

CONSTRUCTABILITY DATABASE KNOWLEDGE MODEL AND GUIDELINES
OF INDUSTRIAL PLANT AT CONSTRUCTION STAGE

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CONSTRUCTABILITY DATABASE KNOWLEDGE MODEL AND GUIDELINES
OF INDUSTRIAL PLANT AT CONSTRUCTION STAGE

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requirements for the award of the degree of
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This research work is dedicated to:
my beloved mother and wife jefni
who I owe them so much for their inspiration and support and to
my children taufiq, faris,miftah and nadiya
who I had to turn down their entertainment just to find more time for this work

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ABSTRACT

Constructability is a common issue faced by the construction industry which is defined as the ability to construct effectively. The separation of design from procurement and construction in the traditional contracting system has led to a certain degree of isolation of the construction knowledge from design in construction projects. This contracting system has resulted in poor constructability implementation, thus exceeding time and cost of construction projects. This study aimed to provide a constructability database knowledge model and guideline for implementation of industrial plant at construction stage. The objective includes to identify the constructability problems, innovations, best practices and develop the constructability guidelines and database knowledge model. An extensive study was performed in five distinct phases including literature review, interviews, two stages of questionnaire surveys, and four case studies. The first questionnaire was distributed among headquarter of an organization and the second questionnaire was distributed among key personnel of four construction sites. Then four case studies were performed to provide a basis of constructability innovation, best practices, and method statement. Finally, a constructability guidelines and database knowledge model were developed for construction stage. The constructability model was developed based on the consideration both of United States of America and Australia Construction Industry Institute (CII) model. The guidelines developed for this research has referred to the American College of Cardiology tools and methods. Frequency, average index analysis and Wilcoxon rank test statistical techniques were used in this research to analyse the quantitative data. Two organization were selected to validate the findings. The results indicated that the lack of understanding on the overall constructability concept, the availability of lesson learned, and qualified personnel has prevented them from being more committed in implementing the constructability. Despite the above results, current constructability practices have had some benefits on projects' performance. Not only design-construction interface and early contractor's involvement were the main factors in improving project performance, but there are also possibilities for significant improvement at the construction stage. The application of this constructability guidelines and database knowledge model were implemented at the organization. It is recommended to improve constructability by adapting constructability concepts which have been developed in other countries but it is necessary to include the following considerations: appropriate construction methods, available resources and, optimum use of lessons learned and best practices. This research is limited on constructability problems, improvement and contracting using the traditional system of industrial plant at construction stage.

