A CONCEPTUAL MODEL TO IMPROVE BUILDING COMMISSIONING IN CONSTRUCTION PROJECTS: CASE STUDIES OF A PUBLIC INSTITUTION OF HIGHER LEARNING IN MALAYSIA

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2013

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THESIS SUBMITTED IN FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

FACULTY OF BUILT ENVIRONMENT
UNIVERSITY OF MALAYA
KUALA LUMPUR

2013

UNIVERSITY OF MALAYA

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Registration/Matric No:	BHA 090008
Name of Degree:	Doctor of Philosophy
Title of Dissertation ("this work"):	A Conceptual Model to Improve Building Commissioning in Construction Projects: Case Studies of a Public Institution of Higher Learning in Malaysia
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ABSTRACT

Commissioning is a systematic process of ensuring all building facility systems perform interactively in accordance with the design documentation and intent. Commissioning begins with planning and includes design, construction, start-up, acceptance and training, and should be applied throughout the life span of the building. Commissioning is usually misunderstood as a process performed after the completion of construction. Nevertheless, in the Malaysian construction industry, there are many different perceptions on building commissioning. This discrepancy on the interpretation of building commissioning by consultants and contractors as compared with the available definitions of building commissioning has led to misunderstanding of building commissioning concept in the Malaysia context. This problem is further aggravated when contractors and consultants presume that unattended problems in the beginning of a project can be mended in the commissioning phase. As such, questions will arise on whether this interference of unattended problems at the beginning of a project life-cycle will affect the planned commissioning and the timely delivery of the project.

Building commissioning is the key to quality assurance in more than one way as it prevents problems from developing, anticipates and regulates system interactions, and implements a systematic method of meeting the buildings mechanical, electrical, and control requirements. However, detail research on project commissioning is relatively small in comparison to other research areas of project management such as project planning, control, success measurement, and risk assessment. This study aims to explore the current scenario of building commissioning in the Malaysian construction industry. To achieve this research aim, the objectives of this study are defined as: 1) to redefine the scope and understanding of building commissioning from the contractors' and consultants' perspective; 2) to identify problems during commissioning and the relationships of these problems with other phases of the project life-cycle; 3) to determine the underlying causes of identified commissioning problems; 4) to measure the importance of building commissioning and its effect on project completion by using Earned Value Analysis; and 5) to develop a conceptual model to improve building commissioning for construction projects in the public institution of higher learning in Malaysia. Case studies from a public institution of

higher learning in Malaysia were selected, as the current process of building commissioning for buildings construction on campus for public institutions of higher learning is generally inefficient.

The conceptual model aims to provide a better understanding on building commissioning for the Malaysia context and by eliminating this unattended problem, the planned duration for commissioning will not be affected and indirectly will aid the improvement of building performance. This study also intends to generate a guideline for the construction practitioners on the common activities of building commissioning that needs to be planned even during the construction stage.

ABSTRAK

Pentauliahan ialah satu proses yang sistematik untuk memastikan semua sistem kemudahan bangunan telah dilaksanakan secara interaktif sejajar dengan dokumentasi dan niat reka bentuk. Pentauliahan bermula dengan perancangan dan termasuk reka bentuk, pembinaan, “start-up”, penerimaan dan latihan, dan sepatutnya digunakan sepanjang jangka hayat bangunan. Pentauliahan biasanya ada disalahertikan sebagai satu proses yang dilakukan selepas penyiapan pembinaan. Walau bagaimanapun, dalam industri pembinaan Malaysia, terdapat banyak persepsi-persepsi yang berbeza tentang pentauliahan bangunan. Perselisihan di dalam penafsiran pentauliahan bangunan oleh konsultant dan kontraktor apabila diperbandingkan dengan definisi pentauliahan bangunan telah mencetuskan salah faham tentang konsep pentauliahan bangunan dalam konteks Malaysia. Masalah ini diperhebatkan lagi apabila konsultan dan kontraktor beranggapan bahawa masalah-masalah yang tidak ditangkap pada permulaan satu projek boleh diperbaiki semasa fasa pentauliahan bangunan. Oleh itu, persoalan akan timbul sama ada gangguan daripada masalah-masalah yang tidak ditangkap pada awal kitaran hayat sesuatu projek akan menjejaskan perancangan untuk pentauliahan bangunan dan penyiapan projek mengikut tempoh yang ditetapkan.

Pentauliahan bangunan merupakan kunci kepada jaminan kualiti melalui lebih daripada satu cara dimana ia mencegah masalah-masalah daripada berkembang, menjangka dan mengatur interaksi sesame sistem, serta melaksanakan satu kaedah yang sistematik untuk mengecapi keperluan-keperluan bangunan dari segi mekanikal, elektrik, dan kawalan. Walau bagaimanapun, penyelidikan yang terperinci di dalam pentauliahan projek adalah agak kecil apabila diperbandingkan dengan bidang penyelidikan pengurusan projek yang lain seperti perancangan projek, pengawalan, ukuran kejayaan, dan penilaian risiko. Kajian ini bertujuan untuk meneroka senario semasa untuk pentauliahan bangunan dalam industri pembinaan di Malaysia. Untuk mencapai tujuan penyelidikan ini, objektif-objektif kajian adalah seperti: 1) mendefinisikan semula skop dan pemahaman tentang pentauliahan bangunan daripada perspektif kontraktor dan konsultan; 2) mengenalpasti masalah-masalah semasa pentauliahan bangunan dan perhubungan masalah-masalah ini dengan kitaran hayat fasa-fasa projek yang lain; 3) menentukan punca-punca kepada

masalah-masalah pentauliahan bangunan yang telah dikenalpasti; 4) mengukur kepentingan pentauliahan bangunan dan kesannya terhadap penyiapan projek dengan menggunakan “Earned Value Analysis”; dan 5) untuk membangunkan satu model konsep bagi meningkatkan pentauliahan bangunan untuk projek pembinaan di institusi pengajian tinggi awam di Malaysia. Kajian kes daripada salah satu insitusi pengajian tinggi awam di Malaysia dipilih kerana proses semasa untuk pembinaan bangunan di kampus untuk institusi pengajian tinggi biasanya adalah tidak efisien.

Model mengkonsepsikan ini bertujuan untuk memberi satu pemahaman yang lebih baik tentang pentauliahan bangunan di konteks Malaysia dan dengan menghapuskan masalah tidak dilayan ini, tempoh yang telah ditetapkan untuk pentauliahan bangunan tidak akan terjejas dan secara tidak langsung akan membantu dalam mempertingkatkan prestasi pembinaan. Kajian ini juga telah menjanakan satu garis panduan bagi pengamal-pengamal di dalam industri pembinaan tentang aktiviti-aktiviti pentauliahan bangunan yang perlu dirancang walaupun semasa peringkat pembinaan.

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to all those who make it possible for me to complete this thesis. I am deeply indebted to my supervisor, Professor Dr. Hamzah Abdul Rahman, whose help, stimulating suggestions and encouragement helped me throughout the research and the writing of this thesis. His understanding, encouragement and guidance have provided a good basis for the presentation of this thesis. His ideas and concepts have made a remarkable influence on my knowledge in doing research. My sincere gratitude and appreciation for his unlimited support, advice, motivation, and trust in conducting this research.

I am grateful to the Ministry of Higher Education and University of Malaya for awarding me a scholarship to complete this research. I also wish to express my warmest and sincere thanks to the members of the Project and Facilities Management (PFM) group who have supported me and gave me tremendous ideas to improve my research especially Dr. Samiaah M. Hassen Al-Tmeemy and Dr. Ali Mohamed Alashwal. Special thanks to all of them who have given me their support and valuable ideas.

I owe my most sincere gratitude to all the interviewees who had given their precious time to participate in this research by providing useful response in completing this research. Without their valuable advice and friendly help, this research would not have been completed successfully.

I would like to give my special thanks and deepest gratitude especially to my dearest beloved mother for her understanding, patience, love and continuous support throughout this period of time. Without her encouragement and understanding, it would have been impossible for me to finish this research. My special dedication to my dearest mother, no matter where she is, she will always be in my heart forever.

DEDICATION

Especially dedicated to
my dearest beloved mother for her invaluable support, motivation and love.

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INTRODUCTION

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INTRODUCTION

1.1 Introduction

This chapter is to provide an overview and outline of the entire research as shown in Figure 1.1. A brief review of building commissioning in the construction projects, problem statements and objectives of this research are presented. The research aim and objectives are then correlated to answer the research questions against which the outcomes of the research can be assessed and generated. Subsequently, it is vital to outline the significance of the research and to identify the research gap. Lastly, this chapter describes brief research methodology employed, organization of the thesis and delineate limitations of the study.

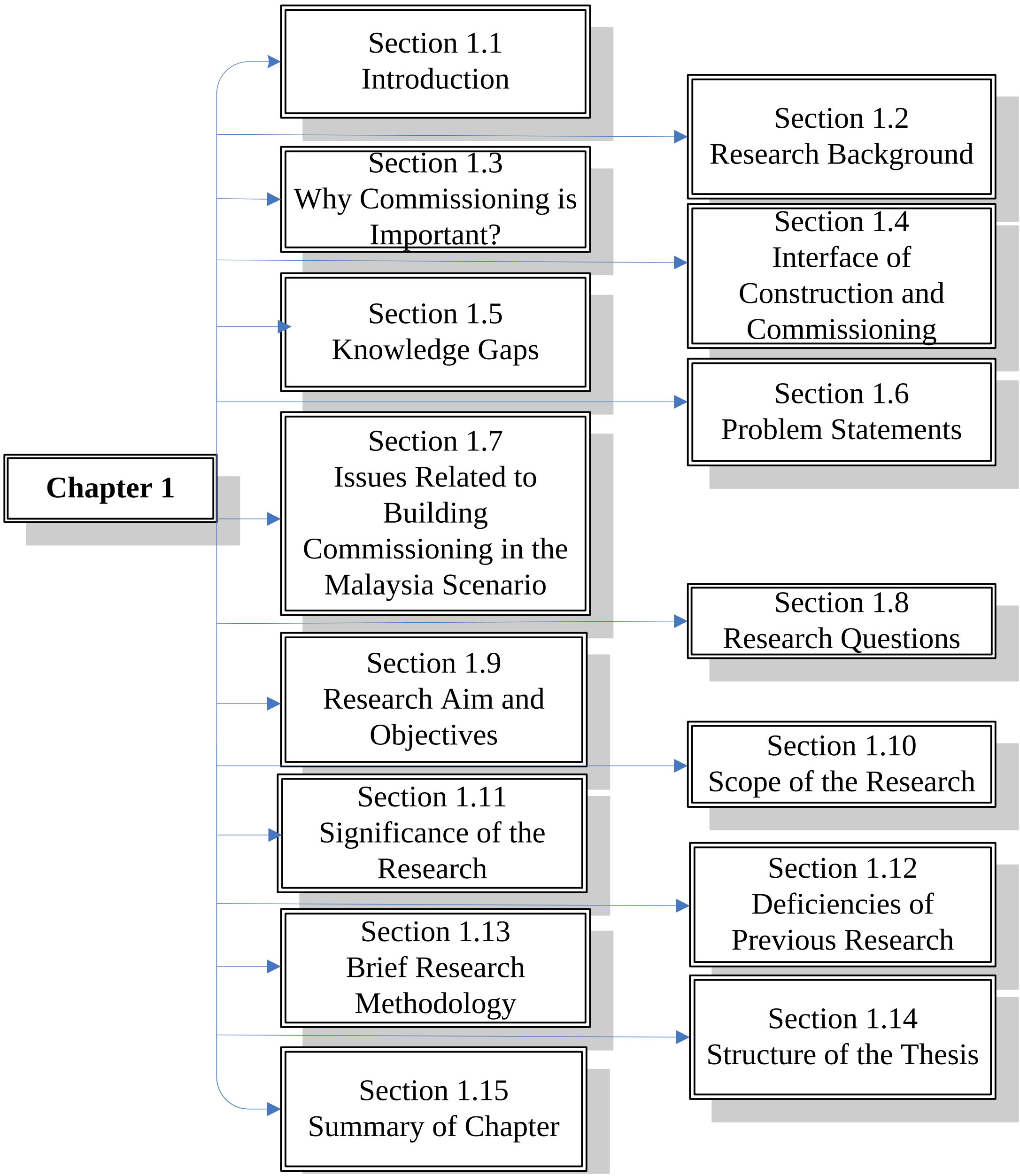


Figure 1.1: Outline of Chapter 1

1.2 Research Background

Generally, the Malaysian construction industry is divided into two main areas which are general construction and special trade works. General construction consists of residential construction, non-residential construction and civil engineering construction. The latter is special trade works, which embraces activities such as metal works, electrical works, plumbing, sewerage and sanitary works, refrigeration and air-conditioning works, painting works, carpentry, tiling and flooring works and glass works.

