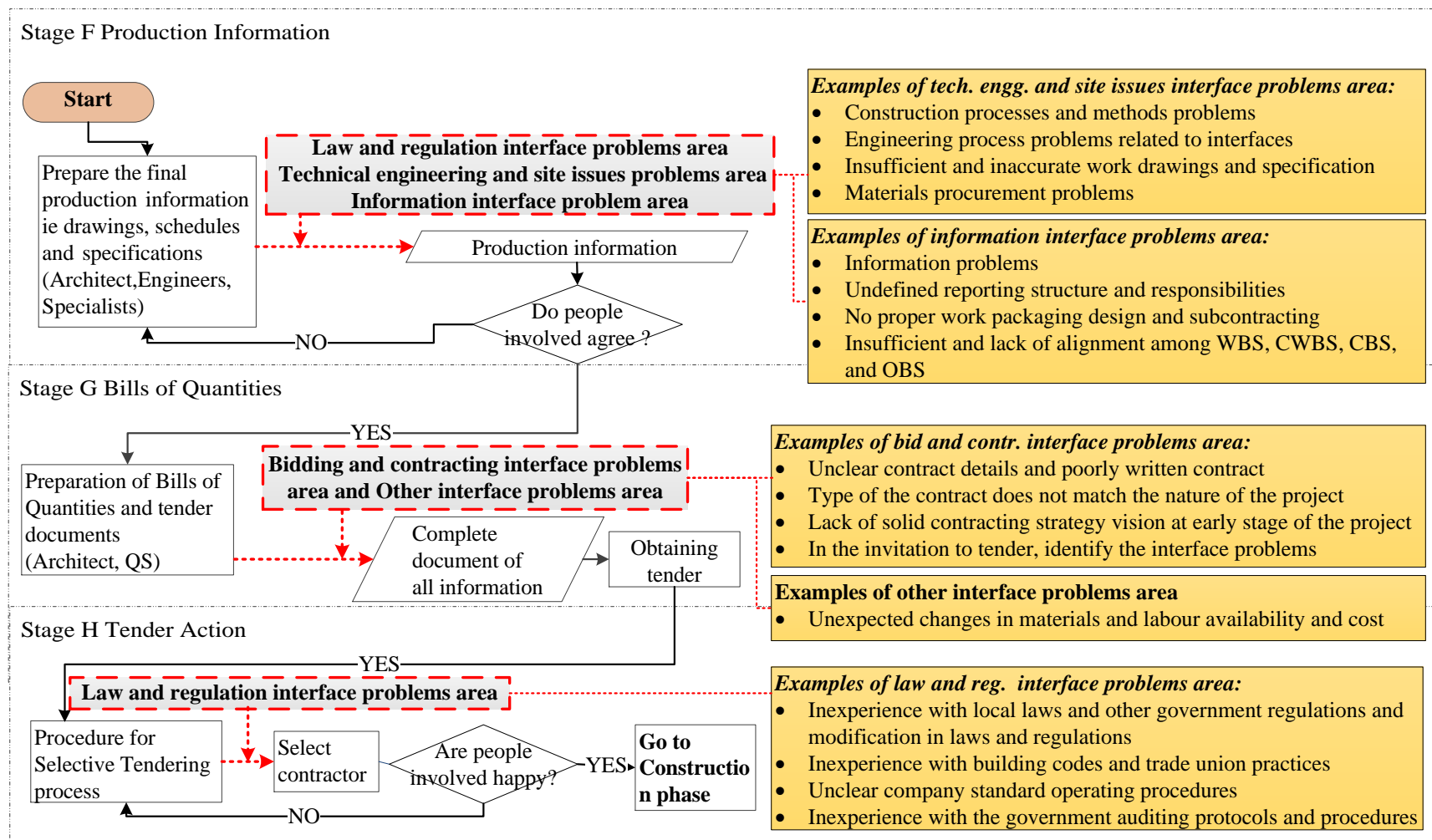


Figure 6.7 A Conceptual Framework of Phase Three (Pre-construction) Including IM Interface Areas

During the *construction phase* almost all the IM areas have to be taken into consideration. This phase consists of two stages: (1) project planning and (2) operation on site as shown in Figure 6.8. The project teams must have a deep knowledge about site circumstances. In addition, when issuing the information to the contractor, the contractor's familiarity with the environmental circumstances and local weather must be discussed and checked. In addition, the geotechnical circumstances have to be studied carefully. After that, when arranging the site handover to the contractor, the contractor must be familiar with local laws and other government regulations and modification in laws and regulations and with building codes and trade union practices. Finally, deep attention has to be paid to the management interface problems and information interface problems. Also, the IM areas considered critical were mapped to the *use* phase, as shown in Figure 6.9.

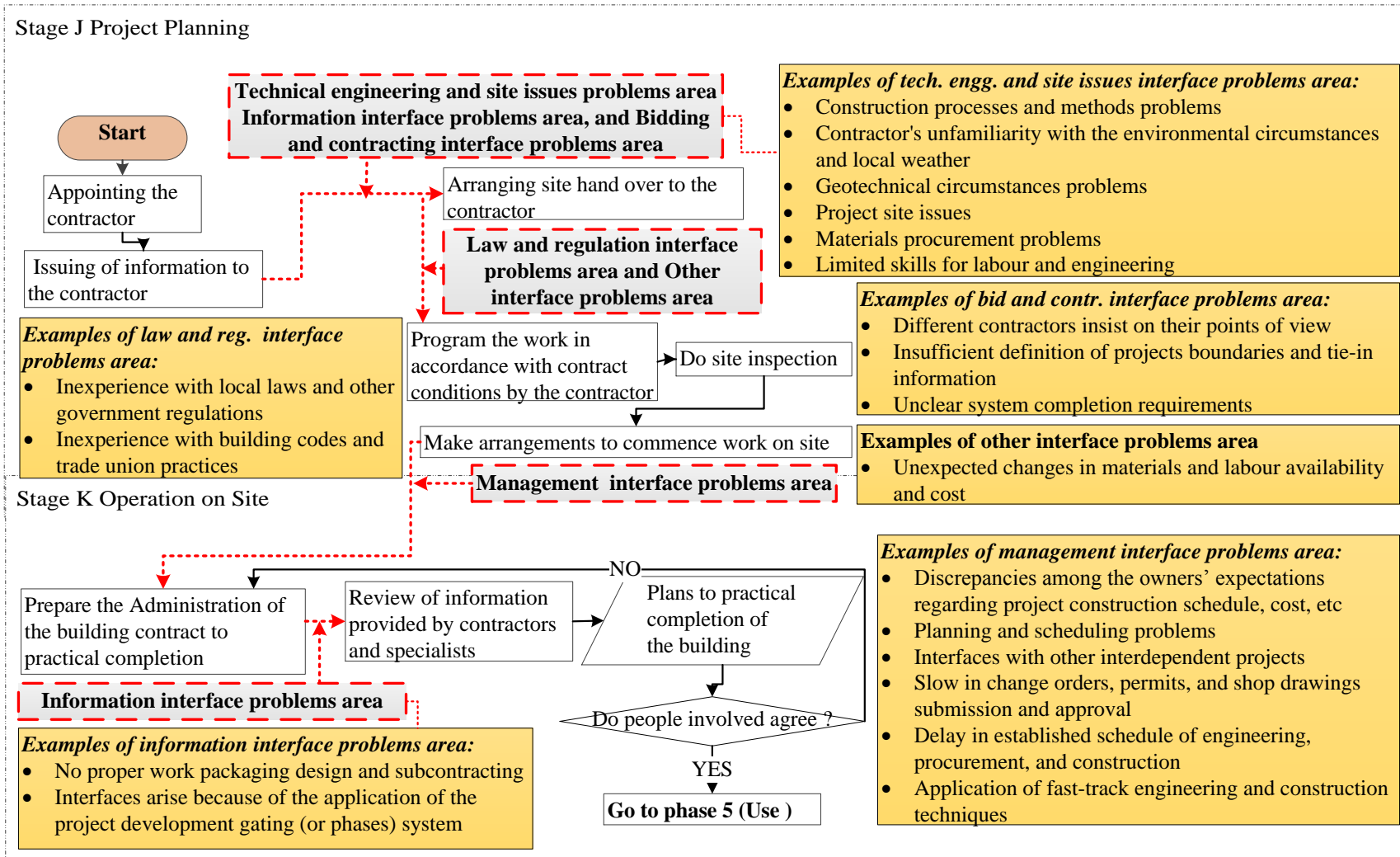


Figure 6.8 A Conceptual Framework of Phase Four (Construction) Including IM Interface Areas

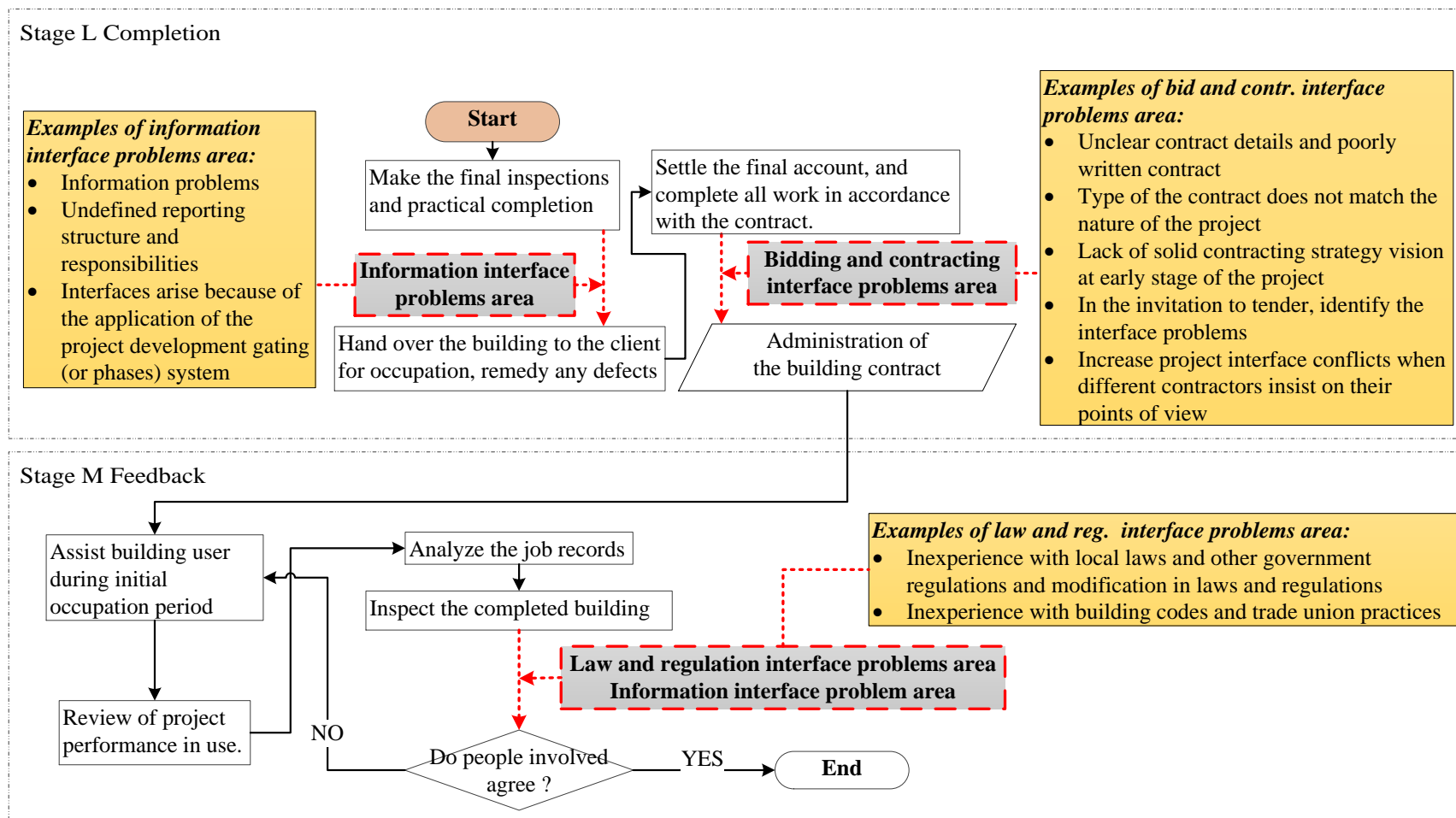


Figure 6.9 A Conceptual Framework of Phase Five (Use) Including IM Interface Areas

6.2.2 Use case model.

This is the first research study using the use case model to analyze interface management; none of the previous studies use this model to study IM. The use case model is a graphical tool that is simple and easy to understand by different project parties. Companies can use the use case models to develop their own systems to manage the interfaces (Pender, 2003). “Each use case describes the functionality to be built in the proposed system, which can include another use case’s functionality or extend another use case with its own behavior” (Pender, 2003). The use case model consists of many elements, such as actors, use cases, and «include» and «extend» relationships. A use case is a list of interactions between what is called an “actor” and a system. An actor can be a human or machine or enterprise that interacts with the system (see Figure 6.10). An include relationship “identifies a reusable use case that is unconditionally incorporated into the execution of another use case” (Pender, 2003).