ABSTRAK

Kebolehbinaan merupakan isu yang biasa dihadapi oleh industri pembinaan yang definisikan sebagai kemampuan untuk membina secara efektif. Pemisahan rekabentuk daripada prokumen dan pembinaan dalam sistem kontrak tradisional telah menyebabkan terasingnya pengetahuan pembinaan daripada rekabentuk pada projek-projek pembinaan. Sistem kontrak ini telah menyebabkan kelemahan di dalam pelaksanaan kebolehbinaan, yang menjadikan projek pembinaan melebihi masa dan belanjawan. Kajian ini bertujuan untuk menyediakan model pangkalan data pengetahuan kebolehbinaan dan garis panduan untuk pelaksanaan daripada loji industri pada masa pembinaan. Objektif termasuk mengenalpasti permasalahan kebolehbinaan, inovasi, amalan terbaik, garis panduan kebolehbinaan dan model pangkalan data pengetahuan. Kajian yang mendalam telah dilakukan dalam lima fasa termasuk kajian literatur, temuduga, dua fasa soalselidik dan empat kajian kes. Soalselidik pertama yang diedarkan kepada ibu pejabat organisasi dan kajian soalselidik kedua diedarkan kepada personel utama daripada empat projek pembinaan. Selepas itu empat kajian kes dijalankan bagi menyediakan dasar kepada inovasi kebolehbinaan, amalan terbaik, dan pernyataan kaedah. Akhirnya, garis panduan kebolehbinaan dan model pangkalan data pengetahuan dibangunkan pada peringkat pembinaan. Model kebolehbinaan ini dibangunkan berdasarkan pertimbangan kepada model institut industri pembinaan (CII) Amerika dan Australia. Garis panduan pada kajian ini dibangunkan merujuk kepada alat dan kaedah daripada Kolej Jantung Amerika. Analisis frekuensi, indeks purata dan teknik statistik ujian tahap Wilcoxon telah digunakan pada kajian ini untuk menganalisa data kuantitatif. Dua organisasi telah dipilih untuk mengesahkan hasil penyelidikan ini. Hasil kajian ini menunjukkan kekurangan pemahaman terhadap keseluruhan konsep kebolehbinaan, perolehan daripada pengajaran-dipelajari dan personel utama yang berkecenderungan terhalang daripada lebih komited untuk melaksanakan kebolehbinaan. Meskipun dengan keputusan tersebut, amalan kebolehbinaan semasa telah memberikan manfaat kepada prestasi projek. Tidak hanya pada antaramuka rekabentuk-pembinaan dan penglibatan awal kontraktor merupakan faktor utama dalam penambahbaikan prestasi projek, tetapi juga ada kemungkinan penambahbaikan penting pada fasa pembinaan. Penggunaan garis panduan kebolehbinaan ini dan model pangkalan data pengetahuan telah dilaksanakan pada organisasi. Adalah dicadangkan untuk penambahbaikan kebolehbinaan dengan penyesuaian konsep kebolehbinaan yang sudah dibangunkan di negara lain, tetapi adalah penting untuk mempertimbangan: tatacara pembinaan yang sesuai, kesediaan sumber, penggunaan optima daripada pengajaran-dipelajari dan amalan terbaik. Penyelidikan ini terbatas kepada masalah kebolehbinaan, penambahbaikan dan penggunaan sistem kontrak tradisional daripada loji industri semasa peringkat pembinaan.

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LIST OF SYMBOLS

Avg. Ind.	-	Average Index
CO ₂	-	Carbon Dioxide
Std. Dev	-	Standard Deviation
a_i	-	constant expressing the weight given to i
x_i	-	variable expressing the frequency of response for $i= 1,2,3,4,5$
3D	-	Three Dimension

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Increased competitiveness in the construction industry requires improvement of a construction organization's capabilities. Many studies in quality improvement focus on project quality improvement technique and efficiency such as total quality management, value engineering, designability, contractibility, constructability, operability, maintainability and other quality improvement techniques (Trigunarsyah, 2001). Early involvement of construction knowledge and experience reduce the likelihood of creating designs that cannot be efficiently built, thereby reducing design rework, improving project schedule, and establishing construction cost saving (Russell, 1994b).

Many construction projects are awarded on a competitive basis using the traditional contract approach. In this approach, design (or engineering), procurement and contractor are engaged in separate contracts. The Business Roundtable (1982) and Tatum et al. (1987) presented that the contractors are usually not involved until the designs have been completed, this approach ignores opportunities of significant savings in both project cost and completion time that result from the careful interaction of planning, design, and engineering with construction. This division has been suggested to be responsible for poor constructability in construction projects (Griffith, 1984) and has been cited as a reason for projects exceeding budgets and schedule datelines (CIIA, 1992). A careful interaction of planning, design (or

engineering) with construction has indicated significant savings in both cost and time required for completing projects.

In the US, the CII (1998) has developed 17 Constructability Concepts, which are grouped under the three main phases of Project Life Cycle, viz. conceptual planning, design and procurement, and construction. Those concepts were based on the experience of the owners and contractors represented by the CII Constructability Task Force, and the findings of researchers directed by the CII Constructability task force. The main purpose of the concept is to stimulate thinking about constructability and how to make it work. The second CII Constructability Task Force appended three additional concepts, two for the planning phase and one for the design and procurement phases (Russell et al., 1992).

The concept of constructability in the US (or buildability in the UK) emerged in the late 1970s. It evolved from studies into how improvements could be achieved to increase cost efficiency and quality in the construction industry. It is an approach that links the design and construction process. It became the subject of a number of research works in the 1980s (Sidwell, 1996). Constructability is the capability of a construction project being constructed. A Constructability program is the application of a disciplined, systematic optimization of the construction-related aspects of a project during the planning, design, procurement, construction, test and start-up phase by knowledgeable, experienced construction personnel who are part of a project team, the program's purpose is to enhance the project's overall objectives (ASCE CM Committee, 1991). Constructability is also defined as the ability of project condition to enable the optimal utilization of construction resources (O'Connors, 1986b).