Although the construction industry contributed only around 3% to the Gross Domestic Product (GDP) in the year 2010, it makes up an imperative part of the Malaysian economy due to the interaction with other industry branches such as the mechanical engineering or the metals processing industry or the tourism sector. The total value of construction work done for the third quarter of 2012 increased slightly by 0.3% from an earlier quarter (RM20.3 billion) to record RM20.4 billion (Department of Statistics Malaysia, 2012). Thus, the construction industry can be portrayed as a substantial economic driver for Malaysia. The vital role of construction industry as an economy contributor recognizes the need to address typical shortfalls of the building industry where it relates to the need for proper commissioning. As such, the issues related to building commissioning in the Malaysian construction industry is addressed to spur growth in the construction sector.

Building commissioning is to ensure that a building owner gets the quality of facility that is expected and deserved. Although the concept of commissioning is straightforward, the building commissioning process can be complex, involve numerous and continually changing players, and span the full life of the building delivery process (Grondzik, 2009). Commissioning is a systematic process of ensuring that all building facility systems perform interactively in accordance with the design documentation and intent. Commissioning begins with planning and includes design, construction, start-up, acceptance and training, and should be applied throughout the life of the building (Djuric & Novakovic, 2007). Commissioning includes installing the equipment, checking the equipment is in good condition, making sure everything conforms and is in accordance with specifications (Kirsila, Hellstrom & Wikstrom, 2007).

American Society of Heating, Refrigerating, Air-Conditioning Engineers (ASHRAE) defines commissioning as the process of ensuring that systems are designed, installed, functionally tested and capable of being operated and maintained to perform in conformity with the design intent. Commissioning has a systematic approach. It starts in the programming phase and ends when the building is turned over to the owner (Turkaslan-Bulbul & Akin, 2006).

Commissioning is not just turning up the day after construction is completed and pressing of the big green button (Killcross, 2012). Nowadays, buildings are no more a collection of individual generic components and parts. All of these separated parts must come together as an inorganic organism, which responds to its owner's changing needs and its environment, with little or no intervention by the building's occupants, as this is what they were led to believe they were getting (Yago, 2005). But in reality, do they get what they were led to belief they were getting?

Commissioning and handing over is described as a process rather than a check point. In essence, commissioning should be considered a less problem solving process, but instead as a preparing process for the handing over of the installation to the customer (Dvir, 2005). Kjelgaard (2005) firmly trusted the process of commissioning because it is the only way to achieve and maintain optimum operating efficiency for new buildings.

In a simple analogy, building commissioning is like an I Phone where the functions of phone, I Pod and camera are integrated together and the total integration result complies with all the desire, design and specifications of a customer (Isaacson, 2011). As illustrated in Figure 1.2, building commissioning integrates all these services together as a functioning whole in conformance with the design intent.

Figure 1.2: Analogy of Building Commissioning with I Phone

In a project, building commissioning which falls under project termination constitutes a significant part which often overlooked by the project managers (De, 2001). The project termination process is not an easy task and it is to be planned, budgeted and scheduled like any other phase of the project life cycle (Dvir, 2005). Avots (1969) conducted a theoretical study to understand the reasons for project failure and concludes that the unplanned project termination is among the main reasons for failure. Hence, this study focuses on the issues during project termination by looking into the problems of building commissioning.

1.3 Why Building Commissioning is Important?

Based on indications from previous researcher (Stuckenbruck, 1986; Pinto & Slevin, 1988; Dvir & Shenhar, 1992; Cooper & Kleinschmidt, 1987), measures of success are categorized into three clusters to access the overall success of the project. "Meeting design goals" are among the clusters identified which referred to the initial contract, agreement or commitment. The operational and technical characteristics of the end product, the time taken to deliver it, and the cost involved are specified under such commitment. Hence, to fulfill this commitment, this research is conducted to enhance operational and technical characteristics of the end product through building commissioning.

According to U.S. Department of Energy, building commissioning is the key to quality assurance in more than one way; it prevents problems from developing, anticipates and regulates system interactions, and implements a systematic method of meeting the buildings mechanical, electrical, and control requirements. A thorough commissioning effort results in fewer installation call backs, long-term tenant satisfaction, lower energy bills, avoided equipment replacement costs, and an increased profit margin for building owners.

The commissioning process is chosen as the central focus of the delivery chain as it typically constitutes the end phase from a supply side point of view. It can be considered as the point in the delivery chain where all the parts of the project come together and should be verified as a working whole (Dvir, 2005). Therefore, the whole chain of activities–ranging from sales and design to handing over and warranty – has been addressed (Kirsila, Hellstrom & Wikstrom, 2007).

1.4 Interface of Construction and Commissioning

As shown in Figure 1.3, to ease the information loss and interface problem, the project information loses considerably between different project phases, such as concept phase, design phase, construction phase, and occupancy phase even within the construction project itself. The loss of information during the last phase, occupancy phase, is the most significance compared to other phases (Hu, 2008).

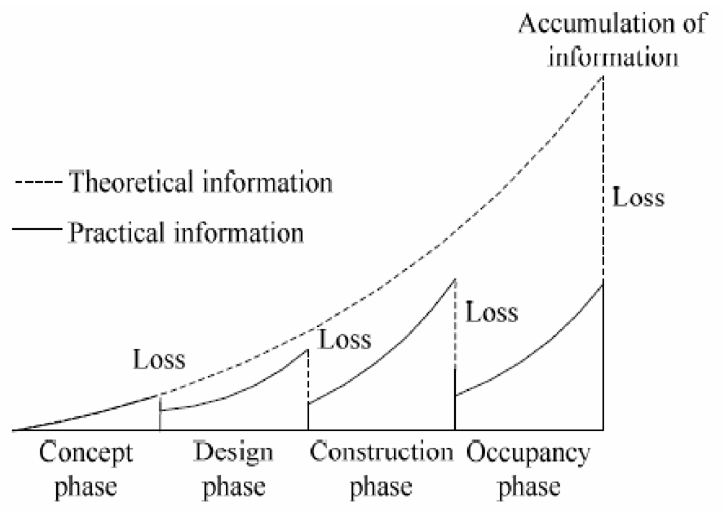


Figure 1.3: Information Losses in Construction Project Lifecycle
(Source: Hu, 2008:373)

As an intermediate process between construction and occupation or operation, testing and commissioning which was carried out during handing over of the project, integrate all the delivery systems for the first time. Testing and commissioning took place from the transition of construction phase to occupation or operation phase. Therefore, the integration of all these items would be of necessity to ensure building performance and functionality in handing over of the building to the client. Professional inconsistencies at the project design and construction interface are identified by many researchers. These researchers such as Assaf and Al-Hammad (1988), Al-Hammad and Assaf (1992), Al-Hammad (2000), Al-Yousif (2001) and Arain (2002) have found that these inconsistencies can be deemed as looking at projects from front forwards. In conjunction with this, little research has been done to identify inconsistencies at the construction and commissioning interface which implies a necessity to look at projects from the end backwards. This will enable clearer visualization of outstanding works that hinder the project handing over. Therefore, integration of construction and commissioning are needed to ensure good interfaces for achieving customer satisfaction when handing over the project.

It also could be argued that most, if not all, measurable success factors from the subsequent phases of the project can be related back to the initial success variable project mission—that is, clearly defined goals and direction (Hamilton, 2003). Eliminating the existence of inconsistencies can enable projects to be completed successfully. Inconsistencies at the interfaces between parties can either result in delay in project duration, compromise on quality, or increase in cost. Considering these disagreements which can ultimately affect any construction project, there is a need to institute better and comprehensive solutions to coordinate activities at the interface. It is important to determine the potential causes of inconsistencies in the project life-cycle. These potential causes of inconsistencies can hinder the progress of a building project substantially (Arain, Low & Assaf, 2006).

To create multi-product solutions for customers, companies must therefore work through lateral networks. This networks which simultaneously face different forms of structural complexity and different types of interdependencies among interacting units (Galbraith, 2002; Danese, Romano & Vinelli, 2004). The same applies to the construction project; high interaction is utmost essential amongst the project life-cycle and also amongst the parties involved.

It is quite obvious that the interfaces, no more than the products themselves, can be standardized or even specified to a high degree in project business where the products often can be classified as complex products and systems (Hobday, 1998). As the customers often experience uncertainty receiving the installation, these aspects of commissioning and handing over (or involvement of client into the project before beginning of the actual commissioning) need consideration prior to commissioning. This entails the urge for looking at projects from the end backwards, where it all starts from a customer need. This can be compared to the ‘V-model’ used in systems engineering (International Council on Systems Engineering, 2004). The social integration again ensures the complex interfaces between suppliers and customers which form the basis for achieving a satisfied customer (Kirsila *et al.*, 2007).

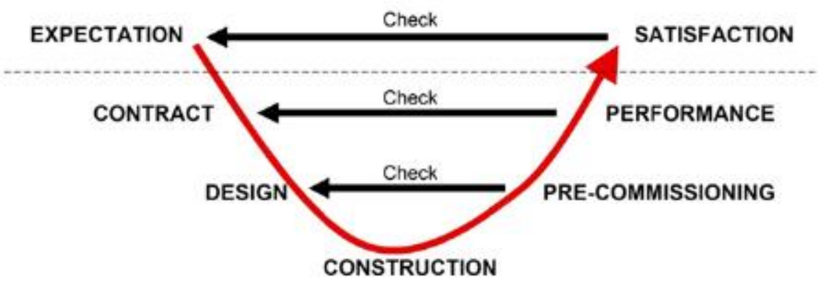


Figure 1.4: The V-Model Applied to Customer-Oriented Commissioning
(Source: Kirsila et al., 2007: 179)

1.5 Knowledge Gaps

Commissioning is directly related to the building operational efficiency (Kjelgaard, 2005) and it involves team effort that includes not only the commissioning authority but also many others associated with the design, construction, and future operation of the commissioned systems (Ellis, 2010). Commissioning fills the gaps of conventional maintenance programs and addresses the anomalies that form the achilles' heel of planned preventive maintenance (Wilkinson, 2011) but it failed to depict the exact understanding and purpose of building commissioning. According to ASHRAE Guideline 1-1996 (1998), improved understanding of the commissioning process can provide commissioning savings. This savings is resulted from the understanding of the purpose of the facility and the reason for its existence to serve the end-user in commissioning. It is seemed that the basic nature of the project definition process is poorly understood and modeled as compared with the later stages in project management. This has unavoidably led to unsatisfactory practical implementation of the project (Kalle, 1999). Project definition is defined as the process prior to final investment decision-making. In a somewhat familiar term this process usually covers the preparation of project proposal, project initiation, design and appraisal. The process incorporates also the necessary decision-making (Turner, 1993; Gibson, Kacczmarowski & Lore, 1995). Moreover, there are no researches which have been done in Malaysia in relation to building commissioning. Subsequently, the first research gap is the need to determine the perceived understanding of building commissioning from the contractors' and consultants' perspectives in the Malaysian construction industry.