This section presents the development of the use case models to study the IM relationships among owner, contractor, and designer (architects and engineers) and identify the main responsibilities for each one throughout the project lifecycle phases in commercial and building projects. Consequently, areas and actions that are adequate to all project participants engaged in different construction projects can be suggested for improving and enhancing IM.

There are three primary players (actors): owner, designer, and contractor, as shown in Figure 6.10 (CSC, 2006). The owner secures competitive bids from contractors based on the contract documents that were developed by the designer. Based on an accepted bid, the owner signs a contract with the selected contractor for construction of the project. For more details,

Figure 6.10 shows the traditional project delivery approach, which consists of three steps as follows:

Step one: An owner assigns a designer to prepare the design documents and to prepare contract documents based on the owner needs.

Step two: Competitive bids are obtained from the contractor using the contract document.

Step three: A contract is signed with the selected contractor for construction of the project.

There are two separate main contracts between the owner and the designer and the owner and the construction contractor. The first contract is directly with the designer to prepare the detailed design drawings, specifications, and procurement and contracting services. The second contract is signed with the construction contractor for construction of the project (The American Institute of Architects and The Associated General Contractors of America, 2011).

Figure 6.11 shows the current UML use case model packages of the owner, designer, and contractor. Figure 6.10 and Figure 6.11 show the responsibilities for each player; one such example is the design team (architects and engineers). According to the owner requirements the design team prepares the detailed design documents and prepares the contract documents. The design team is to first “finalize project design and specifications” in three stages, stages as shown in Table 6.1: outline proposals, scheme design, and detail design (The Royal Institute of British Architects (RIBA), 2007). The “finalize project design and specifications” step is included as step number 4 in Figure 6.10 and Figure 6.11. Table 6.1 provides details about the design phase and helps to explain step number 4 in Figure 6.10 and Figure 6.11. As well, it helps to build the use case model of the current relationships among owner, designer, and contractor.

Furthermore, the key deliverables of the detailed design phase can be broken down into seven components: (1) “Scope definition and engineering execution strategy”, (2) “Commencement of detailed design”, (3) “Initial design development and hazard identification”, (4) “Initial design review & audit”, (5) “Approval for design”, (6) “Approval for construction”, and (7) “Design close-out” (AMEC, 2013). Many people are involved during the design phase (as shown in Table 6.1), including client, architects, engineers, specialists, and all statutory and approving authorities. Then the design team (architects and engineers) finalize the contract documents. The contract documents consist of drawings, specifications, and supporting information. Based on the contract documents, competitive bids are obtained from the contractors to sign a contractor to construct the project. Then, the design team administers the building contract to practical completion.

Table 6.1 Royal Institute of British Architects Work Stages during the Design Phase

Adapted from RIBA (2007)

Stage	Purpose of work	People directly involved	Commonly used terminology
Outline proposals	To determine general approach to layout, design and construction in order to obtain authoritative approval of the client on the outline proposals	Client, architects, engineers, and specialists, as essential	Sketch plans
Scheme design	To complete the brief and decide on particular proposals, including planning arrangement appearance, constructional method, outline specification, and cost, and to obtain all approvals	Client, architects, engineers, specialists, all statutory, and approving authorities	Sketch plans
Detail design	To obtain final decision on every matter related to design, specification, construction and cost	Architects, engineers, specialists, and contractor	Working drawings

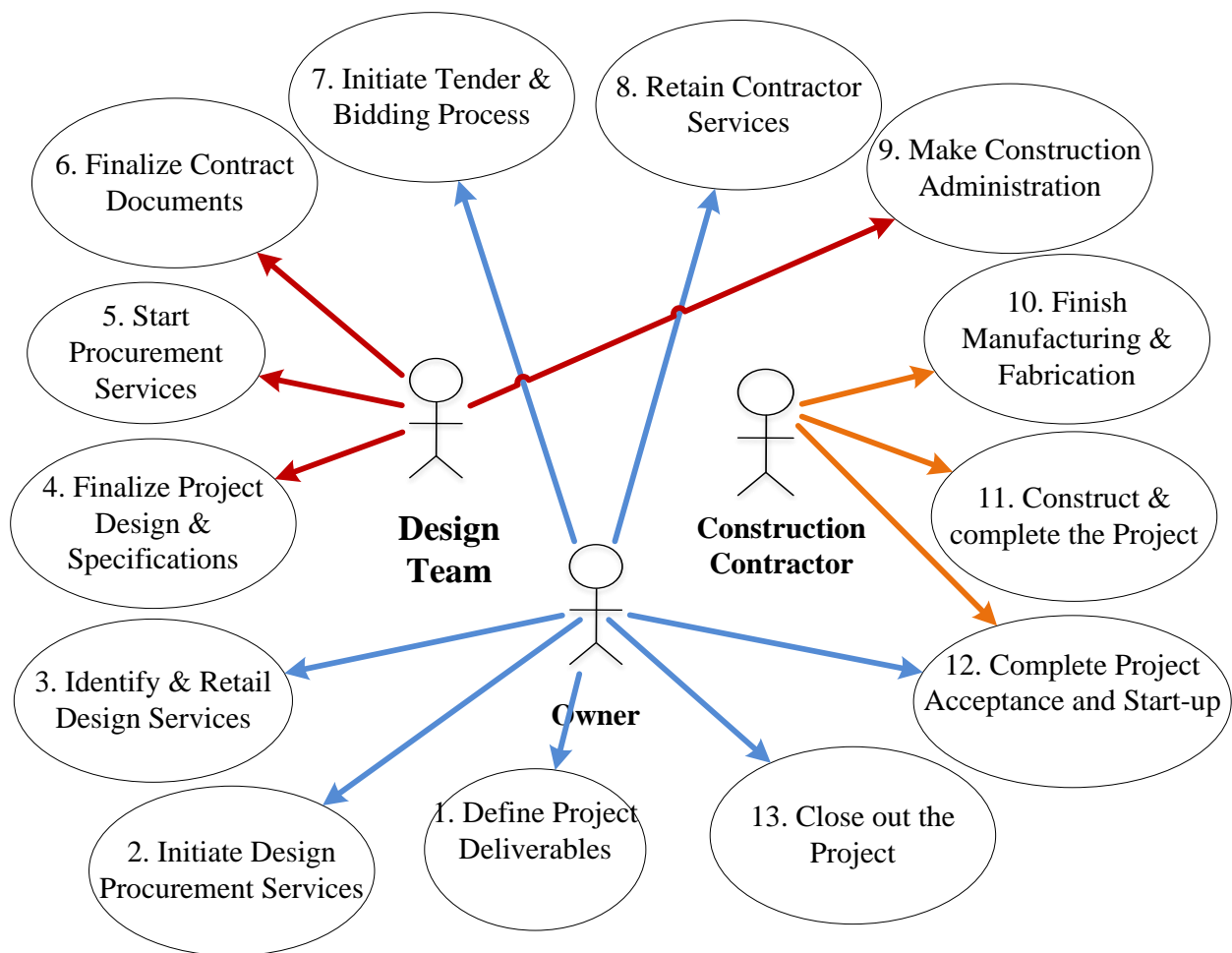
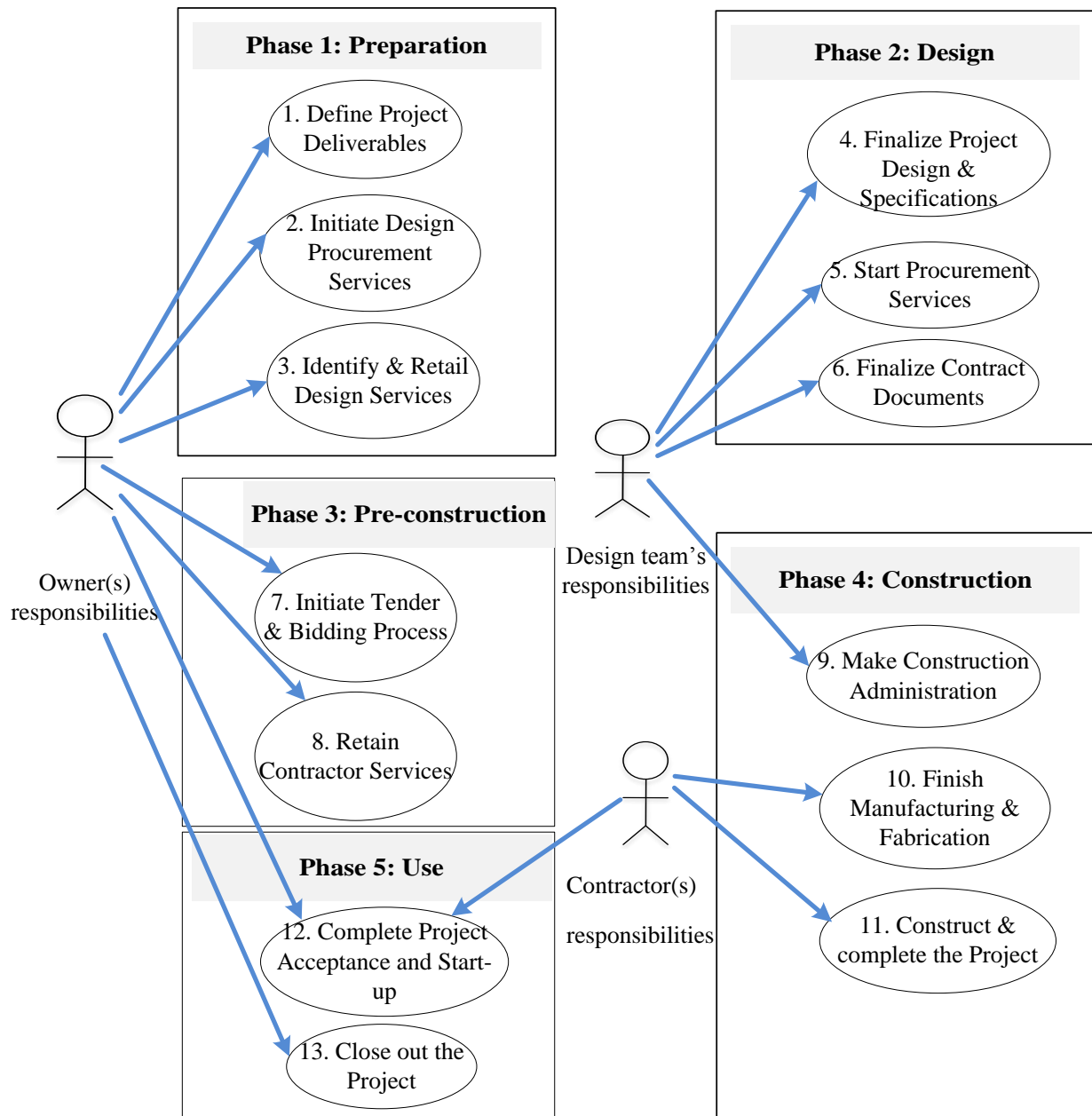


Figure 6.10 UML Use Case Model of the Current Relationships among Owner, Designer, and Contractor (adapted from The American Institute of Architects and The Associated General Contractors of America (2011))



“A use case package contains use cases and relationships” (Pender, 2003).