The constructability concept was born out of the realisation that designers and contractors see the same project from different perspectives, and optimising the project that requires the knowledge and experience of both parties be applied to project planning and design processes (Gibson, 1996). However, many owners, engineers, and contractors are still not aware of the potential benefits of improved constructability, the opportunities to reduce the schedule, improve the functionality of the final product, and reduce costs are lost when construction is separated from planning and engineering (CII, 1996).

The CII has developed 'Constructability Concepts' to stimulate idea about constructability and how to make it implement, the CII has also shown benefits of implementing constructability, especially in terms of project cost and schedule (Trigunarsyah, 2001). In implementing improvement in constructability, the study by the Australian Construction Industry Institute (Francis and Sidwell, 1996) suggests that it is important to consider the uniqueness of the construction industry in a specific country. The separation of design from procurement and construction in the construction process has led to a certain amount of isolation of the professionals from technical development in the construction industry (Jergeas, 1989; Haider, 2009).

In this study the constructability problems during construction due to the separation of design from procurement and construction, method statement, constructability innovation at project level, project lesson learned, best practices have been identified and investigated. A conceptual guidelines to improve the constructability implementation during construction stage was formulated. The result of this research provides a constructability guideline and constructability improvement model using web-based platform. This research focuses on constructability (or buildability) for implementation at project level during construction stage.

1.2 Background and Justification of Research

The traditional contracting system is a common contracting method used in Malaysia and Indonesia, the traditional approach to construction projects tends to create divisions between design (or engineering) and construction. Russel (1992a) reported in the UK and the US have suggested that this division has led to poor constructability in construction projects, resulting in projects exceeding budgets and schedule. Following these reports, research work in improving constructability was conducted both in the UK and the US which showed that improved constructability can lead to significant savings in both the cost and time required for completing projects and the CICE Task Force of the Business Roundtable has shown benefit-cost

ratios of 10:1 to 20:1 from incorporating construction resources into engineering using a planned constructability program (Trigunarsyah, 2001).

Later case studies by the CII have also indicated a benefit-cost ratio of 10:1 on projects implementing more formal constructability programs, it is believed that this ratio is an underestimation because it was based only on documented and quantified estimates of savings, a significant reduction in total project schedule is also identified as the result of improved project constructability, this case studies showed 5 to 10 per cent reductions in total project duration (Russell, 1992a).

In the UK, research in improvement in constructability stressed the design phase and the designer's ability to incorporate constructability, but no emphasis was placed on management systems and the involvement of owners and contractors. In the US, the constructability researchers placed emphasis on management systems and the involvement of owners and contractors. They considered constructability to be an integral part of the whole project life cycle. The Construction Industry Institute (CII), which is the leader in this area, has established 17 concepts of constructability and guidelines on programs for implementing constructability (Trigunarsyah, 2001).

Further research work on the implementation of constructability improvements has shown significant benefits in terms of project costs and schedules. However, it is important to consider the type of construction when implementing the CII's constructability concepts. Russell (1992b) suggested that there are differences in how and when specific constructability concepts can be applied, based on the facility delivery process or, in other words, on the type of the construction, i.e. residential, buildings, heavy engineering or industrial. The study by the Australian CII (Francis and Sidwell, 1996) went even further. Their starting point was that in implementing constructability improvements, it is important to consider the uniqueness of the construction industry in a specific country. The CIIA used the CII's constructability concepts as references and examined them against Australian conditions. Their research findings resulted in twelve principles that embody the overriding concepts of constructability. They represent what are considered as current good practices in constructability in Australia, and are designed to stimulate thought about constructability and its application within the Australian construction industry.