Basically, there are two opposing views on commissioning. Some believed that any services related to the commissioning process should be provided by a third party. The design and construction management teams believed that if anyone from the design or construction team is responsible for commissioning, there will be conflict of interest. Others believed that the commissioning scope of work is already included in the base contract, and it is just a matter to enforce the contract documents. However, the author strongly believed that the standards for commissioning process can be streamlined significantly without negatively affecting the process, regardless of whether a third party agent is appointed (Kjelgaard, 2005). Commissioning is perceived by many as a process to solve problems for project, rather than the start-up of the equipment, or the preparation for the handing over to the client (Kirsila *et al.*, 2007). Some people perceive commissioning as a luxury and "added" cost in which it is only a measurement or barometer of the cost of mistakes promulgated by other parties previously involved in the design, construction, or operation of buildings (Mills, Bourassa, Piette, Friedman, Haasl, Powell & Claridge, 2005). The presence of this ambiguity further highlighted the need to re-define the perceived understanding of building commissioning from the contractors' and consultants' perspective for the Malaysian construction industry.

If someone is to ask five people for their definitions of commissioning, someone might get five different answers. And there are many opinions on how best to deliver commissioning services (Kjelgaard, 2005). This argument by Kjelgaard (2005) is paralleled with study conducted by Dvir (2005). In Kjeelgard's study, a commissioning manager opined that if all the X engineers of his companies are asked to define commissioning, someone will get X different answers (Dvir, 2005). Limiting the investigation of building commissioning solely relying on these available definitions of building commissioning may not result in a holistic view that reflect the current scenario of commissioning for the Malaysian construction industry. Therefore, conceptualizing the model of building commissioning classifications is utmost important to achieve a shared opinion and understanding on building commissioning.

Problems due to building performance are pervasive. Deficiencies, such as construction defects, design flaws, malfunctioning equipment, and deferred maintenance, have a host of consequences, ranging from equipment failure to compromised indoor-air quality and comfort. Building performance problems can also cause unnecessarily elevated energy use or the underperformance of energy-efficiency strategies (Mills *et al.*, 2005). However, study conducted by Mills *et al.* (2005) failed to disclose problems of building performance as a lesson learned for conduct of commissioning in future. For existing building to achieve better efficiency, commissioning approaches quality of facility-operations as a mandate for uniform improvements (Wilkinson, 2011). More specifically, there is an obvious shortage of empirical studies to address commissioning problems for building constructions. The second knowledge gap opines the need to determine the causes for these commissioning glitches for construction projects.

In practice, the scope of commissioning rarely covers all the methods in energy savings for building systems. Commissioning usually only cover the main important energy saving methods and these recommendations are implemented to optimized cost effectiveness. Apart from that, significance first-cost and ongoing non-energy benefits are rarely quantified, but these are important drivers to carry out commissioning and significant among the perceived benefits to reduce change orders and to prevent premature equipment breakdown (Mills *et al*., 2005). It was not in the scope of a research conducted by the U.S. Department of Energy through Lawrence Berkeley National Laboratory (LBNL) about how each project adhered to existing building commissioning (Effinger & Friedman, 2010). Supposedly, building commissioning is an emerging form of quality assurance able to detect and remedy most deficiencies (Mills *et al*., 2005). However, a growing concern with the commissioning industry is the deterioration of the quality of commissioning (Tseng, 2005). According to Turkaslan-Bulbul and Akin (2006), commissioning is often treated as one-time operation. Building information produced during the commissioning process is seldom used as a reference for maintenance activities during the occupation phase.

Furthermore, there is lack of information on the adherence of this project with the scopes of commissioning. Therefore, this study attempts to fill this gap by identifying problems that arise during commissioning. These problems whether is due to commissioning-related problem or non-commissioning related problem, will aid future projects in the Malaysian institutions of higher learning to adhere with the scopes of commissioning.

The research body on project termination is relatively small in comparison to other research areas of project management such as project planning, control, success measurement, and risk assessment (Dvir, 2005). Buell (1967) in an early article claims that the main reason for so little information on the subject is simply because it is hard to spell out specific guidelines for termination of projects. Most research on project termination focused on reasons for premature termination and not on the introduction of the outcomes of successful projects into use (Dvir, 2005). There is almost a unanimous agreement (Meredith & Mantel, 2000) that the termination stage of the project rarely has much impact on technical success or failure of the project. It has though, a great deal to do with residual attitudes toward the project – ‘‘the taste left in the mouth’’ of the client, senior management, and the project team, which is important for future projects, but of course have no impact on the current one (Dvir, 2005).

While many explanations of the complexities in terminating projects effectively are plausible, two reasons can be named: 1) the design and construction professions tend to try for perfection and want the job to be perfect before moving on, when a standard less than perfection is sufficient; and 2) The project environment is familiar and comfortable, so there is a reluctance to “let go” and move to the next project, especially if there is no immediate prospect for a next project. Thus, the construction manager must deal with both the tendency to look beyond the project termination activities and move on to the next project. This will lead to negligence of this phase and the reluctance to terminate the project. Subsequently, resulting in inefficiencies in executing many activities required at this phase.

1.6 Problem Statements

Problem statement involves a succinct statement of the questions or issues that is to be investigated with the goal of finding an answer or solution (Cavana *et al.*, 2001: 62). In relation to the knowledge gaps in the preceding section and the problems stated above, three research problems have been identified for this research. The first research problem is the overlook and negligence of project commissioning as an integral part of the project life-cycle. Only a few researchers shared that project commission, when the projects outcome is handed over to its customers for use, is perceived as an essential part of the project life-cycle (Pinto & Slevin, 1987; Tishler, Dvir, Shenhar & Lipovetsky, 1996; (Bennett, 2003). This claim is further supported by Rubinstein, Avery, Jennings and Blanc (1997) who have identified that some of these flaws for lighting controls can be traced to inadequate commissioning and calibration during or after installation to assure acceptable system operation. This is probably the cause for the lack of research on this issue. The transfer or handing over phase to the success of projects is very important, not only as the residual attitudes toward the project. This is indirectly evident from some of the studies on critical success factors of projects which have identified the act of “selling” the project to its final users as one of the critical success factors (Pinto & Slevin, 1987; Tishler, Dvir, Shenhar & Lipovetsky, 1996). Projects do not usually accomplish this condition because the collaboration ends with project completion, and future collaboration is uncertain (Branconia & Lochc, 2004). There is also lack of proper attention in the planning of commissioning (Dvir, 2005) as an essential part of the project life-cycle. Hence, this has emphasized the need to conduct this study to mitigate the residual attitudes towards handing over of projects in the Malaysian institutions of higher learning. This will also help to enhance the perceived understanding of commissioning and to improve the building performance.

Secondly, the reality to building owners is that there seem to be an absence of quality in the finished product and to a vast majority of building owners, buildings performance is not as anticipated. Commissioning is expected by owners to result in a high-performance building and to ensure the building systems work as intended. Unfortunately, the result of commissioning is not as expected. This unmet expectation together with the perceived high cost of commissioning have created gap between elevated expectation and delivered result (Tseng, 2005). Substantial completion on many projects is merely the start of a lengthy shakedown period for a myriad of building system problems that often take a year or longer time to sort out the bugs and defects (Tseng, 1998).

Woods (1990) found that there is a continuum exists in the degradation of building performance. Degradation reflects that a building has failed to perform or behave as anticipated by its designers (Woods & Arora, 1992). A complete measure of productivity of design, construction and operations should take into account the efficacy in which the completed building serves the objectives of the organization sheltered within it (Ventre, 1988). Even with Leadership in Energy and Environmental Design (LEED) Certification for green building rating system, many buildings in the past have not performed up to the standard as expected (Piette, 1994). This underperformed is more evident when a study of 60 commercial buildings found that more than 50% of these buildings had control problems, 40% with heating, ventilation and air-conditioning (HVAC) problems, 33% had sensors that were not operating properly, 15% with missing specified equipment, and 25% had improper operation of energy management control systems (EMCS), economizers, and/or variable speed drives that did not function properly (Piette, 1994). A major study on new and existing commercial buildings of various types carried out by Mills *et al*. (2005), have identified that 3,500 projects had deficiencies (11 per building from 85 reported projects) among existing buildings and 3,305 (28 per building from 34 reported projects) among new construction projects. Various building system problems and building performance problems have deduced that there is an urge to delve into deficiencies in the practice of commissioning. Unmet expectations of commissioning from the client's view point further confirmed this need.

Besides that, lack of awareness on the impact of poor commissioning on building has affected the performance of many projects. Faulty construction, malfunctioning equipment, incorrectly configured control systems and inappropriate operating procedures have increased realization that many buildings do not perform as intended by their designers (Haves, Claridge & Lui, 2001). Therefore, it is of necessary to identify the effects of poor commissioning on the projects performance.

Thirdly, project commissioning is considered as a mere administrative formality to obtain the construction license for the party involved. This ignorance of what a project really is has implied that quality is not the prerequisite of it, and it is also deemed to be not important (Merchan, 2000). This ignorance of the party on the importance of building commissioning might negatively impact the building performance without people knowing.

Apart from this, accumulated delays from previous phases may lead to operational errors during execution of commissioning procedures. Delays can result in time constraint and impose pressure that could affect project scheduling prior to final delivery to the customer (Cagno, Caron & Mancini, 2002). The project organization is aware of that it has to carry out work more carefully in the previous project phases for preventing confusions and delays during commissioning. Still the commissioning activities are not meeting the desired level (Dvir, 2005). There is no indication by Cagno *et al.* (2002) and Dvir (2005) that these commissioning problems are intrinsic from which phase of the project life-cycle. The purpose of commissioning and its outcome, which appear to be a major state of uncertainty for the delivery organizations at this point, need to be elucidated to perform commissioning more effectively (Dvir, 2005). From literature review, uncertainty on the effects of commissioning might be the conceptual basis for this inefficacy. It can then be inferred that there is a degradation of focal point on the research on building commissioning as compared with others project life-cycle such as design, planning and construction phase.

The basic commissioning process is integrated with the phases of construction and should begin in the pre-design phase and continue through construction and the warranty period. Commissioning enhances communication among project team members and ensures that they all understand the project goals. This allows the project team to identify problems early, before they can affect later phases of the project and cause delays (Oregon Office of Energy, 2000). Dvir (2005) recommended that further research should be carried out in others country other than Israel and in different industries to study the termination or hand over phase of projects in order to develop better ways for introducing projects into service and to ensure final users' satisfaction, which is the ultimate proof of project success (Dvir, 2005). Without having insight into these problems of building commissioning in the construction industry, it is hard to improve the project timely completion. Figure 1.5 demonstrated the formulation of research problems for this research to address commissioning problems to improve the project performance. What are the causes which had caused these problems?