Figure 6.11 UML Use Case Model Packages of the Current Relationships among Owner, Designer, and Contractor within different Project Phases

According to the literature review and distributed questionnaires, different actions, recommendations, and areas were proposed in order to improve IM for each project player, as shown in Table 6.2 and Table 6.3. The IM problems in bold text, 65% of the areas for improving IM, were new and never mentioned in previous studies. The underlined IM problems, 20% of the areas for improving IM, were identified in previous studies and the distributed questionnaires. The rest were identified only in previous studies (15% of the areas for improving IM).

While the owner is responsible for 30% of the actions for improving IM, the design team is responsible for 45% and the contractor is responsible for 25%. These results demonstrate the importance of the design team's role and the design phase.

In addition, Table 6.2 and Table 6.3 show the hard and soft actions. The soft actions can be defined as the actions that need more discussion, communication, engagement, and coordination among different project participants such as “engagement of all stakeholders from the very start to completion of projects”. The hard actions can be defined as the actions that need a hard document to be circulated among the parties involved in a project. While 70% of the areas were considered as hard actions, 30% were considered as soft actions. After that, proposed use case models were developed to illustrate the responsibilities and actions of each project player, as shown in Figures 6.12, 6.13, and 6.14. The dashed lines are the relationships between the use cases. The solid lines indicate the connection between the actor(s) and the use cases.

Table 6.2 Hard Areas for Improving IM for each project player based on Literature

Review and Distributed Questionnaires

Hard	Owner	Designer	Contracter
1	<u>Clearly define the scope of project</u> (Mortaheb & Rahimi (2010) and distributed questionnaires)	Clear understanding of the design team interdisciplinary coordination problems	Have a clear understanding of the site/fabrication facility quality requirements
2	<u>Approve the design on time, pay the contractor, and approve the change orders</u> (Mortaheb & Rahimi (2010) and distributed questionnaires)	Split the program of the project into sub-programs (Mortaheb & Rahimi, 2010)	Ensure modularization and corresponding fabrication and shipment are well managed, as are regulatory, transportation, weight requirements, etc.
3	Use appropriate tools for choice of the contractors (Mortaheb & Rahimi, 2010)	Accelerate the design events in terms of interface issues (Mortaheb & Rahimi, 2010)	Clear expectations from contractors at the time of awarding of the contract
4	<u>Implement engineering, procurement and construction standards</u> (Alarcón & Mardones (1998) and distributed questionnaires)	Take into consideration the interface issues during the design activities	Expedite the mobilization process
5	Appoint the specialist contractor earlier (Pavitt & Gibb, 2003)	Standardize interface designs (Pavitt & Gibb, 2003)	<u>Schedule, plan, and monitor the interface problems with other project participants</u> (Mortaheb & Rahimi (2010) and distributed questionnaires)
6	Clearly define proper contracting strategy	Review value engineering, constructability	Define clear site access responsibilities
7	Define a clear project organization structure	Quickly respond to any request for information (RFIs) from the contractors	Reduce the overlapping between multiple construction contractors

Table 6.2 cont'd

Hard	Owner	Designer	Contracter
8	Appoint Interface Manager (Mortaheb & Rahimi (2010) and distributed questionnaires)	Consider the application of engineering standards and specifications	Understand the site/fabrication facility quality requirements
9	Get information on time, get someone to take responsibility for problems	Use 3D computerized modeling software (Mortaheb & Rahimi, 2010)	Identify the site-wide services
10	Organize the regulatory and permit procedures	Reduce disagreements or errors in engineering deliverables (Mortaheb & Rahimi, 2010)	Improve programming and sequencing at site level (Pavitt & Gibb, 2003)
11	<u>Control the circulation of data within the project teams</u> (Alarcón & Mardones (1998) and distributed questionnaires)	Clear and concise alignment on the design parameters of the project. What are we building — fit for purpose, life cycle, etc?	Prepare boundary information at an early stage of the project
12	Appoint general construction manager or project manager contractor	<u>Understand the owner's requirements and the local law and regulations</u> (Mortaheb & Rahimi (2010) and distributed questionnaires)	
13		Coordination between drawings for various disciplines	
14		<u>Prepare the internal and external interfaces list and IM plan</u> (Mortaheb & Rahimi (2010) and distributed questionnaires)	

Table 6.2 cont'd

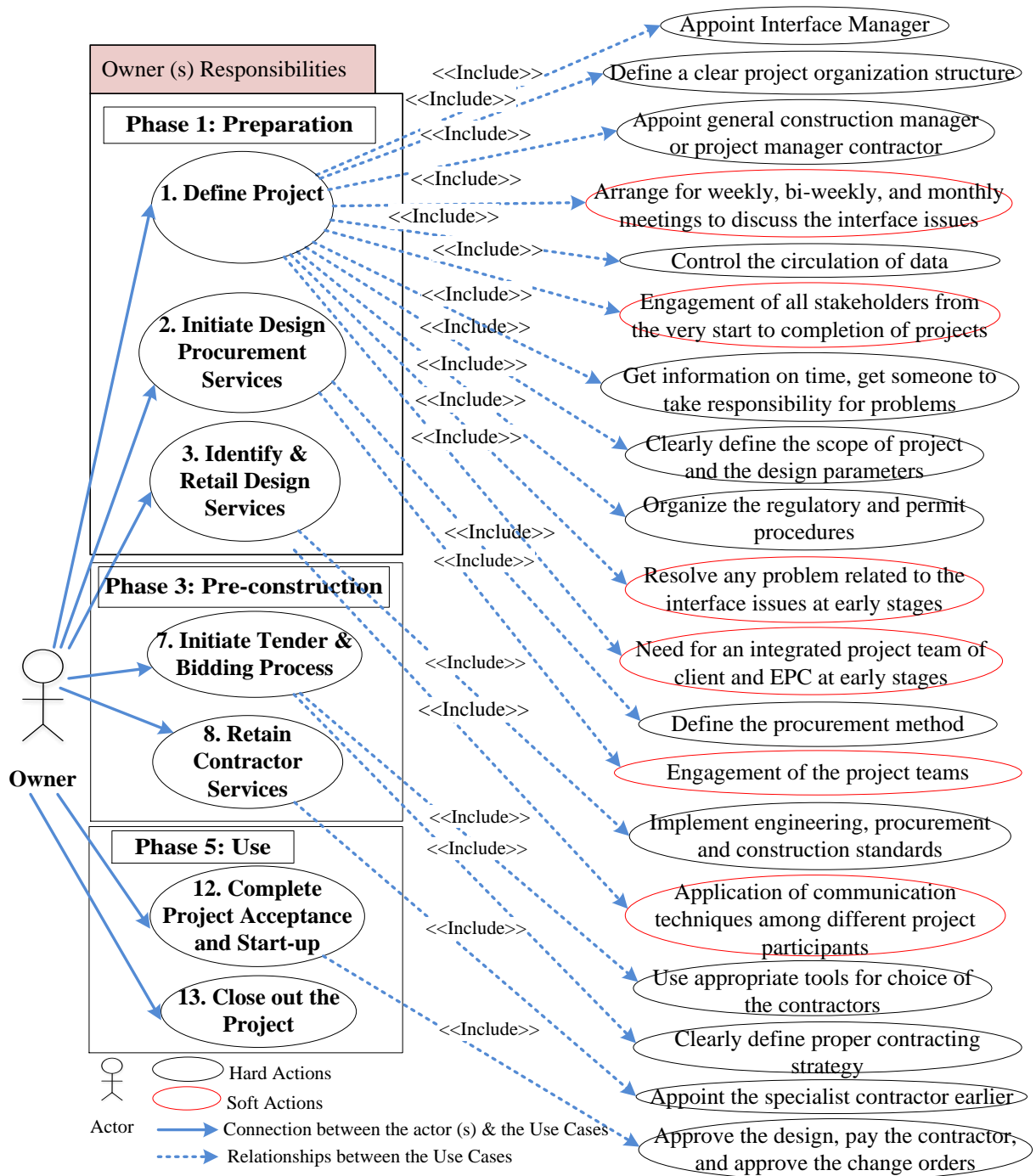
Hard	Owner	Designer	Contracter
15		<u>Identify the interface responsibility as early as possible</u> (Pavitt & Gibb (2003) and distributed questionnaires)	
16		Consider the time difference between offices at different remote locations	
17		Alignment on the design parameters	
18		Early order of long-lead items and special materials	

Key: The IM problems in bold text were new and never mentioned in previous studies.
The underlined IM problems were identified in previous studies and the distributed questionnaires.

Table 6.3 Soft Areas for Improving IM for each project player based on Literature Review and Distributed Questionnaires

Soft	Owner	Designer	Contracter
1	<u>Resolve any problems related to the interface issues</u> (Mortaheb & Rahimi, 2010)	<u>Coordinate among multi-disciplines and specialties</u> (Alarcón & Mardones, 1998)	Good communication with the owners
2	Engagement of the project teams (regulatory, engineering, procurement, etc.)	Consider the time difference between offices at different remote locations	Lessons learned from past projects. Utilize experienced project workers
3	Need for an integrated project team of client and EPC	Arrange for internal meetings among each discipline	Set the obligations on or before the kickoff
4	Engagement of all stakeholders from the very start to completion of projects	Need to get engineers to site and construction people into the office	<u>Communicate and coordinate with other project participants</u> (Mortaheb & Rahimi, 2010)
5	Application of communication techniques among different project participants	Personal contact between various disciplines rather than emails and other non-personal contact	Reduce the conflict between various project parties by creating a suitable mechanism to solve problems
6	<u>Arrange for weekly, bi-weekly, and monthly meetings to discuss the interface issues</u> (Mortaheb & Rahimi, 2010)	Alignment between client and contractor standardization of processes and engineering and construction requirements	
7		Expedite the reviewing for the key engineering deliverables	
8		Define clear procedures for engineering review of construction design changes	

Key: The IM problems in bold text were new and never mentioned in previous studies.
The underlined IM problems were identified in previous studies and the distributed questionnaires



“The «include» relationship allows us to include the steps from one Use case into another”

(Pender, 2003)

Figure 6.12 Proposed Use Case Model Package for Owner’s Responsibilities and Actions