In Indonesia, most public work projects, including construction projects under government authority or under state-owned companies (BUMN), are awarded on a competitive basis using a lump-sum contract. Professional designers and constructors are engaged in separate contracts. The contractors are usually not involved until the designs have been completed. This division has been suggested to be responsible for the poor constructability of construction projects in Indonesia, leading to projects exceeding budgets and schedule deadlines. Furthermore, most project planning and design is prepared in the national capital, Jakarta. Infrastructure projects throughout the country, for example, are planned and designed in Jakarta. Similarly, many companies such as banks plan and design their branch offices in their head office in Jakarta, and contractors are not involved until after the contract has been awarded. Problems arise during construction where buildings or facilities cannot be built as planned and designed, or cannot be constructed efficiently. It is not uncommon that construction projects exceed budgets and schedules. With improved constructability both the cost and time required to complete projects are expected to be reduced (Trigunarsyah, 2001).

In the Malaysian Construction Industry, there is no distinction between practiced and unpracticed and between the known and the unknown requirement for enhancing constructability. This is due to mainly to the lack of reliable documentation of cases in which those requirements are applied or ignored (Nima, 2000). The construction industry in Malaysia is renowned for its lack of integration between design and construction (Mohd.Zin, 2004).

As suggested by the research findings in the US, Australia, Indonesia and Malaysia, implementation of constructability improvement has to consider the uniqueness of the construction industry in a specific country. Therefore, construction projects shall be studied to improve the constructability in Indonesian and Malaysia.

From the above discussion, it is clear that there is a need to improve the constructability. This research is a continuity of the constructability research from Trigunarsyah (2001), and Bakti (2002) in Indonesia and this organization for Industrial Plant project. This research is the incremental implementation of constructability. It start from awarness of the personnel involvement, and construction

method at construction stage. This approach will mobilize the organization to implement constructability formally for all stages of design, procurement and construction.

Due to the separation above design and construction in the traditional contracting system the designs that are being produced have minimum construction input. This has resulted in a lot of problems which are related to execution at the construction stage. On the other side, the lack of construction experiences and procedures especially in construction method has resulted in poor constructability implementation that lead to project exceeding budget and schedule. To minimize the gap, this research started to implement the constructability from the construction methods as “a trigger”, followed by its adoption by the organization for implementing the constructability concepts at all stages of the projects.

1.3 Aim and Objectives of the Study

This study aimed to develop constructability database knowledge model and guidelines for the constructability implementation of industrial plant at construction stage. The study focussed on the projects that were tendered using the traditional contracting system. The innovation and improvement method if implemented would minimize or overcome the construction related problems.

To achieve the above aim the following objectives have been identified:

1. To identify the constructability problems at construction stage due to separation of design from procurement and construction;
2. To identify and establish the constructability innovation process at project development;
3. To identify and establish the project best practices from the lesson learned process related to constructability;
4. To establish the constructability guidelines at construction stage; and
5. To develop the constructability database knowledge model using web-base platform for construction stage.

1.4 Research Methodology

Research methodology guides the researcher in the process of collecting , analyzing, interpreting and observing. It is a logical model of proof that allows researchers to draw inferences concerning relations among the variable under investigation. To respond to the aim and objectives of this research, Figure 1.1. outlines the methodology of this study.

There are five distinct phases of the study: phase 1 involves literature review and preliminary data; phase 2 and 3 deals with data collection and analysis using interview, two stage of questionnaire survey 1 and 2; phase 4 involves the case studies and, phase 5 comprises developing the constructability guidelines and database knowledge model. Detailed discussion of the research methodology is given in Chapter-4.

1.4.1 Phase 1: Literature review and Preliminary Data

Phase 1 is aimed at reviewing information on construction implementation, problems, constructability/ buildability principles, constructability improvement method, and previous research that has already been conducted at the organization, to establish the problem area. Interviews were performed for the study on the organization.

1.4.2 Phase 2: Questionnaire Survey I

In order to determine the constructability problems, potential and actual benefit of constructability, the following survey and data collection were performed:

1. A self administered questionnaire survey was used to acquire the perception of the key personnel of the project (owner and contractor) on the implementation of constructability at construction stage.