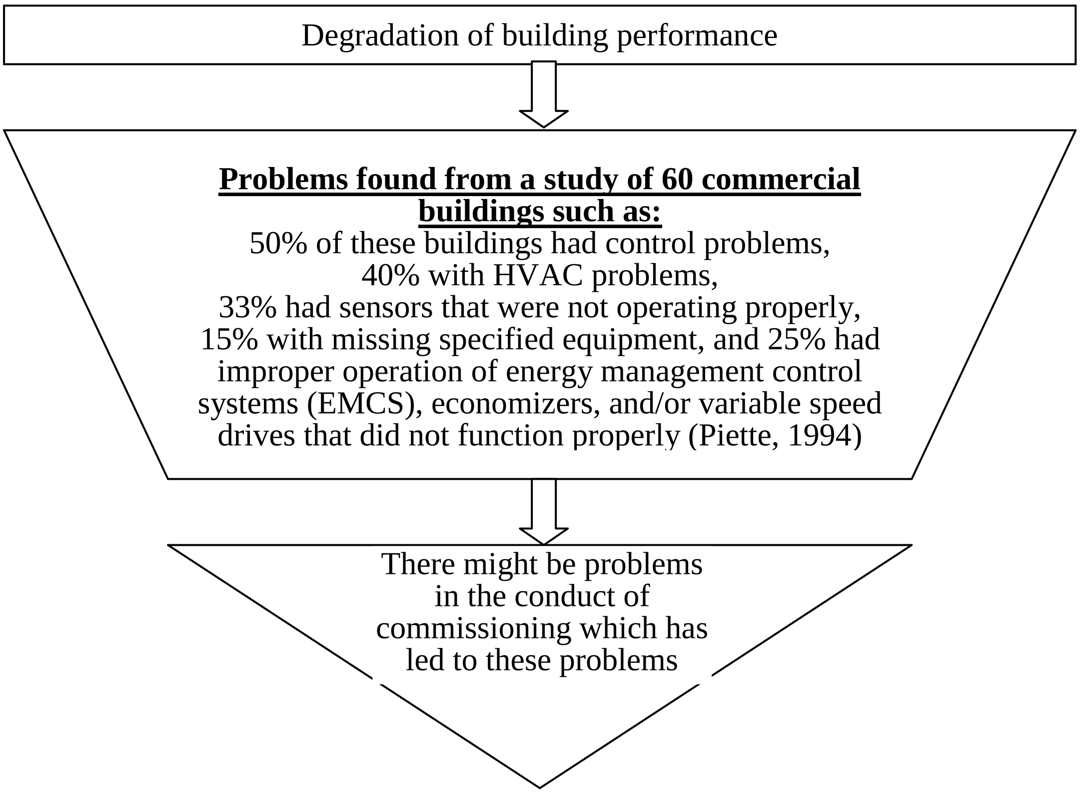


Figure 1.5: Formulating Research Problem

1.7 Issues Related to Building Commissioning in the Malaysia Scenario

Some of the issues highlighted by the National Audit Department, Malaysia in the Auditor General's Report 2010 and 2011 are tabulated in Table 1.1. These projects audited by the National Audit Department Malaysia have revealed several weaknesses which in the researcher's opinion are highly related to the conduct of building commissioning. These weaknesses or problems found from these reports are such as: the equipments have yet to be integrated with the building due to delay in building construction, poor quality, the issuance of Certificate of Practical Completion (CPC) without proper justification, Certificate of Practical Completion (CPC) was issued before the works were completed, work done not in accordance with specifications, the project was certified completed even though certain jobs were not done, and project was not properly planned and Certificate of Completion (CPC) was issued for the project which failed its main component testing and commissioning. The ultimate goal of commissioning is to obtain the Certificate of Practical Completion (CPC) and to ensure the constructed facilities are in accordance with all the specifications and design intent. All these problems have further highlighted the necessity to know what goes wrong with building commissioning and the reasons for it.

Table 1.1: Auditor General's Report 2010 and 2011

Audited Projects	Date of Audit	Revealed Weaknesses
Construction of the Federal Common-User Building in Seberang Perai Utara District, Penang	May to August 2010	• delay in the completion of project by 316 days; and • poor quality of the construction works which were ***not in accordance with specification***
Construction of Islamic Training Centre/Institution	October to December 2010	• delay in project completion; • ***Certificate of Practical Completion was issued even though the project was still not yet fully completed***; and • poor quality construction work and ***work was not done according to the specification as stipulated in the contract.***
Management of Acquisition of Aluminum All Weather Boat for Enforcement Activities	December 2010 to April 2011	• ***equipments were supplied not as per contract*** but full payment was made without any price adjustment.
Construction Project of Information Technology Office Building in Cyberjaya	July to October 2010	• poor quality in construction works and supply of equipments; • lack of monitoring during construction and defect liability period; and • ***poor monitoring on the electrical works*** by the contractor's consultant.
National Space Agency	November 2010 to February 2011	• the ***equipments have yet to be integrated*** with the building due to delay in building construction.
Construction of Rural Clinics and 2 Units of Class G Quarters	Date not mentioned	• 68 projects (80%) were still not handed over at the end of Extension of Time (EOT); • delay in project completion; • Extensions of Time (EOT) were approved between 34 to 413 days after the expiry dates of contracts; • project cost increased to RM 11.27 million; • ***works done was not in accordance to specification*** as well as clinics and equipments were not utilized.

Table 1.1: Auditor General's Reports 2010 and 2011 (Cont'd)

Audited Projects	Date of Audit	Revealed Weaknesses
Service Procurement for Next Generation Communication System	October to December 2010	• ***equipments were not installed but works had been certified as complete***; • a total of RM 3.22 million was paid for services that were not/not yet executed; and • payment made for equipment not yet supplied worth RM 0.78 million.
National Library of Malaysia	July to October 2010 and field visit in October 2010, February 2011 and July 2011	• contractor was unable to complete the construction works within the stipulated time; • the project was ***certified completed even though certain jobs were not done***; ***the building was occupied or operating without Certificate of Fitness for Occupation (CFO)***; • 8 Works Variation Order amounting to RM 1.73 million; and • a price adjustment of RM 383,414 million were approved after the Certificate of Practical Completion (CPC) was issued.
Management of Halal Hub Development Project	November 2011 to February 2012	• The project was not completed on schedule and there were delays of 9 and 11 months; and • The Halal Hub building was completed on 15 December 2010 but is ***still not operational.***
Management of The Construction of Additional Building Project	October 2011 to January 2012	• Delay in completion even though the contractor had been granted 2 Extension of Time; • Poor construction works such as ***non-compliance***, imperfections, defects and damages which require immediate actions by the contractor; and • The contractor ***took a long time to rectify non-compliance of project*** • ***specifications*** which caused delay in completion.

Table 1.1: Auditor General's Reports 2010 and 2011 (Cont'd)

Audited Projects	Date of Audit	Revealed Weaknesses
The Construction of Sultan Yahya Petra Second Bridge, Kota Bahru, Kelantan	June 2007 to December 2011	• failure to complete the works on schedule where 4 Certificates of Delay and Extension of Time (EOT) totaling 891 days had been approved until 30 August 2012; • problems with the design of bore pile system took 2 years to be resolved which contributed significantly to the delay of the project and increase in cost; and • appointment of an inexperienced contractor.
Electrified Double Track Project Between Ipoh and Padang Besar	December 2007 to – (date not mentioned)	• two Extensions of Time (EOT) of 669 days had increased the overall cost of the project due to increase in consultant fees; and • ***construction work did not comply with specifications/of low quality.***
Electrified Double Track Project Between Seremban and Gemas	Date not mentioned	Extension of Time of the project had resulted in the project time overrun of 18 months; and • ***construction works did not comply with specifications*** and inappropriate design had resulted in flash floods.
The Construction of Quarters, Stations and Offices for The Malaysian Meteorological Department	Date not mentioned	• ***Certificate of Practical Completion (CPC) was issued before the works were completed***; and • ***works done by contractors were inappropriate/incomplete/not complying with specifications***/of low quality.
Management of Providing/Upgrading Tourism Facilities Programme	Date not mentioned	• improper project planning; • payment had been made for construction works/supplies that were not done/delivered; and • ***construction works and supplies were not according to specifications*** and of low quality/not fulfilling tourism requirements.

Table 1.1: Auditor General's Reports 2010 and 2011 (Cont'd)

Audited Projects	Date of Audit	Revealed Weaknesses
Construction Management and Equipment Procurement at Advance Technology Training Centre	2009 – 2011	• four Advance Technology Training Centers (ADTEC) were not completed within the original contract period and were approved between 1 to 6 Extension of Time involving a time period between 90 to 706 days; and • ***some works did not conform to specifications***/poor quality/improper. However, the Ministry of Human Resources had pledged to improve the weaknesses raised where immediate action was taken on a number of weaknesses/defects in the work reported.
Construction of The Marine Police Base Lahad Datu, Sabah	Date not mentioned	• the project was delayed and approved with 2 extension of time totaling 299 days for Phase I and 3 extension of time totaling 528 days for Phase II; • work Variation Orders were approved after the contract had expired; • ***design/specifications were not suitable and construction works were unsatisfactory/incomplete***; and • the Ministry did not plan and prepare contract for cleaning services of the construction site after the project was handed over to users.
Indah Water Konsortium Sdn. Bhd.	Date not mentioned	• project was not properly planned and ***Certificate of Completion was issued for the project which failed its main component testing and commissioning.***
SIRIM Berhad	Date not mentioned	• ***non-compliance with regulations***; and • ***responsibility for handing over project was not clear*** and project outputs were not used optimally.

(Source: National Audit Department Malaysia, 2010 & 2011)

1.8 Research Questions

Research questions for this study are stated as follows to provide a clear direction to achieve the research objectives. Therefore, this research will seek to answer these research questions.

1. How is building commissioning being perceived in the Malaysian construction industry from the contractors' and consultants' perspectives?
2. How are problems during commissioning stage are related to planning, design and construction stages?
3. How do the underlying causes for these problems affect the conduct of commissioning? Or are these problems derived from commissioning stage itself?
4. How to measure the importance of building commissioning and its effect on project completion by using Earned Value Analysis?

1.9 Research Aims and Objectives

The aim of the research is to explore the current scenario of building commissioning in the Malaysian construction industry. To achieve the research aims, the research objectives are defined as follows:

1. To redefine the scope and understanding of building commissioning from the contractors' and consultants' perspective;
2. To identify problems during commissioning and the relationships of these problems with other phases of the project life-cycle;

3. To determine the underlying causes of identified commissioning problems;
4. To measure the importance of building commissioning and its effect on project completion by using Earned Value Analysis; and
5. To develop a conceptual model to improve building commissioning for construction projects in the public institution of higher learning in Malaysia.

1.10 Scope of Research

Most of the time, only design and construction during the realization stage of the building life-cycle are taken into account for the process analysis focuses on design for construction. Other life-cycle stages, such as maintenance, operation, renovation, demolition, and retrofit, are not included (Luiten, Tolman & Fischer, 1998). The research scope is delineated and highlighted in Figure 1.6. Thus, by taking into account of this shortcoming, the scope of this study is building commissioning during the project termination phase. Much of the contemporary confusion regarding the assessment of critical success factors in projects may be due to the temporal nature of critical success factors. The relative impact or importance of the various critical factors on project success is subject to change at different points in the project. A logical question would be the attempt to investigate the location of the likely points at which one could see such shifts in critical factor importance in an effort to determine what would be the cause of these changes. The concept of project life-cycles helps to clarify the reasons why different factors may be more important to project success at different times (Pinto & Prescott, 1988). Therefore, this has outlined the scope of this research to investigate the problems of building commissioning in the Malaysian construction industry for the public institution of higher learning in Malaysia.

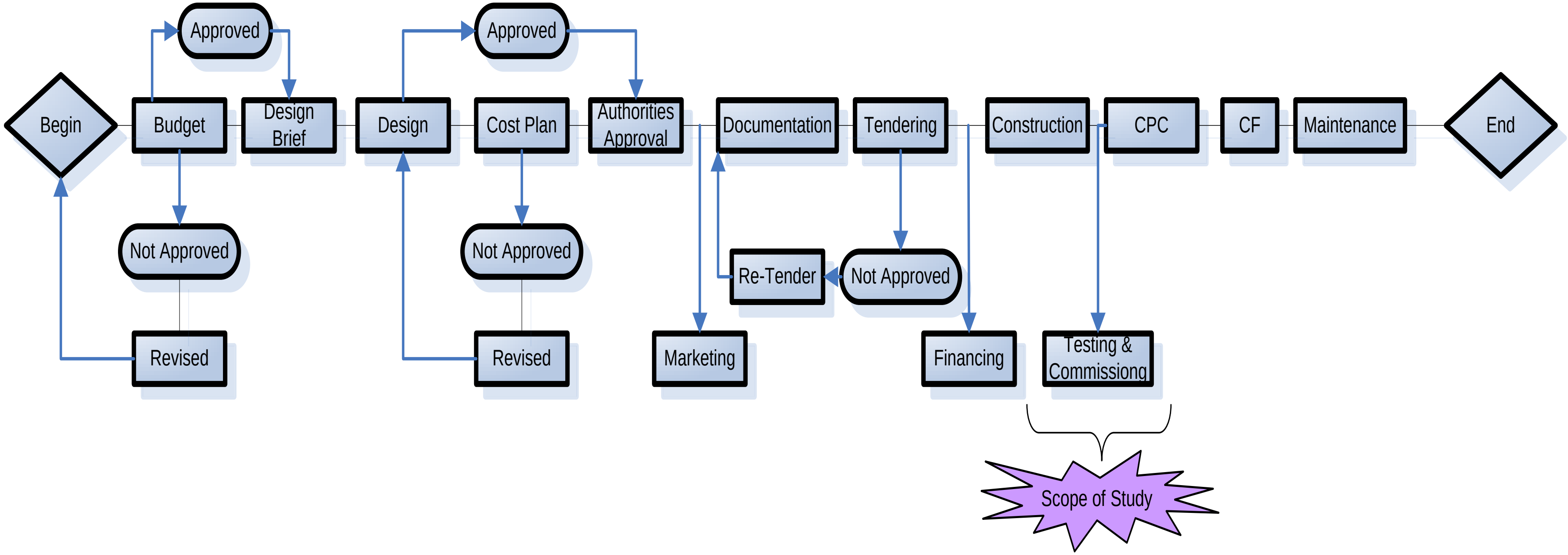
From the data collected from 127 projects, Shenhar (1997) proposed a multidimensional universal framework for considering success. To measure the project success, only one criterion in the delivery phase which was the project efficiency was measured whilst the three other criteria suggested were all in the post-delivery phase. Thus, it is of necessarily to enrich these criteria for project success during delivery phase to improve the project efficiency.