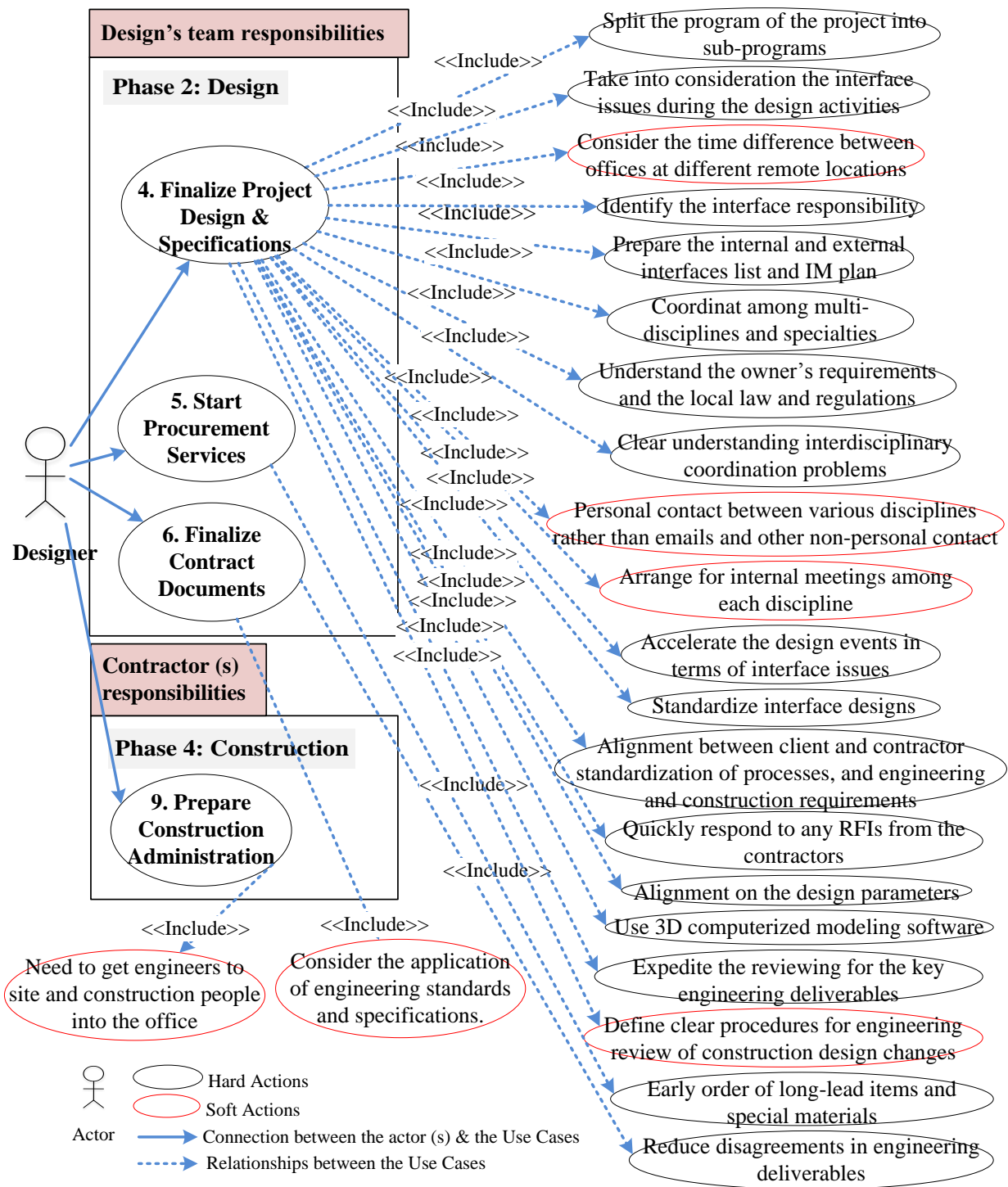
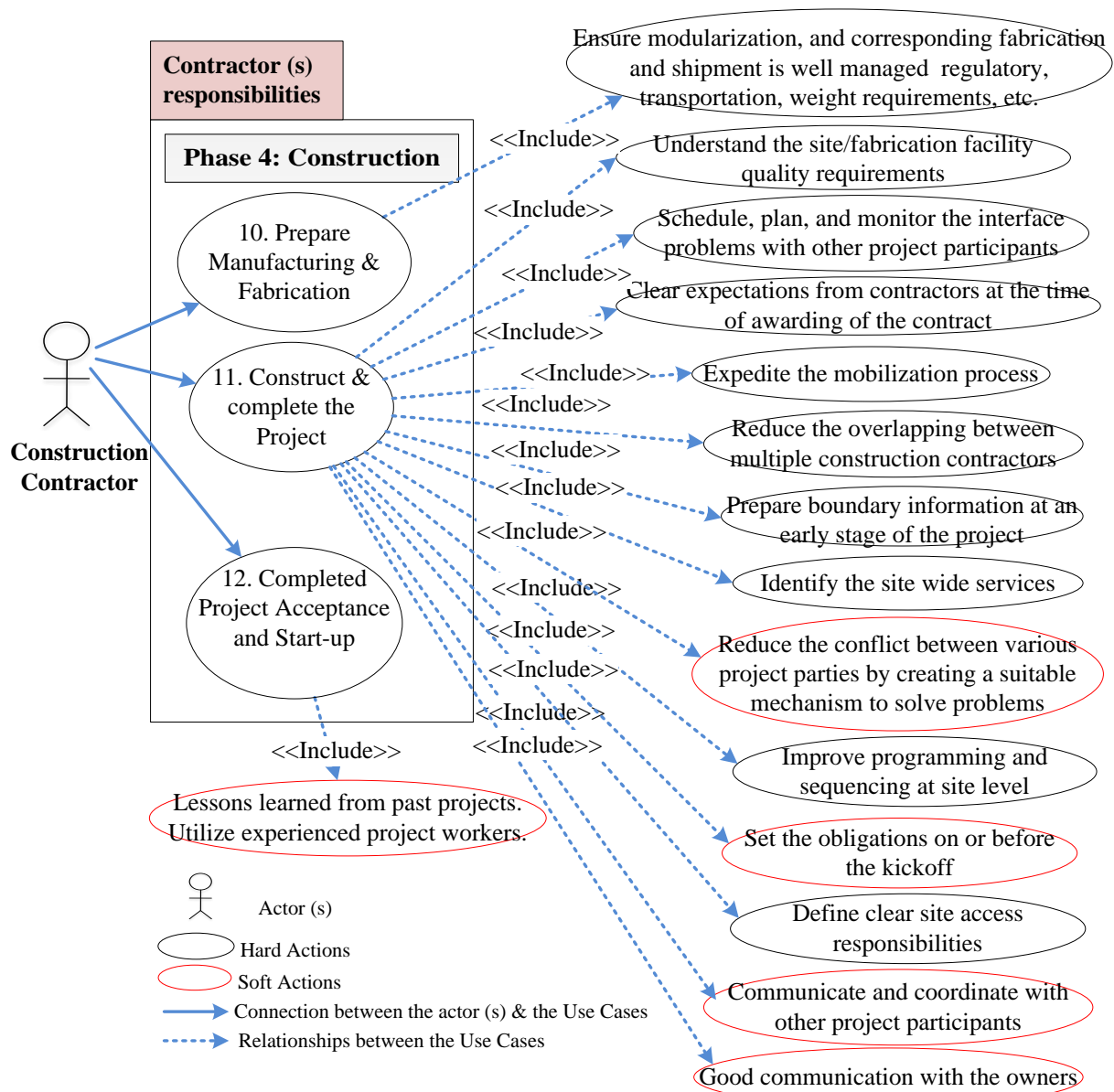


Figure 6.13 Proposed Use Case Model Package for Design Team's Responsibilities and Actions



“The «include» relationship allows us to include the steps from one Use case into another”

(Pender, 2003)

Figure 6.14 UML Proposed Use Case Model Package for Contractor’s Responsibilities and Actions

6.3 Summary and Connection with the Next Chapter

The findings of this chapter present a basis for studying the relationships among owner, contractor, and designer by developing a conceptual framework to study the IM relationships among them throughout a project lifecycle using the UML use case diagrams. In addition, the results of this chapter develop proposals for improving and enhancing IM functionality. Those are adequate for all participants engaged in commercial and building construction projects. Chapter 7 highlights the contributions of this research study and gives suggestions for future research.

Chapter Seven: Research Conclusions and Recommendations

7.1 Chapter Overview

This chapter presents the lessons learned and the theoretical contribution to academia and practical contributions to the industry. The researcher also suggests and recommends areas for future research.

7.2 Conclusion

For this research study, analytical approaches and quantitative statistical approaches were adopted to examine, identify, and categorize interface problems in the construction projects of Alberta. This research study used structured methods (structured face-to-face interviews and web-page questionnaires). Data were collected using two web-based questionnaires that were distributed through the members of different associations in Alberta. The first survey was conducted throughout project lifecycle phases, and the second survey was conducted during the engineering/design phase. The research study during the engineering/design phase consists of examining the interfaces (22 interface management (IM) problems) during the engineering/design phase of projects using a web-based questionnaire with participants from industry. Statistical techniques, such as factor analysis, cross-tabulated analysis, and multiple regressions were used to analyze the collected data. Based on the data analysis, several findings were revealed. Table 7.1 shows a summary of general conclusions. As can be seen in Table 7.1, the big differences between the results during the project lifecycle phases and the engineering design phase were in the MANOVA results and the multiple regression results.

The results of the six multiple regression models studied throughout project lifecycle indicated that the interface problems caused by the technical engineering and site issues factor, the bidding

and contracting factor, the information factor, and the law and regulation factor had the strongest influence on the schedule project performance indicator whereas the interface problems caused by the technical engineering and site issues factor, the bidding and contracting factor, and the information factor had the strongest influence on the cost project performance indicator. On the other hand, the problems caused by the management factor and the law and regulation factor had the most influence on the rest of the project performance indicators, which are quality, scope, safety, and teamwork. As well, the results of the multiple regression models show that the interface problems caused by the information factor, the management factor, and the law and regulation factor had the strongest influence on the quality project performance indicator. The interface problems caused by the information factor and the others factor were strongest and positively influenced the cost and safety project performance indicators. The problems caused by the management factor and the information factor were the most positive influences on the rest of the project performance indicators.

Based on the results of the two surveys and opinions and thoughts of experts from industry, this study developed a conceptual framework using The Royal Institute of British Architects (RIBA) structure in order to highlight the IM areas considered critical and important for each phase in the project lifecycle. Moreover, use case models were developed to study the IM relationships among owner, contractor, and designer (architects, engineers) and to identify the main responsibilities for each one throughout project lifecycle phases in commercial and building projects. Finally, suggestions for improving and enhancing IM that are adequate to all project participants engaged in different construction projects are provided.

Table 7.1 Comparison between the First and the Second Survey Results

Statistical Technique	Project Lifecycle	Engg. Design Phase
Factor analysis	Six IM Factors	Four IM Factors
MANOVA	<ul style="list-style-type: none"> • Management factor is the factor most impacting IM • Strong relationships between the IM factors and the company type, job title type, and years of experience • No relationships between the IM factors and the industry type 	<ul style="list-style-type: none"> • Information factor and law and regulation factor have the most impact on IM • Strong relationships between the IM factors and the company type, industry type, job title type, and years of experience • No relationships between the IM factors and the level of project complexity
Top 10 IM problems	<ul style="list-style-type: none"> • Different company types, industry types, respondent's title types, and experience types are almost in agreement over the general IM problems 	<ul style="list-style-type: none"> • Different company types, industry types, respondent's title types, experience types, and the level of project complexity types are almost in agreement over the general IM problems
Multiple regression	<ul style="list-style-type: none"> • Schedule project performance: technical engineering and site issues factor, the bidding and contracting factor, the information factor, and the law and regulation factor • Cost project performance: technical engineering and site issues factor, the bidding and contracting factor, and the information factor • The rest of the project performance indicators: management factor and the law and regulation factor 	<ul style="list-style-type: none"> • Quality project performance: information factor, management factor, and law and regulation factor • Cost and safety project performance: information factor and others factor • The rest of the project performance indicators: management factor and the information factor

7.3 Research Contributions

Several theoretical and practical contributions to the body of the knowledge in the area of construction industries were provided as follows:

- The most important contribution of this research study is the development of a conceptual framework using RIBA structure to highlight the IM areas considered critical for each phase of a project lifecycle. In addition, use case models were developed to study the IM relationships among owner, contractor, and designer (architects, engineers) and identify the main responsibilities for each one throughout project lifecycle phases in commercial and building projects. These use case models help to reduce the conflict between construction project participants by identifying the interface problems/issues. Accordingly, suggestions were provided for improving and enhancing IM that are adequate to all project participants engaged in different construction projects.
- Identification of 16 new IM problems through the questionnaires and the pilot study.
- Development of 12 multiple-regression models to study the impact of IM on project performance throughout the project lifecycle and especially during the engineering design phase. The following steps were conducted to achieve this point as follows:
 - Confirmation of IM problems, factors, and most critical problems, and their impact on project performance in construction projects.
 - Understanding the relationships between the IM factors and company type, industry type, etc.
- Conceptual research methodology (theoretical framework) for modeling the impact of IM on construction project performance.