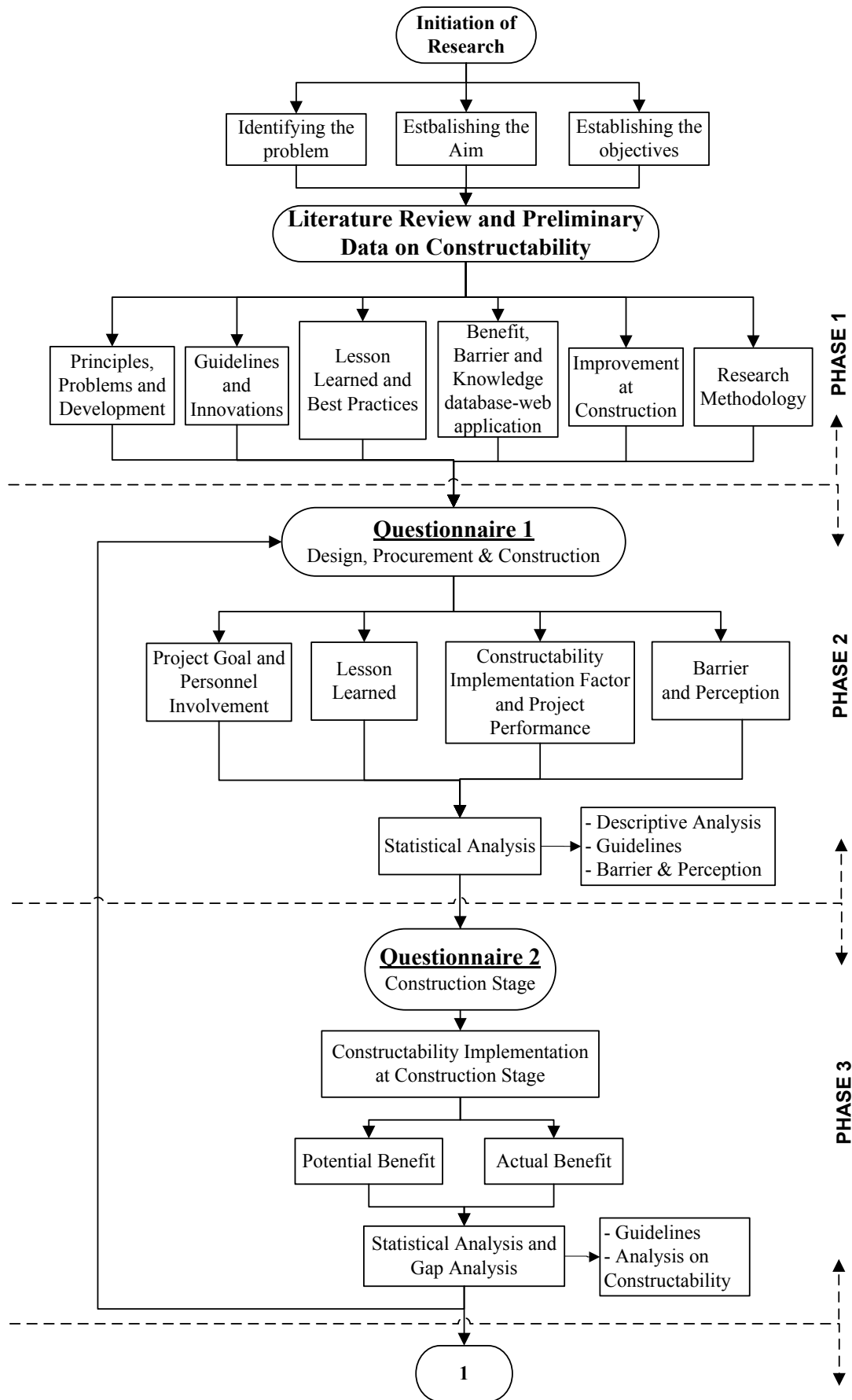


Figure: 1.1: Research Methodology

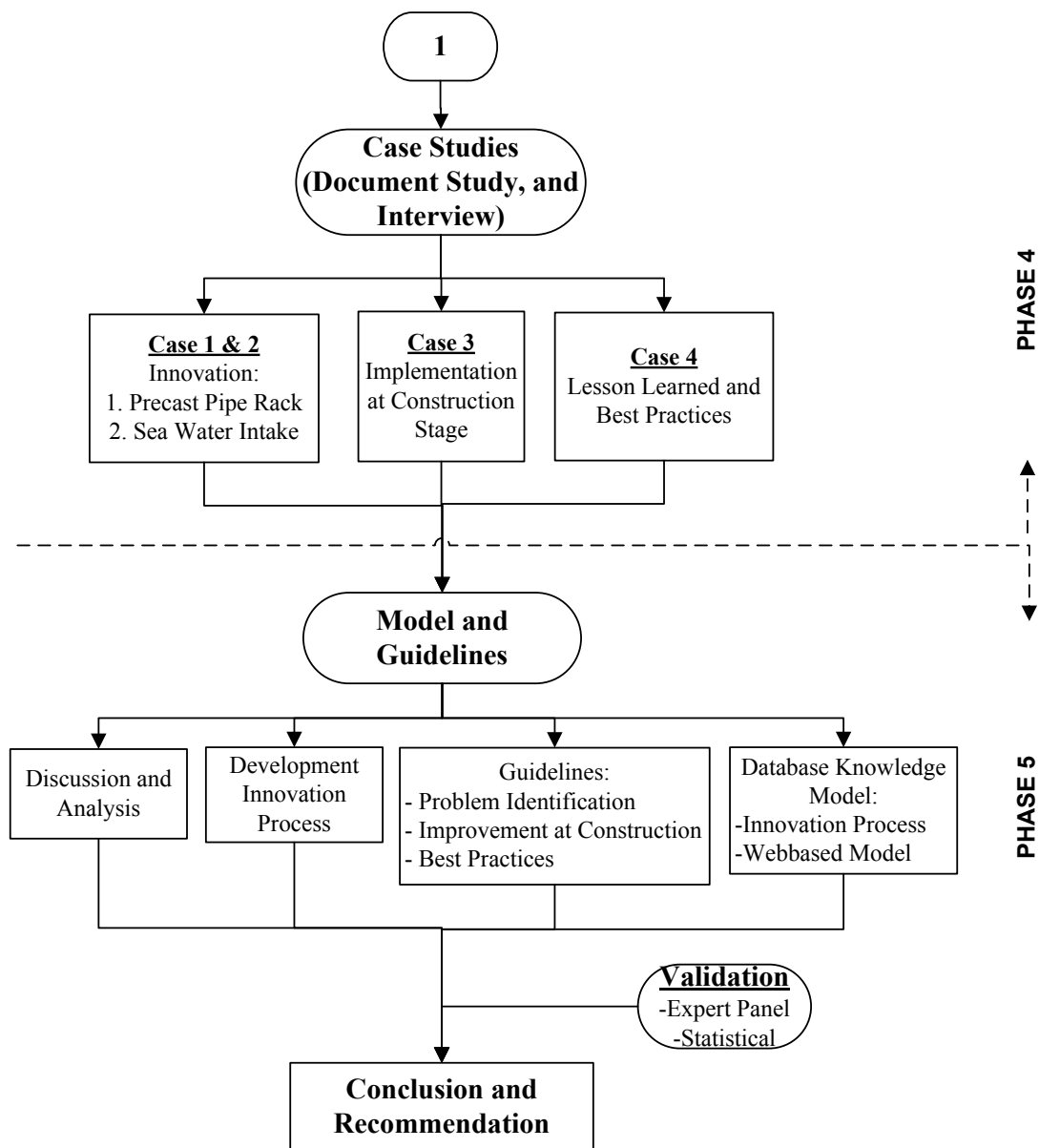


Figure: 1.1: Research Methodology (continued)

- The case studies were used to support the constructability guidelines, documented innovation process and database knowledge model.

The first questionnaire survey was focussed on the understanding of the various disciplines on implementation and improvement in constructability and its impact/ problems on project performance. The questionnaires were distributed among three key personnel of construction projects namely engineering team, procurement

team and construction team. The questionnaire survey was conducted mostly in the organization main office. Data obtained from the survey was tested in a series of statistical tests which include validity, reliability, normality data test, frequency analysis, average severity index, and non parametric test using SPSS software package.

1.4.3 Phase 3: Questionnaire Survey II

Similar to the above survey, the second questionnaire survey more focused on constructability implementation at construction stage and also the gap between potential and actual benefit of constructability implementation. This second questionnaire survey was distributed to the four (4) main industrial plant projects of organization in Malaysia and Brunei that used traditional contracting system.