Most importantly, commissioning is underutilized in public-interest deployment programs and research and development activities (Mills *et al*., 2005). Thus, the scope of research was on-going construction projects in a public institution of higher learning in Malaysia which were scheduled to have testing and commissioning regardless whether these projects are behind schedule or projects with the percentage of completion more than 90% from year 2009 till 2012.

The study covers the commissioning process from inception stage to the final product or equipment or services assembly on the construction site. Special attention has been paid to the construction on site, since it is assumed that the causes of many of these commissioning problems occurring in assembly can be found upstream in the project life-cycle. This has postulated the importance of this research to identify the problems of building commissioning. With this research, it can then generate factors which needed to be emphasized before conducting building commissioning in the Malaysian construction industry.

The need for commissioning in new construction was indicated by the observation that the numbers of deficiencies identified in new construction exceed that for existing buildings by a factor of three. Another point postulated by the same group of researchers is that the costs of commissioning were higher in new construction, especially for larger buildings (Mills *et al*., 2005). Therefore, the scope of this study is directed on commissioning for new construction projects.

Apart from this, this study intends to identify commissioning problems and commissioning-related problems which fall under commissioning phase of construction projects. This is because it is almost impossible to segregate these commissioning problems without relating them to other phases of the project life-cycle.



Feasibility	Design	Costing	Approvals	Documentation	Construction	Maintenance

Figure 1.6: Project Activity Flow Chart

(Source: Tan, 1996:47)

1.11 Significance of Research

The lack of attention on building commissioning as an integral part of the project life-cycle may affect the project performance. Thus, this research emphasizes the importance of building commissioning to ensure the functionality and to improve the quality of building performance in construction projects; the case of the institutions of higher learning in Malaysia. For overall success of the project, effective management of project commissioning is of vital importance (Sohmen, 1992). The commissioning process gives a method to optimize systems, provide valuable checks and balances, and to ensure that systems are functioning properly. The commissioning process also provides a great training opportunity for the owner; it provides a good place to resolve project issues and to make sure that systems are working optimally (Ehrlich & Goldschmidt, 2011).

Hadjikhani (1996) focused his study on the management of the relationship left after project completion and postulated a hypothesis that every project leaves sediment, and accordingly studied cases focused on the phases before negotiation and after project completion. This view is also shared by Faulkner and Anderson (1987) who claims that a project cannot be regarded as isolated from previous projects. Projects are related to each other somehow. Therefore, problems of commissioning found in these cases are significance precedence guidelines for future projects.

With the comprehensiveness of commissioning, energy savings tended to increase (Mills, Bourassa, Piette, Friedman, Haasl, Powell, & Claridge, 2005). Other than being required by LEED, increment of the building operating costs and the increased complexity of modern buildings' operation with sophisticated controls, complicated sequences of operation, and significant interactions among systems have boosted up the demand for commissioning services (i.e.: fire alarm and heating, ventilation, and air-conditioning). Moreover, as postulated by Coleman and Coleman (2004), several states of United States called for commissioning on public projects. For example, Washington State requires that all new educational buildings undergo the commissioning process. In addition to state and local programs, commissioning is mandated on a federal level for federal agencies acting as property owners (FMI, 2005).

To improve energy efficiency, operation, maintenance, and equipment reliability, changes due to potential construction and operations problems which are addressed early during the design phase will have minimal cost impact. However, these changes would cost considerably more if made after the construction phase begins (Elzarka, 2009).

Commissioning is one of the most cost-effective means of improving energy efficiency in commercial buildings. While not a panacea, it can play a major and strategically important role in achieving national energy-savings goals. Commissioning for new construction was more strongly driven by non-energy objectives, such as overall building performance, thermal comfort, and indoor air quality.

1. This study intends to highlight the importance of having a proper building commissioning in lieu of the conventional ways of perceiving building commissioning. With this understanding on the essentiality of building commissioning, this study attempts to overcome the lack of research in this subject matter. This research aimed to add new insight to the existing understanding of building commissioning in the public institution of higher learning from the

consultants' and contractors' perspective. An analysis of their view would be of great usefulness for a further in-depth study. The expected outcome of this study also hoped to highlight the current scenario of building commissioning problems in public institution of higher learning in Malaysia and to make future advancement of knowledge feasible with this to serve as an initial study.

2. The study attempt to provide valuable evidence on the possible influence of building commissioning might have on the project timely completion and to enrich the existing body of knowledge on building commissioning. This study fills the gap between existing theories and practical application of building commissioning in the Malaysian construction industry for the public institution of higher learning towards project timely completion. The findings of this study aim to portray the correlations of commissioning problems with problems occurred during planning, design and construction. Subsequently, the findings of the research are expected to raise the attentiveness of building commissioning from the contractors and consultants to bring new insight on the impact of building commissioning might have on project timely completion. Consequently, it is the aims of this study to adjust the misinterpretations of practitioners and academicians on their perceived understanding of building commissioning which is deemed insignificant or unimportant.
3. This study provides useful information to draw attention on the essentiality of building commissioning problems that need to be focused in handing over the construction project to ensure functionality and to complete the project in a timely manner. Besides, this study also craft an effort to shift away from the conventional way of identifying and evaluating delay factors mostly by focusing on construction problems which are presumably assume to span all through the project life-cycle.

4. This study also aids to present some lessons learned for future projects so that appropriate precautious method can be taken to avoid or mitigate these commissioning problems even during the inception stage of the project.
5. If problems related to commissioning are managed to be identified and made known to the contractors and consultants, such understanding is critical to improve the project performance whilst in the same time to ensure on time delivery of the project to the client. This study also goes one step further to identify the interdependencies of these commissioning problems with other phases of the project life-cycle such as planning, design and construction stage.

1.12 Deficiencies of Previous Research

The commissioning process, which begins in the earliest stages of a project and lasts through the first year of operation, is designed to eliminate problems and resolve issues before they become major problems. When the commissioning process is highly successful, the number of change orders, request for information, scheduling problems, conflicts, and other problems will be greatly reduced. When a project goes smoothly, the owner might doubt the needs of commissioning process. The commissioning authority must document their activities to remind the project team that the seemingly "perfect" project was a direct result of the commissioning effort. For this reason, the industry players and the clients might have unintentionally overlooked the prudent of building commissioning in the construction industry when a project goes smoothly. The seemingly perfect project has led practitioners to feel that the attentiveness of building commissioning is not needed and deemed to be unimportant (Altwies & McIntosh, 2001).

Contrarily, if an issue is found later in the handing over phase, then there are at most two phases (including the handing over phase) in which cost can be avoided based on the resolution of that issue. Sometimes it is very difficult to resolve the issue when identified this late, so the owner are forced to "live with it" for an extended period, or even permanently, during the operation phase while paying for the cost over and over again (Altwies & McIntosh, 2001).

During the last few months before handing over, the project team often focuses its attention on the most critical part such as systems and equipment to obtaining permits and preparing the building for occupancy. At this stage, it is easy to overlook incomplete or deficient systems, but problems that remain after handing over do not disappear without attention. Deficiencies may go undetected for years and can negatively affect building control, energy use, equipment reliability, and comfort of buildings' occupants (Haasl, & Heinemeier, 2006).

In some way, the possible explanation for this was the risk management usage in the execution and planning stages of the project life cycle was found to be higher than that in the conceptual or termination phases (Lyons & Skitmore, 2004). The lower usage of risk management in the conceptual phase is consistent with findings by Uher and Toakleys (1999). However, the result of Lyons and Skitmore (2004) was contradict with Elkington and Smallman (2002), for example, who found that 'the earlier that risk management was used in a project, the more successful it was'. It was then inferred that the lower usage of risk management in the termination phase could be the reason for delay when handing over the building. Therefore, it is the hope of this research TO highlight the importance of building commissioning from the practitioners in the construction industry. Ultimately, this will assist the industry to anticipate the likelihood of delay occurrence during project handing over stage. This is why the commissioning process, which begins early in a project's timeline, can offer far more value to the owner than commissioning begun later during construction or startup (Altwies & McIntosh, 2001).

The lack of commissioning summary documentation and unresolved building problems point to the use of commissioning as an umbrella term for a variety of activities (Friedman, Potter, & Haasl, 2003). This finding is supported by previous market research in California which identified that education is needed on the commissioning process, since the majority of owners define commissioning as primarily the testing of systems (Haasl & Friedmann, 2001). Each commissioning process encountered was defined differently. Troubleshooting activities during construction and simple checklists were referred to as commissioning. In the search for buildings participants, commissioning providers and owners often claimed that their project was not a good example of commissioning, because the process was inserted late into the construction process or had a contentious end. In effect, the persistence of the entire commissioning process, from design phase to post-occupancy, was not investigated. Instead, the focus was the variety of ways in which commissioning is implemented in practice (Friedman, Potter & Haasl, 2003). Subsequently, this study somehow aims to investigate the issues pertaining to the building commissioning in the Malaysian construction industry.

1.13 Brief Research Methodology

This research attempted to identify problems of building commissioning from each individual being investigated and the influences of this problem on the project handing over. The research also tried to construct a better understanding on building commissioning from the lived experience of human beings. Thus, interpretive research is the most appropriate approach to become fully involved in this subject on building commissioning. This approach also allowed the researcher to uncover the socially constructed meaning as it is understood by an individual or a group of individuals on the perceived meaning of building commissioning. Interpretivist research provides general, predictive laws about human behavior, and presents a rich and complex description of how people think, feel and react under certain contextually specific situations. As this research adopted the interpretivist approach, case studies have been selected to uncover the issues of building commissioning in the Malaysian construction industry. Qualitative method is chosen for this study given the interpretivist paradigm and inductive approach for the research justification.

As illustrated in Figure 1.7, preliminary information is gathered by conducting extensive literature reviews to gain a better understanding on building commissioning in the Malaysian construction industry. The research process began with review of previous empirical work on building commissioning to identify problems and gaps for the present research. After the research problem and questions were developed, in-depth literature review was conducted on the concept of building commissioning. This early stage is necessary to determine the worthiness of this study to be investigated and to address the problem in a clearer manner.

The second phase aimed at generation of research questions and research objectives to enhance building commissioning for the institution of higher learning in Malaysia. By conducting extensive literature reviews on this subject matter and complemented with the findings from four pilot case studies, the interview questions are refined for the actual case study. Case study protocol is developed in this phase as well. This phase is of essentiality to provide a fundamental direction for the later research investigation as well as its overall importance. The issue concerned was defined clearer and to narrow down the research from its broad base to look into this problem from the contractors' and consultants' perspective in the construction industry. It is critical to identify the potential problem before finding solutions to vex issues.