- Focused on the understanding of interfaces during the engineering design phase.

7.4 Benefits of the Research

1. Reduce conflict among owner, design team, and construction contractor. A number of conflicts and omissions can be avoided if the responsibilities and interfaces among owner, architects, engineers, and construction contractors are carefully defined in the beginning of the project. In addition, the research provides the project participants with practical actions on effective and efficient ways to implement IM practices that could result in improved project performance. In addition, they can receive early indication during the lifecycle of an active project of potential IM issues and use this opportunity to take necessary actions to prevent or mitigate the negative impacts of these problems.
2. Companies could use the use case models to develop their own systems to manage the interfaces.
3. The results of this study can assist project managers, architects, engineers, and others to focus on certain tools, areas, and procedures and improve them at the early stages of the project life cycle, so as to optimize the overall project performance. The results of this research study could assist engineers, architects, and others within the construction industry to analyze the project performance during the project's early stages. Furthermore, the results of this research could allow these professionals to have more immediate information about the potential and the most critical IM problems. This information may then minimize project delays and cost and reduce conflict among different project participants involved in construction projects, which may positively influence project performance.

4. Through appropriate communication and coordination techniques among different project participants the potential exists to reduce conflict between phases, disciplines, etc. These interface problems have to be directly, carefully, and effectively resolved.

7.5 Recommendations for Future Research

1. Focus on the understanding of interfaces during different phases of project lifecycle, for instance, the construction phase.
2. Development of a prediction model of the impact of IM on project performance. This step develops a model for prediction of project performance based on IM by using the common methods to predicate the outcomes of the construction projects. Generally, there are many tools being used for project management performance prediction modeling, such as simulation, and neural networks (NN).
3. Study the relationship between the project complexity and the IM by choosing two or more real projects (case studies).
4. Rank and quantify the areas for improving IM that were included in this research study to pick the most important ones to enhance IM.
5. Apply and implement the 12 multiple-regression models that were developed in this research study to real projects in order to study the impact of IM on project performance.
6. Study the IM in different countries and compare IM practices in different countries.
7. Expand this research study to other sectors.
8. Work toward a better understanding of why management and information have the largest impact on the other factors.
9. Study the impact of project delivery methods on IM.

10. Involve other stakeholders in the future research study.
11. Study the relationships between project complexity and IM.

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Appendix I: ETHICS APPROVAL

Appendix II: List of the Collected IM Problems Based on Literature Review

Table II.1 Detailed List of the Collected IM Problems Based on Literature Review

No.	Interface problems	References
1	Insufficient negotiation, communication, and coordination among relevant project participants, e.g., (a) insufficient information standards, (b) poor relationships between organization and human, (c) unknown data required, (d) language and culture differences, (e) ignorance of interface ownership, responsibilities, problems, and (f) poor coordination between design and construction teams..	Al-Hammad & Al-Hammad (1996); Al-Hammad (1993, 2000); Ayudhya (2011); Chen et al. (2008); Graumann & Schlei (1982); R. Huang et al. (2008); Ku et al. (2010)
2	Financial difficulties, e.g., (a) delay in owner payment, (b) disputes among different project participants because of cost, and (c) insufficient budget for project design and construction	Al-Hammad & Assaf (1992); Al-Hammad (1995, 2000); Ayudhya (2011); Chen et al. (2008); R. Huang et al. (2008); Ku et al. (2010)
3	Poor decision making, e.g., (a) delay in decision-making by the clients, (b) the difficulty of the project design and construction, (c) poor policy for managing the relationships inside the company, (d) insufficient experience in design and construction, and (e) outdated and insufficient project data	Al-Hammad (2000); Ayudhya (2011); Chen et al. (2008); R. Huang et al. (2008); Ku et al. (2010)
4	Limited skills for labour and engineering, e.g., insufficient training programs	Al-Hammad (1993, 1995, 2000); Ayudhya (2011); Chen et al. (2008); R. Huang et al. (2008); Ku et al. (2010).
5	Materials procurement problems, e.g., (a) late ordering of long-lead items and special materials, (b) imprecise quantities of project materials, and (c) delay in arrival of project's materials because of bad supply chain management and logistics, poor quality of project materials, and the local market's inability to supply necessary materials	Al-Hammad (2000); Chen et al. (2008)
6	Construction process problems, e.g., (a) bad quality of finished construction work, (b) delays in construction process, (c) the complexity of the construction process because of too many project elements and using a new technology, (d) bad design tasks sequence and management techniques, (e) poor supervision of interfaces, (f) delays in approval for the completed work, and (g) modularization via site fabrication methods	Al-Hammad (1993, 2000); Ayudhya (2011); Chen et al. (2008)

Table II.1 cont'd

No.	Interface problems	References
7	Engineering process problems related to interfaces, e.g., (a) poor quality of the design, (b) level of design complexity of the project because of increased number of physical interfaces, the complexity of system integration, and the diversity of the project components and elements, (c) lack of awareness of design for manufacturing and gathering of the project elements and parties, (d) bad design interfaces because of insufficient understanding of interfaces and lack of experiences and skills by the design team, (e) insufficient well-matched design standards, (f) poor architecture product in terms of modularity and project elements combination, and (g) during the design planning, lack of awareness of the multi-disciplinary type of the project	Al-Hammad & Assaf; (1992); Chen et al. (2008)
8	Project site issues, e.g., (a) insufficient space in the project field for the materials, labour, and equipment because of many reasons, e.g., unorganized project field and simultaneous work tasks, and (b) excessive usage of heavy equipment at site (tower crane, heavy trucks)	Chen et al. (2008)
9	Information problems, e.g., inaccurate and delays in information and repetition in information loop	Chen et al. (2008)
10	Lack of project management, e.g., (a) bad safety management, (b) bad quality management and control, (c) bad risk management, and (d) bad management of the relations among different project sub-contractors	Chen et al. (2008); Mortaheb & Rahimi (2010)
11	Lack of IM, e.g., (a) late starting of IM, (b) lack of awareness of IM and interface problems, and (c) unsuccessful managing of the interface conflicts happening within the project because of inadequate interface documents, insufficient sources, knowledge, and special staffs for IM, and insufficient interface documents and databases	Chen et al. (2008)
12	Planning and scheduling problems, e.g., (a) disagreeing in the project plan, (b) bad scheduling and planning because of: multidiscipline nature of the project, lack of awareness of project tasks relations and orders and sources restrictions, (c) the condensed schedule when the project applies the fast-tracking techniques, and (d) scheduling conflicts among relevant project participants because of bad control on project schedule and update	Chen et al. (2008); R. Huang et al. (2008); Ku et al. (2010)

Table II.1 cont'd

No.	Interface problems	References
13	Imprecise project cost estimate	Al-Hammad & Al-Hammad (1996); Al-Hammad (2000); Ayudhya (2011); R. Huang et al. (2008); Ku et al. (2010)
14	Discrepancies among the owners' expectations regarding project construction schedule, cost, and quality	Ku et al. (2010)
15	Lack of personal experience of the project teams	Al-Hammad & Al-Hammad (1996); R. Huang et al. (2008); Ku et al. (2010)
16	Inability to predict and resolve project's problems related to new technological techniques and materials	Ku et al. (2010)
17	Contractor's unfamiliarity with the environmental circumstances and local weather	Al-Hammad (1995)
18	Project team members' lack of knowledge about site circumstances	Al-Hammad & Assaf (1992)
19	Increased project interfaces conflicts when different contractors insist on their points of view	Ku et al. (2010)
20	Insufficient and inaccurate work drawings and specifications, e.g., (a) lack of interface details within work drawings and specifications, insufficient interface categorization and descriptions in the literature, (b) insufficient standards for the interface, (c) within the scope of the work, unclear interface responsibilities and ownerships, and (d) unclear and insufficient descriptions of work tasks engaged in interface	Al-Hammad & Al-Hammad (1996); Al-Hammad (1993, 2000); Ayudhya (2011); Chen et al. (2008)
21	No proper work packaging design and subcontracting because of many reasons, e.g., (a) lack of awareness of relations among project elements, parties, and sub-systems, (b) lack of awareness of relations between IM and sub-contracting, and (c) unsuitable project breakdown structure	Al-Hammad & Assaf (1992); Chen et al. (2008)

Table II.1 cont'd

No.	Interface problems	References
22	Slow submission and approval of change orders, permits, and shop drawings, e.g., (a) slow change order approval, (b) no attention to interfaces while changing involved project parties, (c) inappropriate schedule of sample materials and shop drawings approval, (d) confused submission procedures, (e) no schedule time for submission and review processes, and (f) bad quality of submitted documents	Al-Hammad (1993, 2000); Ayudhya (2011); Chen et al. (2008); Ku et al. (2010)
23	Unclear contract details and badly written contract, e.g., (a) undetermined labour skills in contract, (b) insufficient penalty clause in contract, and (c) interface responsibilities not included within the contract documents	Al-Hammad & Al-Hammad (1996); Al-Hammad (2000); Ayudhya (2011); R. Huang et al. (2008)
24	Delay in established schedule of engineering, procurement, and construction, and delay in owner approval of completed tasks	Al-Hammad (1995)
25	Application of fast-track engineering and construction techniques	Al-Hammad & Assaf (1992)
26	Weather and climate conditions problems, e.g., (a) not enough consideration of weather issues in planning because of inaccurate weather information and ignoring of the effect of weather conditions on interfaces, (b) unsuccessful management of the risks related to weather conditions, and (c) unanticipated harsh weather circumstances	Al-Hammad (2000); Ayudhya (2011); Chen et al. (2008); R. Huang et al. (2008).
27	Unexpected changes in materials and labour availability and cost	Al-Hammad (1993, 2000); Ayudhya (2011); Chen et al. (2008); R. Huang et al. (2008); Ku et al. (2010).
28	Geotechnical circumstances problems, e.g., (a) lack of information on the geological examination, (b) unsuitable selection of design/construction techniques, and (c) unanticipated site circumstances	Al-Hammad (2000); Chen et al. (2008); R. Huang et al. (2008); Ku et al. (2010).
29	Inexperience with government auditing protocols and procedures	R. Huang et al. (2008); Ku et al. (2010)
30	Inexperience with local laws and other government regulations and modification in laws and regulations	Al-Hammad (2000); R. Huang et al. (2008); Ku et al. (2010)
31	Inexperience with building codes, by-laws, statutes, and other government regulations	Al-Hammad & Assaf (1992); Chen et al. (2008)

Appendix III: Survey Instrument One (Throughout project lifecycle)