1.4.4 Phase 4: Case Studies

Case studies were used to investigate the implementation of constructability improvement in the organization. This case study aimed to support the questionnaire survey result and to answer the fourth and fifth of the research objectives. There are selected four case studies in this research.

1.4.5 Phase 5: Models Development

The analyse results obtained from Phase 1, 2, 3 and 4 formed the basis for development of constructability guidelines, innovation process and database knowledge model using web-base platform.

1.5 Scope of the Study

This research focused on constructability (or buildability) for implementation at project level during construction stage. The specific research was carried out on project execution at the organization related to constructability implementation, improvement and innovation at construction stage. The first questionnaire was developed to obtain the implementation of the constructability practices for all stages of process from the design, procurement and construction. The second questionnaire on the other hand focussed on the current implementation of the project at the construction stage to identify the gap of the potential and actual benefit of the constructability implementation. This research limited on: first, the type of the projects carried out based on the traditional contracting system i.e. the design was separated from procurement and construction; second, narrowing at the construction stage only and; third, the project type was Industrial Plant. On the other hand, the case studies were performed to get an insight on the real implementation and to explore the project document to be proposed as guidelines and knowledge database to the organization. As such constructability improvement for other phases throughout the project life cycle are not covered.

1.6 Significance of Research

The separation of design (or engineering), procurement and construction leads to poor of project performance. The over design, drawing inaccuracy and delay are part of the poor project performance related to separation of design, procurement and construction. The findings of this research show a significant impact can be achieved from constructability improvement at construction stage.

The constructability innovation had the documented cost saving and reduced the time. The qualitative benefits of constructability innovation include: reduction of time schedule; increased focus on common goal; increased understanding of purpose/ effect of individual involvement; increased commitment from team member;

improved quality and site accessibility; safety enhancement; and better control of risks.

The main contribution of this study to the body of knowledge falls under the following aspects: first, the study give emphasis on identifying the constructability problems due to traditional contract and support of the constructability theory and practice; second, to provide and establish constructability innovation process, guidelines and database knowledge model using web-base platform to the organization and construction industry. This research would implement constructability from the construction methods as “a trigger”, followed by its adoption by the organization to implement constructability at all stages of the projects.

1.7 Structure of the Thesis

This thesis consists of nine chapters. A review of the relevant literature is given in Chapters 2,3, and 4. To achieve the aim of this research, the thesis starts with an overview of the constructability principles and improvement in Chapter 2, This chapter begins with a discussion of the definition of constructability. This is followed by a description of constructability principles, constructability development, constructability implementation program, improvement and innovation. The principles of constructability suitable for implementation were referred particularly from publication of the Construction Industry Institute (CII) of US, Australia, Singapore and Construction Industry Research Information Association (CIRIA) of UK. Other important sources of reference included journals and conferences papers.

Chapter 3 then discusses constructability improvements in construction stage and also discusses the common problem of separation of design from construction resulting from the current construction process, particularly from the selection of project delivery approaches. This division has led to poor constructability of projects, which has been suggested as a reason for projects exceeding budgets and schedule.

Chapter 4 describes the research methodology adopted in the study. This Chapter sets the concept of the research that leads to the establishment of the methodology to answer the objectives of the research. Methods for answering these questions were then selected and discussed. The first method assessed current constructability practices using a questionnaire survey distributed to the organization, i.e. the engineering, procurement and construction division of the organisation. The second questionnaire focussed on the project using traditional contracting system at construction stage. The respondents were selected from the key construction personnel at project site. This chapter also reviews the analytical methodologies and statistical analysis used in this research.

Chapter 5 gives details of the questionnaire survey, and the results obtained. The second method used case studies to provide the basis for achieving the fourth and fifth research objectives. The selection of the case study projects, the work done on them and the results obtained are described in Chapter 6.

Chapter 7 discusses the constructability guidelines. This will lead to the conclusions of this research, the constructability knowledge model using web-base platform which are presented in Chapter 8.

Finally Chapter 9 concludes the research and brings forward recommendations for future studies.

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