The third phase aimed to collect data from the construction projects by conducting case studies which was achieved through semi-structured interviews, reviewed of archive records and the conduct of participant observations at site meeting. The resulted findings are of extremely high value to aid the development of the building commissioning model later on.

The last phase concerned with development of the proposed conceptual framework for building commissioning derived from the previous phase. In this phase, a systematic combining of the proposed conceptual framework, previous empirical work, the case of the public institution of higher learning and theory related to building commissioning are matched and combined. The results derived from this approach will be discussed and presented to achieve the specified research objectives.

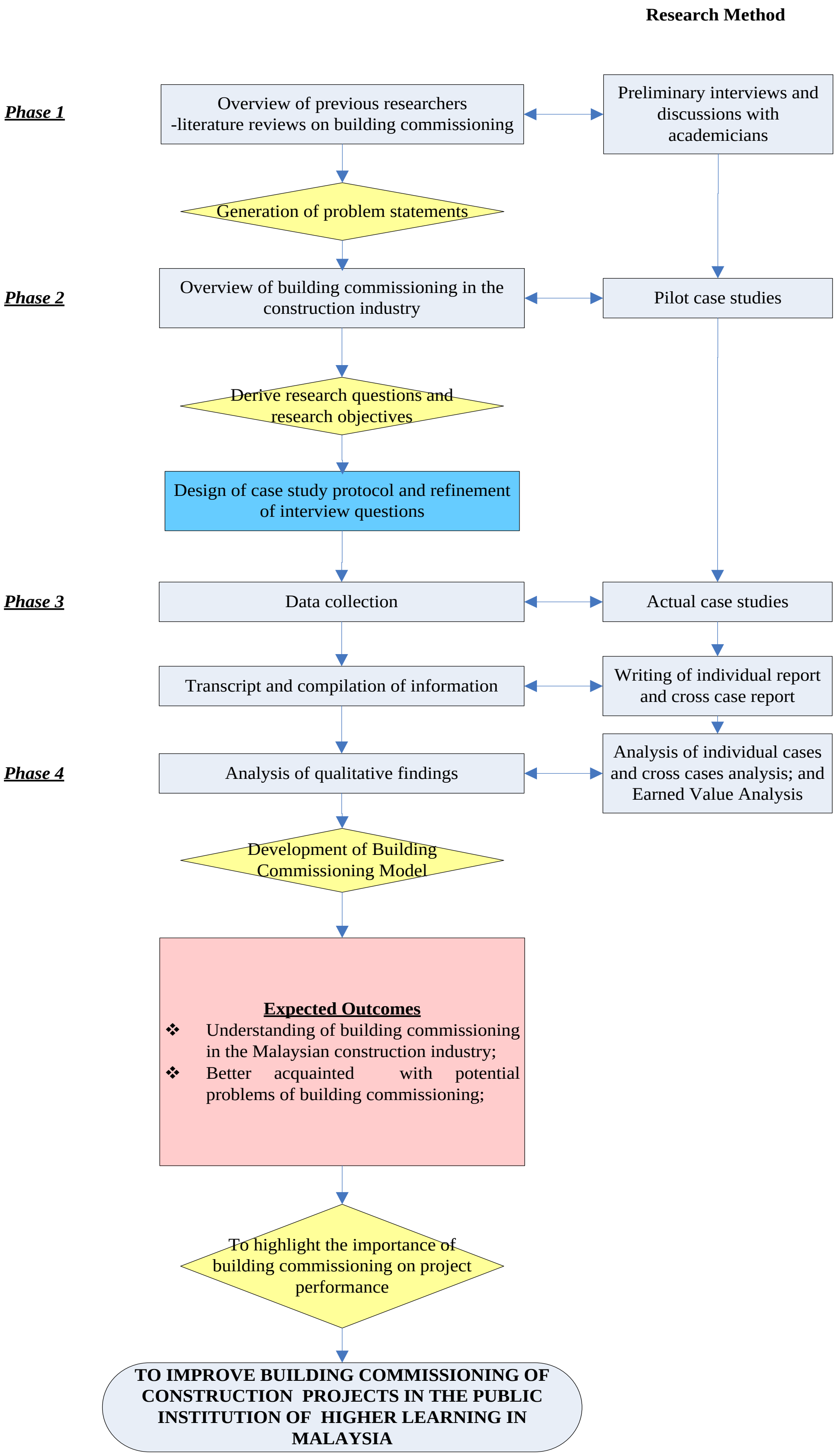


Figure 1.7: Research Phases

1.14 Structure of the Thesis

The structure of the thesis comprises of seven major chapters as follows. Figure 1.8 illustrated a general structure of the thesis for this study.

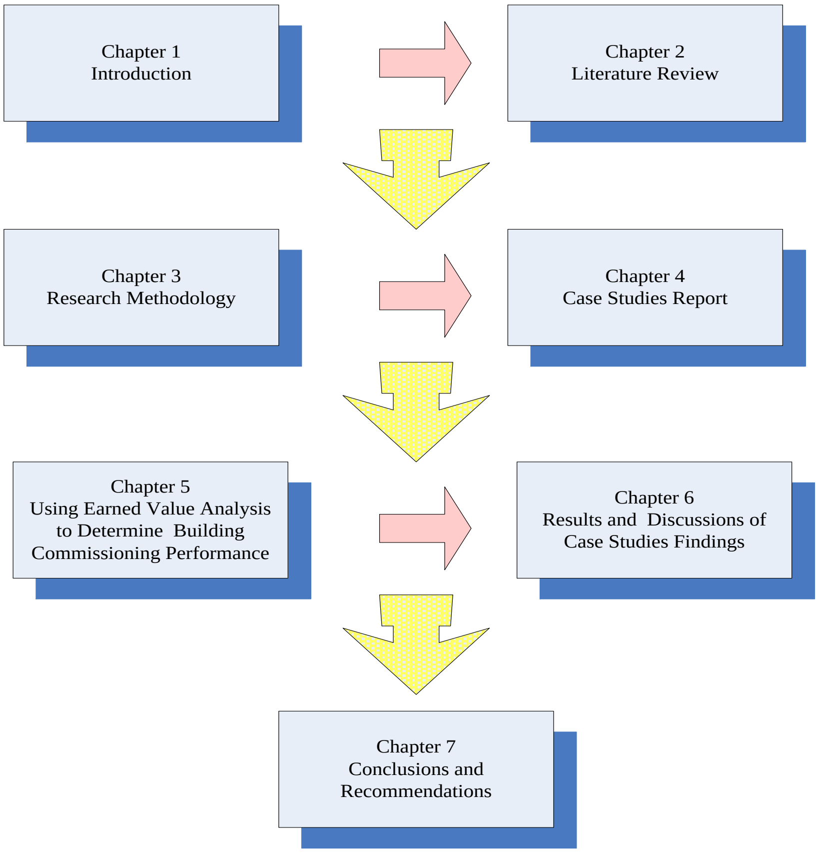


Figure 1.8: Thesis Structure

1.15 Summary of Chapter

This chapter provides an overview of the research framework and serves as a research background for the following chapters. This chapter highlights the issues pertaining to building commissioning and the significance of building commissioning in the Malaysian construction industry.

CHAPTER 2

A BACKGROUND AND SIGNIFICANCE OF BUILDING COMMISSIONING

CHAPTER 2

BACKGROUND AND SIGNIFICANCE OF BUILDING COMMISSIONING

2.1 Introduction

The outline of this chapter is illustrated in Figure 2.1. This chapter provides the readers an insight of previous research on commissioning, especially those related to the construction industry and the formation of research questions. This chapter begins with the literature reviews on building commissioning in the Malaysian construction industry. This is followed with the delineations of available definitions on building commissioning and some empirical studies on this topic. Besides that, this chapter illustrates and elaborates a model of the variables related to building commissioning. Apart from these subtopics, this chapter also highlights goals to be achieved by postulates clauses related to commissioning from the standard form of contract from the Public Works Department (PWD) in Malaysia.

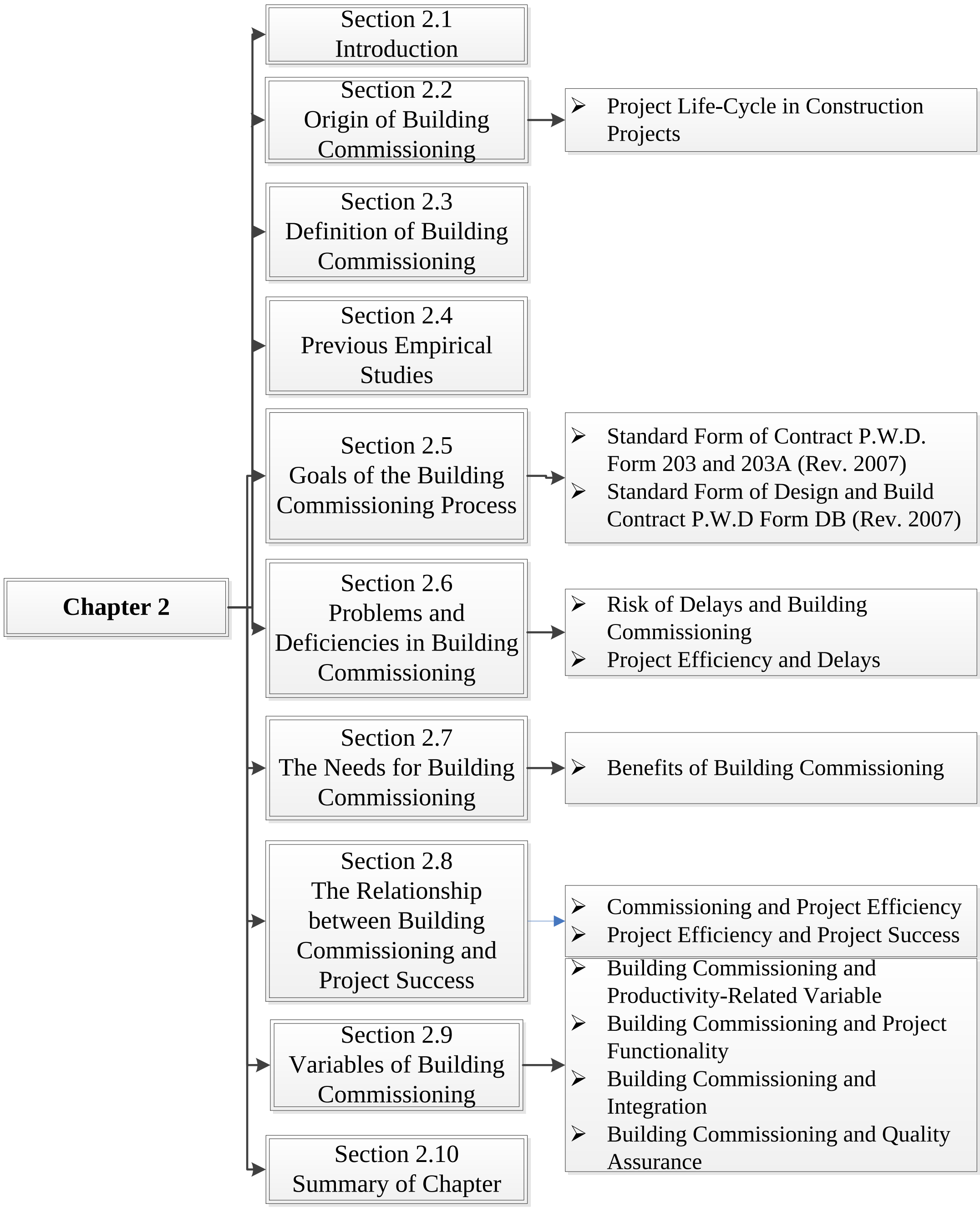


Figure 2.1: Outline of Chapter 2

2.2 The Origin of Building Commissioning

The term "commissioning" is borrowed from naval practice. A ship joins the navy as an operating unit through the commissioning ceremony. With this, the ship is placed under the responsibility of the commanding officer who together with the ship's crew has the task of making and keeping the ship ready for service. Commissioning insures that the newly launched ship passes several sea trials during which deficiencies are uncovered and corrected (Reilly Jr., 1975). The development of building commissioning was tabulated in Table 2.1.