SECTION 1. Demographic Information:

1.1 The type of company you are working for (please check the most appropriate one):

- | | |
|--|--------------------------|
| Owner | <input type="checkbox"/> |
| EPC | <input type="checkbox"/> |
| EPCM | <input type="checkbox"/> |
| Construction Contractor/Sub-contractor | <input type="checkbox"/> |
| Engineering Consultant | <input type="checkbox"/> |
| Architecture Firms | <input type="checkbox"/> |
| Architecture and Engineering Firms | <input type="checkbox"/> |
| Construction Management Company | <input type="checkbox"/> |
| Other (Pls. specify)..... | <input type="checkbox"/> |

1.2 Respondent's title/position (please check the most appropriate one):

- | | |
|----------------------------------|--------------------------|
| Lead (Safety, Procurement, etc.) | <input type="checkbox"/> |
| Project Controls | <input type="checkbox"/> |
| Interface Coordinator | <input type="checkbox"/> |
| Contract Administrator | <input type="checkbox"/> |
| Project Engineer | <input type="checkbox"/> |
| Commissioning Engineer | <input type="checkbox"/> |
| Quality Engineer | <input type="checkbox"/> |
| Planning Engineer | <input type="checkbox"/> |
| Project Manager | <input type="checkbox"/> |
| Construction Manager | <input type="checkbox"/> |

- Construction Planner ☐
- Contractor/sub-contractor ☐
- Engineer (Structural, Mechanical, Electrical) ☐
- Architect ☐
- Project Eng. Manager ☐
- Student (Pls. specify in which Faculty)..... ☐
- Other (Pls. specify)..... ☐

1.3 The main industry your company is working in (you can pick more than one answer):

- Infrastructure ☐
- Oil and Gas ☐
- Transportation ☐
- Commercial and Buildings ☐
- Manufacturing ☐
- Other (Pls. specify)..... ☐

1.4 Highest Educational Qualifications:

- Diploma ☐
- Post Diploma ☐
- BSc ☐
- MSc ☐
- PhD ☐
- Other (Pls. specify)..... ☐

1.5 Total years of experience:

5 years or less	<input type="checkbox"/>
6-9 years	<input type="checkbox"/>
10-14 years	<input type="checkbox"/>
15-19 years	<input type="checkbox"/>
20 & above	<input type="checkbox"/>

SECTION 2. The Interface Problems/Issues

2.1 From your experience;

First, what is the probability of occurrence of each one of the following *interface problem/issues* (According to the scale below; select a number in the first cell, “Probability of Occurrence”)?

Second, what is the impact of each of the following *interface problem/issues* in establishing a proper interface management system among different parties involved in construction and oil and gas projects? (According to the scale below; select a number in the second cell “Impact”).

Third, how important are the *interface problem/issues* on project performance (quality management, schedule management, cost management, scope management, safety management, and teamwork) in Alberta’s construction and oil and gas projects? (According to the scale below, select a number in the third, fourth, fifth, sixth, seventh, and eighth cells; quality, schedule, cost, scope, safety, and teamwork?)

Table III.1 Survey questions

		Negligible	Disastrous	Unimportant		Very Important		
	Interface Problems/Issues	Impact	Project Performance					
			Quality	Schedule	Cost	Scope	Safety	Teamwork
2.1.1	Lack of enough negotiation and communication & coordination.							
2.1.2	Financial difficulties.							
2.1.3	Poor decision making.							
2.1.4	Limited skills for labour and engineering, for example, insufficient training programs.							
2.1.5	Materials procurement problems.							
2.1.6	Construction processes and methods problems.							
2.1.7	Engineering process problems related to interfaces.							
2.1.8	Project site issues.							
2.1.9	Information problems.							
2.1.10	Lack of project management.							
2.1.11	Lack of interface management system.							
2.1.12	Planning and scheduling problems.							
2.1.13	Type of organization structure.							
2.1.14	Interfaces with other interdependent projects							
2.1.15	Undefined reporting structure and responsibilities							
2.1.16	Interfaces arise because of the application of the project development gating (or phases) system.							

Table III.1 cont'd

		Negligible	Disastrous	Unimportant		Very Important		
	Interface Problems/Issues	Impact	Project Performance					
			Quality	Schedule	Cost	Scope	Safety	Teamwork
2.1.17	Insufficient and lack of alignment among WBS, CWBS, CBS, & OBS.							
2.1.18	Imprecise project cost estimate.							
2.1.19	Discrepancies among the owners’ expectations regarding project construction schedule, cost. and quality							
2.1.20	Lack of personal experience of the project teams.							
2.1.21	Inability to predict and resolve project’s problems related to new technological techniques and materials							
2.1.22	Contractor’s unfamiliarity with the environmental circumstances and local weather.							
2.1.23	Project team members’ lack of knowledge about site circumstances							
2.1.24	Increase project interfaces conflicts when different contractors insist on their points of view.							
2.1.25	Lack of trust among different project parties.							
2.1.26	Insufficient and inaccurate work drawings and specifications.							
2.1.27	No proper work packaging design and subcontracting.							
2.1.28	Slow submission and approval of change orders, permits, and shop drawings.							

Table III.1 cont'd

		Negligible	Disastrous	Unimportant		Very Important		
	Interface Problems/Issues	Impact	Project Performance					
			Quality	Schedule	Cost	Scope	Safety	Teamwork
2.1.29	Unclear contract details and poorly written contract.							
2.1.30	Delay in established schedule of engineering, procurement, and construction, and delay in owner approval of completed tasks.							
2.1.31	Type of the contract doesn’t match the nature of the project.							
2.1.32	Application of fast-track engineering and construction techniques.							
2.1.33	Lack of solid contracting strategy vision at early stage of the project.							
2.1.34	Type of contracting strategy; EP, EPC, and EPCM.							
2.1.35	In the invitation to tender, identify the interface problems.							
2.1.36	Complete appraisal of bids to comprise an assessment of contractor’s understanding of interface management.							
2.1.37	Weather climate conditions problems.							
2.1.38	Unexpected changes in materials and labour availability and cost.							
2.1.39	Geological circumstances problems. For example, lack of information on the geological examination.							

Table III.1 cont'd

		Negligible	Disastrous	Unimportant	Very Important			
	Interface Problems/Issues	Impact	Project Performance					
			Quality	Schedule	Cost	Scope	Safety	Teamwork
2.1.40	Unclear company standard operating procedures.							
2.1.41	Inexperience with the government auditing protocols and procedures.							
2.1.42	Inexperience with local laws and other government regulations and modification in laws and regulations.							
2.1.43	Inexperience with building codes, by-laws, statutes and other government regulations.							
2.1.44	Project extension versus greenfield (new) project type.							
2.1.45	Free issue items. For example, owner supply concrete and gravel, fly-in-out and camp services to the construction contractors for free.							
2.1.46	Insufficient definition of projects boundaries at early stage of the project.							
2.1.47	Unclear system completion requirements.							

From your experience, what do you suggest and recommend improving the interface management? (Please write below.)

.....
.....

- Do you agree to go for an interview as part of follow up? 1. Yes 2. No
- If yes, please write down your email address (Print please)

.....

- If you would like to get the final findings of this study, please write down your email address (Print please).....

Appendix IV: Survey Instrument Two during the Engineering Design Phase

Title: Interface Management during Engineering/Design phase projects/ Inside Alberta.

Purpose: The purpose of the first survey is to collect data during the design phases.

SECTION 1. Demographic Information:

1.6 The type of company you are working for (please check the most appropriate one):

- | | |
|------------------------------------|--------------------------|
| Owner | <input type="checkbox"/> |
| EPC | <input type="checkbox"/> |
| EPCM | <input type="checkbox"/> |
| Engineering Consultant | <input type="checkbox"/> |
| Architecture Firms | <input type="checkbox"/> |
| Architecture and Engineering Firms | <input type="checkbox"/> |
| Construction Management Company | <input type="checkbox"/> |
| Other (Pls. specify)..... | <input type="checkbox"/> |

1.7 Respondent's title/position (please check the most appropriate one):

- | | |
|-------------------------------------|--------------------------|
| Lead (Structural, Mechanical, etc.) | <input type="checkbox"/> |
| Project Controls | <input type="checkbox"/> |
| Interface Coordinator | <input type="checkbox"/> |
| Project Engineer | <input type="checkbox"/> |
| Quality Engineer | <input type="checkbox"/> |
| Planning Engineer | <input type="checkbox"/> |
| Project Manager | <input type="checkbox"/> |
| Contractor/sub-contractor | <input type="checkbox"/> |

Engineer (Structural, Mechanical, Electrical) ☐

Architect ☐

Project Eng. Manager ☐

Other (Pls. specify)..... ☐

1.8 The main industry your company is working in (you can pick more than one answer):

Infrastructure ☐

Oil and Gas ☐

Transportation ☐

Commercial and Buildings ☐

Manufacturing

Other (Pls. specify)..... ☐

1.9 Highest Educational Qualifications:

Diploma and Post Diploma ☐

BSc ☐

MSc ☐

PhD ☐

Other (Pls. specify)..... ☐

1.10 Total years of experience:

5 years or less ☐

6-9 years ☐

10-14 years ☐

15-19 years ☐

20 & above ☐

1.11 In your current projects, what is the average complexity of the construction projects?

High complexity	<input type="checkbox"/>
Medium complexity	<input type="checkbox"/>
Low complexity	<input type="checkbox"/>

SECTION 2. The Interface Problems/Issues

2.1 From your experience;

First, from your experience what is the impact of the IM problems during Engineering Design phase projects?

Second, how important are the interface problem/issues on project performance (quality management, schedule management, cost management, scope management, safety management, and teamwork) during Engineering Design phase of EPC (Engineering, procurement, and construction) projects? (According to the scale below, select a number in the third, fourth, fifth, sixth, seventh, and eighth cells; quality, schedule, cost, scope, safety, and teamwork?)

Table IV.1 Survey questions

		Negligible	Disastrous	Unimportant		Very Important		
	Interface Problems/Issues	Impact	Project Performance					
			Quality	Schedule	Cost	Scope	Safety	Teamwork
2.1.1	Lack of enough negotiation and communication and coordination.							
2.1.2	Financial difficulties.							
2.1.3	Poor decision making.							
2.1.4	Limited skills for labour and engineering.							
2.1.5	Engineering process problems related to interfaces							
2.1.6	Information problems.							
2.1.7	Lack of project management.							
2.1.8	Lack of interface management system.							
2.1.9	Planning and scheduling problems.							
2.1.10	Type of organization structure.							
2.1.11	Interfaces with other interdependent projects							
2.1.12	Undefined reporting structure and responsibilities.							
2.1.13	Insufficient and lack of alignment among WBS, CWBS, CBS, & OBS.							
2.1.14	Lack of personal experience of the project teams.							

Table IV.1 cont'd

		Negligible	Disastrous	Unimportant		Very Important		
	Interface Problems/Issues	Impact	Project Performance					
			Quality	Schedule	Cost	Scope	Safety	Teamwork
2.1.15	Lack of trust among different project parties.							
2.1.16	Insufficient and inaccurate work drawings and specifications.							
2.1.17	No proper work packaging design and subcontracting.							
2.1.18	Delay in established schedule of engineering, and delay in owner approval of completed tasks.							
2.1.19	Type of contracting strategy; EP, EPC, and EPCM.							
2.1.20	Inexperience with local laws and other government regulations and modification in laws and regulations.							
2.1.21	Inexperience with building codes, by-laws, statutes and other government regulations.							
2.1.22	Unclear system completion requirements.							

- If you would like to get the final findings of this study, please write down your email address (Print please):

.....

Appendix V: Determining Sample Size

There are four factors and assumptions that must be considered in determining sample size: the level of significance (α), the power of the test ($1 - \beta$), the effect size (ES) or standardized effect size (d), and the directional nature of the hypothesis (one- or two-tailed tests). Using the significance level of 0.05 and a 4:1 ratio of β to α results in $\beta = 0.20$ and power = 0.80, which appears to be sufficient. The appropriate sample size was calculated using the formula for the standardized two-tailed tests as follows (Hinkle, Wiersma, & Jurs, 2003):

$$n = 2(Z\beta - Z\alpha/2)^2 / d^2 \quad (\text{Hinkle et al. 2003}) \quad (1)$$

where

n = sample size

α = level of significant (0.05)

d = standardized effect size (0.80)

$Z\beta$ = value on a standard normal curve. Using the table (areas under standard normal curve for values of Z), $Z\beta = 0.842$ (Hinkle et al., 2003).

$Z\alpha$ = value on a standard normal curve. Using the table (areas under standard normal curve for values of Z), $Z\alpha = 1.96$ (Hinkle et al., 2003).

Given standard deviation = 6.25 and the assumed difference for significance = 5 the standardized effect size $d = 5/6.25 = 0.80$.

Based on the above discussion, $n = 2(0.842 - (-1.96))^2 / (0.80)^2 = 22$.

Therefore, with a 10 % attrition rate we should try for 25 participants per company type, industry type, respondent's title, and respondent's years of experience in the construction industry.

Appendix VI: Results of the Pearson Product-Moment Correlation: Project Lifecycle
Table VI.1 Results of the Pearson Product-Moment Correlation: Project Lifecycle

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	1																						
2	0.4	1																					
3	0.3	0.3	1																				
4	0.3	0.4	0.3	1																			
5	0.3	0.3	0.4	0.4	1																		
6	0.3	0.3	0.4	0.3	0.4	1																	
7	0.4	0.3	0.4	0.5	0.5	0.5	1																
8	0.3	0.2	0.3	0.3	0.4	0.4	0.5	1															
9	0.4	0.4	0.4	0.4	0.5	0.4	0.6	0.5	1														
10	0.4	0.4	0.4	0.3	0.4	0.4	0.5	0.4	0.5	1													
11	0.5	0.3	0.4	0.4	0.5	0.4	0.5	0.5	0.6	0.5	1												
12	0.3	0.3	0.4	0.4	0.4	0.4	0.5	0.4	0.5	0.4	0.5	1											
13	0.4	0.4	0.3	0.5	0.3	0.3	0.4	0.3	0.5	0.5	0.5	0.4	1										
14	0.3	0.3	0.3	0.3	0.4	0.3	0.4	0.2	0.4	0.4	0.4	0.4	0.4	1									
15	0.4	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.4	0.4	0.4	0.5	0.4	1								
16	0.3	0.2	0.3	0.4	0.3	0.3	0.3	0.3	0.4	0.3	0.3	0.3	0.5	0.3	0.4	1							
17	0.4	0.3	0.2	0.4	0.4	0.3	0.5	0.4	0.5	0.4	0.6	0.5	0.6	0.4	0.6	0.4	1						
18	0.3	0.3	0.3	0.4	0.4	0.2	0.4	0.3	0.5	0.3	0.4	0.5	0.3	0.4	0.5	0.4	0.5	1					
19	0.4	0.3	0.4	0.4	0.4	0.3	0.5	0.3	0.5	0.4	0.4	0.5	0.4	0.4	0.3	0.3	0.4	0.5	1				
20	0.4	0.3	0.3	0.3	0.4	0.3	0.5	0.4	0.5	0.4	0.5	0.4	0.4	0.4	0.4	0.2	0.5	0.3	0.4	1			
21	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.3	0.3	0.4	0.4	0.3	0.3	0.4	0.4	0.2	0.2	0.4	0.4	0.4	1		
22	0.2	0.3	0.3	0.4	0.3	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.4	0.3	0.2	0.3	0.4	0.4	0.4	1	
23	0.4	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.4	0.5	0.4	0.3	0.4	0.4	0.4	0.4	0.3	0.3	0.4	0.4	0.5	0.7	1
24	0.4	0.3	0.3	0.3	0.3	0.3	0.4	0.3	0.3	0.3	0.4	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.4	0.4	0.5	0.5
25	0.4	0.4	0.3	0.4	0.5	0.4	0.5	0.4	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.5	0.5	0.4	0.5	0.5	0.4	0.5	0.5
26	0.4	0.4	0.4	0.4	0.6	0.4	0.6	0.4	0.5	0.5	0.6	0.5	0.4	0.4	0.4	0.3	0.5	0.4	0.5	0.5	0.4	0.4	0.5
27	0.4	0.2	0.3	0.3	0.5	0.4	0.5	0.5	0.5	0.5	0.6	0.4	0.4	0.4	0.5	0.4	0.4	0.2	0.4	0.4	0.5	0.5	0.6
28	0.3	0.3	0.4	0.3	0.4	0.4	0.5	0.3	0.4	0.4	0.5	0.5	0.5	0.4	0.3	0.3	0.4	0.3	0.3	0.4	0.4	0.4	0.5
29	0.4	0.3	0.3	0.3	0.4	0.4	0.5	0.3	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.3	0.4	0.4	0.4	0.4	0.4	0.5	0.6
30	0.4	0.4	0.4	0.3	0.4	0.3	0.5	0.2	0.5	0.4	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.4	0.4	0.4	0.4
31	0.2	0.3	0.3	0.2	0.4	0.2	0.5	0.3	0.3	0.4	0.4	0.4	0.3	0.3	0.4	0.3	0.3	0.4	0.2	0.3	0.5	0.4	0.5
32	0.3	0.3	0.4	0.3	0.4	0.3	0.4	0.2	0.5	0.3	0.4	0.5	0.4	0.4	0.4	0.3	0.4	0.4	0.5	0.4	0.3	0.4	0.4
33	0.2	0.2	0.2	0.2	0.4	0.3	0.3	0.3	0.3	0.4	0.4	0.5	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.4
34	0.3	0.3	0.2	0.2	0.4	0.4	0.5	0.3	0.3	0.3	0.4	0.4	0.4	0.3	0.2	0.3	0.4	0.3	0.2	0.3	0.2	0.3	0.4
35	0.3	0.2	0.3	0.3	0.4	0.3	0.4	0.4	0.4	0.3	0.4	0.4	0.4	0.4	0.3	0.3	0.4	0.3	0.4	0.4	0.3	0.4	0.5
36	0.3	0.2	0.2	0.3	0.3	0.3	0.4	0.3	0.3	0.3	0.3	0.4	0.4	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.2	0.4	0.4
37	0.4	0.3	0.2	0.4	0.4	0.2	0.3	0.2	0.3	0.3	0.3	0.2	0.3	0.4	0.3	0.2	0.2	0.4	0.3	0.1	0.3	0.3	0.4
38	0.4	0.4	0.3	0.4	0.5	0.3	0.5	0.3	0.4	0.5	0.5	0.5	0.3	0.4	0.4	0.3	0.5	0.5	0.4	0.5	0.4	0.4	0.5
39	0.3	0.3	0.2	0.2	0.3	0.3	0.4	0.2	0.3	0.4	0.3	0.3	0.2	0.4	0.3	0.1	0.2	0.2	0.3	0.2	0.4	0.4	0.5
40	0.4	0.3	0.2	0.4	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.4	0.3	0.4	0.3	0.2	0.3	0.3	0.4	0.6
41	0.3	0.3	0.1	0.2	0.3	0.2	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.3	0.2	0.2	0.3	0.5	0.6
42	0.3	0.2	0.2	0.3	0.3	0.4	0.4	0.4	0.3	0.3	0.3	0.2	0.3	0.4	0.3	0.2	0.2	0.2	0.3	0.3	0.4	0.5	0.7
43	0.3	0.3	0.2	0.3	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.4	0.2	0.1	0.1	0.3	0.3	0.3	0.4	0.4	0.6
44	0.4	0.1	0.2	0.2	0.2	0.3	0.4	0.2	0.4	0.2	0.3	0.2	0.2	0.3	0.3	0.2	0.4	0.2	0.1	0.2	0.0	0.2	0.2
45	0.3	0.3	0.3	0.2	0.2	0.3	0.3	0.2	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.2	0.5	0.2	0.3	0.3	0.2	0.2	0.2
46	0.1	0.1	0.2	0.1	0.2	0.3	0.3	0.2	0.3	0.3	0.3	0.4	0.4	0.3	0.3	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.3
47	0.3	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.5	0.5	0.4	0.4	0.4	0.2	0.4	0.4	0.3	0.3	0.3	0.3	0.4

Table VI.1 cont'd

24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
1																							
0.5	1																						
0.5	0.5	1																					
0.5	0.5	0.6	1																				
0.5	0.4	0.5	0.6	1																			
0.5	0.6	0.6	0.5	0.5	1																		
0.5	0.5	0.6	0.5	0.6	0.6	1																	
0.5	0.4	0.5	0.5	0.3	0.5	0.5	1																
0.4	0.5	0.5	0.4	0.5	0.4	0.5	0.3	1															
0.5	0.4	0.4	0.5	0.3	0.5	0.4	0.5	0.3	1														
0.5	0.3	0.3	0.5	0.4	0.4	0.5	0.5	0.4	0.6	1													
0.5	0.4	0.4	0.4	0.4	0.5	0.4	0.4	0.4	0.5	0.5	1												
0.4	0.3	0.4	0.4	0.4	0.4	0.4	0.3	0.4	0.4	0.5	0.6	1											
0.2	0.3	0.4	0.3	0.2	0.3	0.3	0.3	0.2	0.2	0.2	0.3	0.2	1										
0.5	0.4	0.6	0.4	0.5	0.4	0.6	0.5	0.5	0.3	0.4	0.4	0.3	0.4	1									
0.4	0.3	0.4	0.4	0.4	0.5	0.5	0.4	0.4	0.4	0.4	0.3	0.4	0.3	0.4	1								
0.5	0.4	0.3	0.5	0.4	0.4	0.3	0.4	0.2	0.5	0.5	0.4	0.5	0.2	0.3	0.4	1							
0.5	0.4	0.4	0.5	0.4	0.5	0.4	0.4	0.3	0.4	0.4	0.5	0.5	0.3	0.4	0.4	0.6	1						
0.5	0.4	0.4	0.5	0.4	0.5	0.4	0.4	0.3	0.3	0.4	0.4	0.5	0.3	0.4	0.5	0.6	0.8	1					
0.4	0.4	0.4	0.5	0.3	0.5	0.4	0.4	0.2	0.3	0.2	0.3	0.4	0.3	0.4	0.4	0.4	0.6	0.8	1				
0.3	0.2	0.4	0.3	0.3	0.3	0.4	0.1	0.2	0.3	0.5	0.3	0.3	0.2	0.3	0.2	0.2	0.2	0.2	0.1	1			
0.3	0.4	0.3	0.3	0.3	0.4	0.3	0.3	0.3	0.4	0.5	0.4	0.3	0.2	0.3	0.2	0.4	0.4	0.3	0.2	0.4	1		
0.3	0.4	0.2	0.3	0.3	0.4	0.3	0.3	0.3	0.5	0.4	0.4	0.5	0.2	0.2	0.3	0.4	0.4	0.4	0.4	0.4	0.5	1	
0.5	0.4	0.4	0.5	0.4	0.5	0.4	0.4	0.3	0.6	0.5	0.5	0.5	0.2	0.3	0.3	0.6	0.5	0.4	0.4	0.3	0.5	0.6	1

Appendix VII: Multiple-Regression Results for Six Project Performance Indicators: Project Lifecycle

This materials in this appendix were included in Weshah et al. (2014).