Commissioning is an essential new research area and practice in the industry to promote the evaluation of buildings during several points in the delivery process. During the past 25 years, commissioning has emerged as a central function of building delivery that is accountable for evaluating building systems and verifying design intent. Building commissioning is a multi-phase process to ensure that the interacting systems in a building are properly installed and operating. At the early phases of design, the commissioning process is concerned with whether the program and the design deliver the owner's desired functionalities. During the construction process, commissioning is concerned with ensuring that the building performance is in line with the design specifications and delivers the intended functionality (Turkaslan-Bulbul & Akin, 2006).

Table 2.1: Development of Building Commissioning

Year	Evolution of Building Commissioning
1950	Building commissioning introduction in Europe
1960	Growth of environmental consciousness
1970	Testing, Adjusting and Balancing (TAB) introduction in North America Energy crisis
1980	Building commissioning introduction in North America
1990	US Energy Policy Act of 1992 ASHRAE Guideline 1-1996 CIBSE Commissioning codes
2000-	Testing, Adjusting and Balancing (TAB) of automatic controls and building commissioning growth all over the world

(Source: Xiao & Wang, 2009)

2.2.1 Project Life-Cycle in Construction Projects

Mainstream of research in the studies of critical success factor has assumed a static view of the significance of various factors over the life of a project. In other words, a critical success factor was assumed to have the same degree of importance throughout the life of the project (Locke, 1984; Archibald, 1976; Martin, 1976). Team effort in all the phases was the integral part of the project completion process (Adrian, 1982).

One of the most accepted project life-cycle frameworks have been suggested by Adams and Bamdt (1983) and King and Cleland (1983). The initial stage, conceptualization, refers to the time frame at which a strategic need has been recognized by top management. In general, alternative courses of action and preliminary goals are established at this point, along with discovering the availability of the means to accomplish these activities. The second stage is planning. In this stage, a set of more formalized plans to achieve the initially developed goals are established. Among the important activities in the planning phase is the enlisting of top management support to commit a variety of organizational resources (human, budgetary, etc.) as required. The third stage in the project life-cycle is execution. During this stage, the actual work of the project is carried out. Materials and resources are procured and transformed into the intended project result. Further, performance capabilities are verified. The fourth and final stage in the project life-cycle is the termination phase. Once the project has been completed, resources allocate to the project must be released, personnel from the project team are usually reassigned to other duties, and the project is transferred to its intended users (Adams & Bamdt, 1978; King & Cleland, 1983). Stages in the project life-cycle are as illustrated in Figure 2.2.

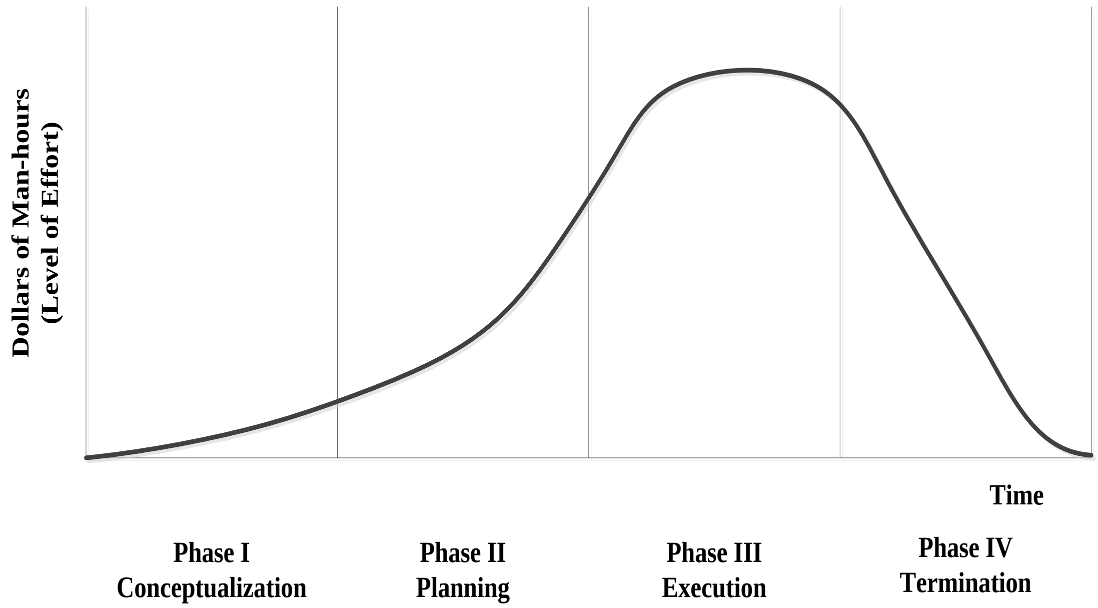


Figure 2.2: Stages in the Project Life-Cycle
(Source: Adams & Bamdt, 1978; King & Cleland, 1983)

The project close-out and termination phase can be considered as a project in itself. This phase often termed commissioning, which must be planned and programmed, to assign task, and to be executed effectively by controlling its costs, schedule and quality (De, 2001). Many contractors are guilty of placing too little focus on this final phase in the construction project life cycle (Bennett, 2003). They felt guilty mostly because before the project can be declared finished, a number of activities must take place and several responsibilities must be fulfilled. Nevertheless, only little focus is placed during this final phase. These contractors have chosen to look on to the next project instead to look beyond the end of the current project. It is observed by a sage observer of project management that “Projects proceed smoothly until 95% complete, and then remain at 95% forever”. Another observed “90% of the effort is expended on the first 90% of the project, and the other 90% is expended on the other 10% of the project”. In other words, someone has to put in the same amount of effort as in the other phases during this remaining 10% of the project. This has indirectly implied the criticality and difficulties to deal with this 10% of the project in closing out the project (Bennett, 2003). Though project termination, constitutes a significant part in the total project, it is often overlooked by the project managers as well (De, 2001).

In coalition with the aforementioned statement by Locke (1984), Archibald (1976), and Martin (1976), the relative importance, variations, and the associated metrics of the variables for success were different at every stages of the project. For example, the success factors that would be appropriate at the end of the production phase will be different and more extensive than those at the end of the design phase, which in turn will be more extensive and different to what applies at the end of the concept phase (Arain & Low, 2005a). For effective management of variations, consideration must be given to the construction phenomena from the early stages of the project until commissioning (Arain, & Low, 2005a).

Project management life-cycle was required because each phases of a project's life-cycle was different, and this was a very different management approaches to traditional general management (Adams, 1988). Cleland stated that the traditional hierarchical organization was not designed to cope with the constantly changing management requirements dictated by life cycles (Cleland, 1988b). These variances in management processes were highlighted by the nature of phases in the chronological life-cycle project management model. As reflected in the what/how matrix, the chronological viewed uncertainty as diminishing over the project life-cycle. During the conceptual phases the project structure and culture were organic (Burns, 1963). As the project proceeds through detailed documentation and into implementation, the project structure and culture become increasingly more bureaucratic and standardized (Adams & Brandt, 1988). When the project become more structured and standardized, people might thought that there are not much problems towards the end of the project. This is what has been generally perceived by most of the practitioners which have then led to the overlooked of the potential problems of building commissioning. This underestimation of the essentiality of commissioning might influence the project timely completion. This is considered being the normal practice in the construction industry but how true was this when the project itself is delayed? Or what are the possible effects of these problems on the project timely completion if the project itself is already suffered from delay?

Scott (1993) claimed that delays that have occurred throughout the construction process will probably lead to lateness in completion as a direct result of the knock-on effect on the project as a whole. Apart from this knock-on effect, logically, delays during construction together with the delays in commissioning will further exacerbate the lateness in completion. In other words, causes of delay will change in accordance with the changing nature of the project itself through its life-cycle. Supplementary to delays generated by the construction stage, delays transpire due to commissioning problems, altered the magnitude of project timely completion. In fact, identification of the changes of these causes of delay might actually benefit the project as new indicators in addition to factors of delay during construction. This can bring new insight to the project instead of perceiving construction delays as a whole through the project life-cycle.

The concepts of process consulting proposed by the organizational change literatures (Cook & Campbell, 1990; Harrison, 1989; McCall & Bobko, 1990; and Schein, 1990) underlined the lack of recognition of overlap between project phases (PMI, 1994a). The chronological model sees uncertainty decreasing and task routines increasing along the project life-cycle (Adams & Brandt, 1988).

2.3 Definition of Building Commissioning

Historically, the term "commissioning" has referred to the process by which the heating, ventilation and air conditioning (HVAC) systems of a building are tested and balanced according to established standards prior to acceptance by the building owner. Nowadays, commissioning recognized the integrated nature of all building systems' performance, which impact sustainability, workplace productivity, occupant safety and security (Moravec, 2005).

Interestingly, there are basically two opposing views on commissioning, on one extreme; there were those who believe that any and all services related to the "commissioning process" should only be provided by a "third party." The design and construction management teams believed that there is conflict of interest if anyone from the design or construction team is responsible for commissioning. Others believed that the scope of commissioning work has been included in the base contract, and it is just a matter of enforcing the contract documents. However, if someone is to ask five people on the definitions of commissioning, one might obtain five different answers (Kjelgaard, 2005).

Commissioning has traditionally being viewed as a task performed after system assembly and before hand-over as a final checkout and acceptance test (Xiao & Wang, 2009). This view by Xiao and Wang (2009) who perceived commissioning as an acceptance test is almost similar with Tseng (2005). Tseng (2005) who also claimed that commissioning often is considered to be a task, a completion exercise, or an acceptance checkout. It is viewed by contractors and designers as a necessary evil such as code inspection. Tseng also mentioned three key attributes about commissioning that need to be emphasized which are: commissioning is a process, commissioning is about quality and commissioning focuses on performance.

Table 2.2: Definitions of Building Commissioning

Author(s)	Year	Definition of Building Commissioning
Western Area Power Administration	2005	Building commissioning for new buildings is a quality-assurance process to verify and document that building systems function as designed and meet the operational needs of the building owner and building users. Commissioning pays for itself many times over through operating savings, improved staff performance, and by avoiding costly construction problems.
The Building Commissioning Association	2005	*A quality-based process with documented confirmation that building systems are planned, designed, installed, tested, operated and maintained in compliance with the owner's project requirements.* Building commissioning has becoming more common for large or complicated buildings but it is not a standard practice.
The Building Commissioning Association	-	To provide documental confirmation that building systems function in compliance with criteria set forth in the project documents to satisfy the owner's operational needs. Building commissioning goes beyond standard testing, adjusting, balancing and beyond traditional inspections.
Dasher, Potter, and Stum	2000	Building commissioning is the process of ensuring that building systems are designed, installed, functionally tested, and capable of being operated and maintained according to the owner's operational needs (p: 155). The objective of commissioning is to increase the likelihood that a newly constructed building will meet the expectations of the owner, occupants, and operators.
IEA ECBCS ANNEX 40	-	Clarifying building system performance requirements set by the owner, auditing different judgments and actions by the commissioning related parties in order to realize the performance, writing necessary and sufficient documentation, and verifying that the system enables proper operation and maintenance through functional performance testing. Commissioning should be applied through the whole life of the building.
Energy Design Resources	-	Commissioning is a systematic process of ensuring that all building systems perform interactively according to the contract documents, the design intent and the owner's operational needs. Commissioning is a quality-assurance process that increases the likelihood that a newly constructed building will meet client expectations (p: 2).
ASHRAE (the American Society of Heating, Refrigerating, and Air Conditioning Engineers)	-	Commissioning is the process of ensuring that systems are designed, installed, functionally tested and capable of being operated and maintained to perform in conformity with the design intent. Focuses on verifying and documenting the facility, and all of its systems and assemblies are planned, designed, installed, tested, operated, and maintained to meet the owner's project requirement.
ASHRAE Guideline 0, The Commissioning	2005	Commissioning as defined in the new construction building industry is a quality-oriented process for achieving, verifying, and documenting that the performance of facilities systems and assemblies meet defined objectives and criteria.