“Multiple regression is a statistical technique that allows us to predict someone’s score on one variable on the basis of their scores on several other variables”, where the researchers can predict one variable on the basis of a number of other variables (Brace et al., 2006). The contribution of each predictor variable can be measured by using various techniques such as the stepwise method. The stepwise method is an approach that assists the researcher to end up with the smallest number of significant predictor variables to be included in the final model.

Researchers must abide by two assumptions before applying the multiple-regression analysis: (1) the square distances of the points to the regression line need to be normally distributed. The SPSS® prints out a scatter plot to see if the researchers conform to this assumption, and (2) the correlation between criterion variables and predictor variables must not be higher than 0.80. To check this, the bivariate correlation between the criterion variables and predictor variables should be examined; this is titled “collinearity” in SPSS®. The collinearity diagnostics table “gives some useful additional output that allows you to assess whether you have a problem with Collinearity in your data” (Brace et al., 2006). The term collinearity “is used to describe the situation when a high correlation is detected between two or more predictor variables. Such high correlations cause problems when trying to draw inferences about the relative contribution of each predictor variable to the success of the model” (Brace et al., 2006). The results show that our data conforms to these two assumptions and are reasonable enough to build multiple-regression models. For more details, Table VII.1 illustrates the model where “quality” is used as

the dependent variable. The overall p -value for this model was 0.00, lower than 0.05, which indicated that different interface problems would have a major influence on the quality project performance. In addition, R^2 was 0.464 and the adjusted R^2 was 0.456: These values were much better than the lowest accepted standard of 0.18 (Flury & Riedwyl, 1988). In more detail, the p -values for the management factor and the law and regulation factor were 0.00 and 0.00, respectively, which is lower than 0.05. Consequently, it can be seen that quality management would be positively influenced by these two interface problem factors only. Moreover, the β for the management factor and the law and regulation factor were 0.487 and 0.285, respectively, which indicated that the law and regulation factor influences the quality management less than the management factor.

Moreover, Table VII.1 illustrates the full details of the model where schedule management is used as the dependent variable. Consequently, it can be seen that schedule management would be positively influenced by these four interface problem factors only. Also, the β for the technical engineering and site issues factor, information factor, bidding and contracting factor, and law and regulation factor were 0.354, 0.225, 0.181, and 0.152, respectively, which indicates that the technical engineering and site issues factor positively influences the schedule management more than the information factor, bidding and contracting factor, and the law and regulation factor.

In addition, Table VII.1 also shows full details on the model where cost management is used as the dependent variable. The β for the technical engineering and site issues factor, bidding and contracting factor, and information factor were 0.399, 0.259, and 0.218, respectively, which indicates that the technical engineering and site issues factor positively influences cost management more than the bidding and contracting factor and the information factor.

Moreover, Table VII.1 gives full details on the model where scope management is used as the dependent variable. Consequently, it can be seen that scope management would be positively influenced by these two interface problem factors only. Moreover, the β value for the management factor and law and regulation factor were 0.521 and 0.204, respectively, which indicated that the management factor positively influences cost management more than the law and regulation factor. In addition, Table VII.1 shows details on the model where safety management is used as the dependent variable. Consequently, it can be seen that safety management would be positively influenced by this problem factor only.

Moreover, Table VII.1 shows full details on the model where teamwork management is used as the dependent variable. β for the management factor and law and regulation factor were 0.455 and 0.338, respectively, which indicated that the management factor influences teamwork management more than the law and regulation factor.

Table VII.1: Multiple-Regression Results for Six Project Performance Indicators

1. Dependent value: quality management			
Independent variable	<i>B</i>	Standardized coefficient (β)	<i>P</i> value
Constant	0.529		0.129
Management factor	0.621	0.487	0.00
Law and regulation factor	0.248	0.285	0.00
Model <i>P</i> value 0.000; R^2 =0.464; Adjusted R^2 = 0.456. Note: means <i>p</i> value <0.05			
2. Dependent value: schedule management			
Independent variable	<i>B</i>	Standardized coefficient (β)	<i>P</i> value
Constant	0.828		0.003
Technical engineering and site issues factor	0.434	0.354	0.000
Information factor	0.231	0.225	0.008
Bidding and contracting factor	0.199	0.181	0.041
Law and regulation factor	0.132	0.152	0.049
Model <i>P</i> value= 0.049; R^2 = 0.631; Adjusted R^2 = 0.620. Note: means <i>p</i> value <0.05			

Table VII.1 cont'd

3. Dependent value: cost management			
Independent variable	<i>B</i>	Standardized coefficient(β)	<i>P</i> value
Constant	0.547		0.064
Technical engineering and site issues factor	0.514	0.399	0.000
Bidding and contracting factor	0.301	0.259	0.001
Information factor	0.236	0.218	0.011
Model <i>P</i> value= 0.011; $R^2 = 0.619$; Adjusted $R^2 = 0.611$. Note: means <i>p</i> value <0.05			
4. Dependent value: scope management			
Independent variable	<i>B</i>	Standardized coefficient (β)	<i>P</i> value
Constant	0.532		0.153
Management factor	0.684	0.521	0.000
Law and regulation factor	0.183	0.204	0.009
Model <i>P</i> value= 0.000; $R^2 = 0.424$; Adjusted $R^2 = 0.416$. Note: means <i>p</i> value <0.05			
5. Dependent value: safety management			
Independent variable	<i>B</i>	Standardized coefficient (β)	<i>P</i> value
Constant	0.407		0.409
Management factor	0.725	0.477	0.000
Model <i>P</i> value= 0.000; $R^2 = 0.228$; Adjusted $R^2 = 0.222$. Note: means <i>p</i> value <0.05			
6. Dependent value: teamwork management			
Independent variable	<i>B</i>	Standardized coefficient (β)	<i>P</i> value
Constant	0.294		0.430
Management factor	0.633	0.455	0.000
Law factor	0.321	0.338	0.000
Model <i>P</i> value= 0.000; $R^2 = 0.483$; Adjusted $R^2 = 0.475$. Note: means <i>p</i> value <0.05			

Appendix VIII: Results of the Pearson Product-Moment Correlation: Engineering Design Phase

Table VIII.1 Results of the Pearson Product-Moment Correlation: Engineering Design Phase

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	1																					
2	0.35	1																				
3	0.43	0.41	1																			
4	0.36	0.31	0.37	1																		
5	0.38	0.31	0.46	0.40	1																	
6	0.35	0.31	0.52	0.33	0.49	1																
7	0.42	0.28	0.48	0.26	0.48	0.56	1															
8	0.27	0.22	0.41	0.28	0.47	0.51	0.47	1														
9	0.22	0.21	0.34	0.14	0.20	0.42	0.31	0.42	1													
10	0.22	0.21	0.11	0.13	0.11	0.14	0.22	0.40	0.32	1												
11	0.31	0.23	0.25	0.21	0.34	0.29	0.24	0.31	0.32	0.32	1											
12	0.41	0.16	0.33	0.30	0.37	0.52	0.51	0.45	0.40	0.30	0.31	1										
13	0.35	0.28	0.27	0.33	0.35	0.44	0.43	0.47	0.32	0.41	0.40	0.42	1									
14	0.18	0.23	0.26	0.29	0.39	0.45	0.31	0.44	0.36	0.32	0.23	0.43	0.42	1								
15	0.32	0.17	0.33	0.20	0.32	0.43	0.38	0.43	0.25	0.29	0.29	0.46	0.36	0.38	1							
16	0.31	0.25	0.43	0.38	0.36	0.55	0.42	0.52	0.46	0.31	0.30	0.57	0.43	0.51	0.49	1						
17	0.31	0.30	0.41	0.41	0.41	0.55	0.39	0.57	0.43	0.34	0.31	0.50	0.42	0.49	0.47	0.63	1					
18	0.21	0.24	0.41	0.38	0.36	0.52	0.38	0.46	0.39	0.26	0.29	0.40	0.48	0.44	0.34	0.54	0.50	1				
19	0.17	0.28	0.18	0.28	0.23	0.22	0.27	0.24	0.29	0.20	0.34	0.22	0.36	0.16	0.11	0.21	0.14	0.26	1			
20	0.37	0.24	0.31	0.38	0.28	0.40	0.30	0.27	0.26	0.20	0.39	0.31	0.29	0.29	0.33	0.47	0.49	0.41	0.22	1		
21	0.34	0.27	0.36	0.38	0.43	0.42	0.40	0.34	0.19	0.16	0.40	0.39	0.33	0.30	0.39	0.44	0.48	0.48	0.29	0.74	1	
22	0.27	0.29	0.37	0.37	0.41	0.52	0.47	0.51	0.26	0.27	0.26	0.53	0.48	0.35	0.41	0.51	0.57	0.43	0.21	0.35	0.43	1

Appendix IX: Multiple-Regression Results for Six Project Performance Indicators: Engineering/Design Phase

There are two assumptions that one must abide by to apply the multiple-regression analysis:

- (1) the square distances of the points to the regression line need to be normally distributed and
- (2) the correlation between criterion variables and predictor variables must not be higher than 0.80. Table IX.1 illustrates the six multiple regression models.

Table IX.1 Multiple-Regression Results for Six Project Performance Indicators

1. Dependent value: quality management			
Independent variable	<i>B</i>	Standardized coefficient (β)	<i>P</i> value
Constant	−0.400		
Information factor	0.662	0.548	0.00
Management factor	0.303	0.200	0.009
Law and regulation factor	0.117	0.129	0.028
Model <i>P</i> value 0.000; $R^2 = 0.620$; Adjusted $R^2 = 0.613$. Note: means <i>p</i> value <0.05			
2. Dependent value: schedule management			
Independent variable	<i>B</i>	Standardized coefficient (β)	<i>P</i> value
Constant	0.19		
Information factor	0.497	0.428	0.000
Management factor	0.248	0.170	0.011
Others factor	0.409	0.332	0.000
Model <i>P</i> value= 0.000; $R^2 = 0.720$; Adjusted $R^2 = 0.715$; Note: means <i>p</i> value <0.05			
3. Dependent value: cost management			
Independent variable	<i>B</i>	Standardized coefficient(β)	<i>P</i> value
Constant	0.302		
Information factor	0.581	0.493	0.00
Others factor	0.475	0.379	0.00
Model <i>P</i> value= 0.000; $R^2 = 0.665$; Adjusted $R^2 = 0.661$; Note: means <i>p</i> value <0.05			

Table IX.1 cont'd

4. Dependent value: scope management			
Independent variable	<i>B</i>	Standardized coefficient (β)	<i>P</i> value
Constant	-0.505		
Information factor	0.744	0.562	0.00
Management factor	0.350	0.211	0.012
Model <i>P</i> value = 0.000; $R^2 = 0.539$; Adjusted $R^2 = 0.533$. Note: means <i>p</i> value <0.05			
5. Dependent value: safety management			
Independent variable	<i>B</i>	Standardized coefficient (β)	<i>P</i> value
Constant	-0.436		
Information factor	0.447	0.284	0.005
Others factor	0.507	0.302	0.003
Model <i>P</i> value = 0.000; $R^2 = 0.45$; Adjusted $R^2 = 0.55$. Note: means <i>p</i> value <0.05			
6. Dependent value: teamwork management			
Independent variable	<i>B</i>	Standardized coefficient (β)	<i>P</i> value
Constant	-0.227		
Information factor	0.647	0.470	0.00
Management factor	0.406	0.235	0.010
Model <i>P</i> value= 0.000; $R^2 = 0.51$; Adjusted $R^2 = 0.55$. Note: means <i>p</i> value <0.05			