Table 2.2: Definitions of Building Commissioning (Cont'd)

Author(s)	Year	Definition of Building Commissioning
Process		
Oregon Office of Energy– New Construction Commissioning Handbook	-	Commissioning is a systematic process of quality control and assurance, and is recommended, as qualified, for all state projects. In general, the heating, ventilating and air conditioning systems and controls, lighting controls and life safety systems should be commissioned.
Bistrol City Council	2010	Commissioning is the process of specifying, securing and monitoring services to meet people's needs at a strategic level. This applies to all services, whether they are provided by the local authority, National Health Service (NHS), other public agencies, or by the private and voluntary sectors.
U.S. Department of Energy	-	Commissioning is the process of ensuring that systems are designed, installed, functionally tested, and capable of being operated and maintained according to the owner's operational needs. Commissioning is a systematic process that begins, ideally, in the design phase of a building retrofit project and lasts at least one year after the project is completed. It is a systematic process that helps building equipment and integrated building systems provide peak performance.
Chartered Institution of Building Services Engineers (CIBSE)	-	CIBSE defines the term "commissioning" as "the advancement of systems from static completion to dynamic operation according to requirements". This is obviously a process to test the building systems after completion before the owner and operators take over them.
Sheet Metal and Contractors National Association (SMACNA)	-	The process of advancing systems from a state of static physical completion to a state of full demonstrated, and documented working order, according to design requirements, during which time the owner's operating staff are instructed in correct systems operation and maintenance.
Haasl, and Heinemeier	2006	Building commissioning is a systematic quality assurance process that spans the entire design and construction process, helping ensure that the new building's performance meets owner expectations.
James	2005	Building commissioning is to provide documented confirmation that building systems are planned, designed, installed, tested, operated, and maintained in compliance with the owner's project requirements.
Florida Power & Light	1997	A systematic process of ensuring that all building systems perform interactively according to documented design intent and the owner's operational needs.

As referred to Table 2.2, the common words repeatedly used for the definitions of commissioning are: quality assurance, process, document, building systems, design, install, testing, functional, and operational. From these words, it can then be proposed that, the definition of building commissioning for the present context can be defined as a quality assurance process to verify and document the building systems where the buildings are designed, installed, tested and function to meet the operational needs of the building's owner and the end-user.

2.4 Previous Empirical Studies

From extensive literature reviews, it is found that not much research has been done on building commissioning. Review of literature mapping as tabulated in the Table 2.3 revealed that this subject matter is not being given the equal significance as it deserves and not many studies have been done in this research area.

Table 2.3: Literature Review Mapping on Previous Work on Building Commissioning

No.	Author(s) and Year	Location	Objective(s)/Some highlight(s)	Method/ Approach	Name of Journal
1.	Effinger and Friedman, 2010	U.S.	• To conduct a comprehensive study to identify the costs and benefits of commissioning; and • To provide detailed analysis of measures implemented through existing building commissioning projects.	-	ASHRAE journal
2.	Kjelgaard, 2005	U.S.	Provide some suggestions for building commissioning based on the author's observations of a good sample of projects. These projects included public schools, commercial buildings, and pharmaceutical research laboratory buildings.	Observations	Engineered Systems
3.	Wilkinson, 2011	U.S.	Highlighting the benefits of existing building commissioning and to approach building Operation & Maintenance from a different perspective. • To assist the operation and maintenance staffs to elevate the quality of their facilities and to make a building's operation and maintenance better. • To retrain, helping the entire staff comprehend a building's systems.	-	HPAC Engineering
4.	Mills, Bourassa, Piette, Friedman, Haasl, Powell, and Claridge,	U.S.	• There is lacking of standardized information on costs and benefits of detecting and correcting deficiencies;	Scattered case studies and anecdotal information	HPAC Engineering

Table 2.3: Literature Review Mapping on Previous Work on Building Commissioning (Cont'd)

No.	Author(s) and Year	Location	Objective(s)/Some highlight(s)	Method/ Approach	Name of Journal
4.	Mills, Bourassa, Piette, Friedman, Haasl, Powell, and Claridge,	U.S.	• The most frequently cited obstacle for commissioning is uncertainty of the decision maker's about its cost-effectiveness.	Scattered case studies and anecdotal information	HPAC Engineering
5.	Dvir, 2005	Israel	• To examine the relationship between planning and preparing the project for transfer to its final users and project success; • To analyze the relationship between the amounts of effort invested in planning and preparing the project for transfer to its final users and the degree of success achieved from different points of view.	Questionnaires	International Journal of Project Management
6.	James, 2005	Texas	• To emphasize the importance for commissioning providers to hold credible commissioning certification.	-	HPAC Engineering
7.	Hydeman, 2005	California	• To present a process that can be used to review and test the system design to achieve a high degree of system reliability; and • To emphasize the importance of close coordination required in the design of the electrical, mechanical and control systems and summaries the experience of two firms (one mechanical and one electrical) that have collaborated in the design and commissioning of many data centers.	-	ASHRAE Journal
8.	Ehrlich and Goldschmidt, 2011	-	Careful attention on the part of the design engineer to lay out the system — and most importantly, the sequences — is an important first step for delivering a quality installation. This paper also provide a review of the recommended steps for making sure a system works properly, such as: a) Good design; b) Great contractors; c) Commissioning; and d) Continuous commissioning (or continued commissioning).		Engineered Systems
9.	Kirsila, Hellstrom, and Wikstrom, 2007	Finland, India, Italy, The Netherlands and Poland	• To increase the understanding of integration as a management concept for complex industrial projects; • To stress the importance of integration through relationships all through the project life-cycle; • To outline a framework focusing on different kinds of integration for the deliveries of industrial projects.	Interviews and observations	International Journal of Project Management
10.	Tseng, 2005	U.S.	• To define what commissioning a sustainable building needs to be; and • To describe how commissioning providers can contribute to a more	Anecdotal evidence	A Supplement to ASHRAE Journal

Table 2.3: Literature Review Mapping on Previous Work on Building Commissioning (Cont'd)

No.	Author(s) and Year	Location	Objective(s)/Some highlight(s)	Method/ Approach	Name of Journal
10.	Tseng, 2005	U.S.	effective project delivery process.		
11.	Turkaslan-Bulbul and Akin, 2006	U.S.	• To propose a building information model to make architectural evaluation a persistent part of the building lifecycle.	Interviews, documentations	Automation in Construction
12.	Rubinstein, Avery, Jennings, & Blanc, 1997	U.S.	Proper commissioning is often absent in lighting projects and the lack of commissioning can significantly reduce a project's energy savings potential. To focus on the significance of good commissioning practice for obtaining acceptable performance from lighting control systems and discusses the complexity of commissioning today's systems.	Experiment	Proceedings of the Right Light 4 Conference

As tabulated in Table 2.4 is some previous empirical works on construction delays and the findings from these studies. It can be seen that most of these studies failed to specify from which stage of the project life-cycle these delays were derived. These studies also remain anonymous in delineating the interrelatedness of these delay factors with other stages in the project life-cycle.

Table 2.4: Previous Studies on Construction Delay

Author(s)	Year	Title of Journal Paper	Causes of Delay In Construction Project/Objectives	Delineation of Project Life-Cycle
Scott, S.	1993	The Nature and Effects of Construction Delays	Delays that have occurred throughout the construction process have probably directly resulted in tardiness of completion.	Did not mention specifically which project phase
Kumaraswamy & Chan	1998	Contributors to Construction Delays	To highlight the main findings of the third phase of the Hong Kong investigation, such as: • To identify the main factors causing delays as perceived by different industry subsectors; • To identify the degree of agreement or disagreement between subsectors. • To illustrate differences in collective perspectives and any possible popular misconceptions or prejudices.	No information was given as with the occurrence of delay at different project's life cycle.
Bordoli & Baldwin	1998	A Methodology for Assessing Construction Project Delays	• To identify the different categories of delay and the existing of different types of delay. • To present a new method of delay analysis incorporating assessment of three important issues which are: a) Progress of the project at the time delay occurred; b) The changing nature of the critical path; c) The effects of action taken to minimize potential delays; d) This new method of delay analysis is best used contemporaneously with the project to assess future delays wherein assessment is often made when the project is complete.	Either to be used contemporaneously or after project completion.
Khosrowshahi & Alani	2003	A Model for Smoothing Time-Series Data in Construction	The study focus on the explanation of time series' behavior rather than the prediction of future values.	No.
Al-Momani	2000	Construction Delay: A Quantitative Analysis	• To investigate the causes of delays and the level of time extension on public projects in Jordan; • To aid construction managers in establishing adequate evaluation prior to the contract award using quantitative data.	No.

Table 2.4: Previous Studies on Causes of Delay (Cont'd)

Author(s)	Year	Title of Journal Paper	Causes of Delay In Construction Project/Research Objectives	Delineation of Project Life-Cycle
Al-Momani	2000	Construction Delay: A Quantitative Analysis	• To investigate the causes of delays and the level of time extension on public projects in Jordan; • To aid construction managers in establishing adequate evaluation prior to the contract award using quantitative data.	No.
Chalabi & Camp	1984	Causes of Delay and Overruns of Construction Projects in Developing Countries	The study found that delay and cost overruns of construction projects are dependent entirely on the very early stages of the project.	During planning and construction stages
Proverbs & Holt	2000	A Theoretical Model for Optimum Project (Time) Performance Based on European Best Practice	To develop a best practice contractor performance models based on performance data from firms in France, Germany and the United Kingdom.	No.
Odeh & Battaineh	2002	Causes of Construction Delay: Traditional Contracts	• To identify major causes of delay in the construction industry • To assess the relative importance of these causes from the contractors' and consultants' perspectives.	No.
Ogunsemi & Jagboro	2006	Time-Cost Model for Building Projects in Nigeria	This study therefore attempts to explore a time-cost relationship that will be suitable for predicting project duration in Nigeria.	No. Focused on building works.
Abdul Majid & McCaffer	1998	Factors of Non-Excusable Delays that Influence Contractors' Performance	To classify the main causes of non-excusable delays and to identify the factors that contributes to those causes.	No.
Sweis, Sweis, Abu Hammad & Shboul	2008	Delays in Construction Projects: The Case of Jordan	The consultants' responses classified the following three delay causes as the most critical: 1. Poor planning and scheduling of the project by the contractor 2. Financial difficulties faced by the contractor 3. Too many change orders from owner The contractor accepted the following as critical top three delay causing factors: 1. Financial difficulties faced by the contractor 2. Too many change orders from owner 3. Shortage of manpower (skilled, semi-skilled, unskilled	No.

Table 2.4: Previous Studies on Causes of Delay (Cont'd)

Author(s)	Year	Title of Journal Paper	Causes of Delay In Construction Project/Research Objectives	Delineation of Project Life-Cycle
Sweis, Sweis, Abu Hammad & Shboul	2008	Delays in Construction Projects: The Case of Jordan	labor) The owners viewed the following three delay causes as most critical: 1. Poor planning and scheduling of the project by the contractor 2. Financial difficulties faced by the contractor 3. Incompetent technical staff assigned to the project	No.
Mohamed & Tarek	2013	Analyzing Delay Causes in Egyptian Construction Projects	This research presents a list of construction delay causes retrieved from literature. The feedback of construction experts was obtained through interviews.	No.
Doloi, Sawhney, Iyer & Rentala	2012	Analyzing Factors Affecting Delays in Indian Construction Projects	To identify the key factors impacting delay in Indian construction industry and to establish the relationship between the critical attributes for developing prediction models for assessing the impacts of these factors on delay.	No.
Hamzah, Khoiry, Arshad, Tawil & Che Ani	2011	Cause of Construction Delay – Theoretical Framework	The causes of delay are taken from the pass literature review. There are two main type of delay: excusable delay and non-excusable delay. The literature reviews are summarized and the delay framework is constructed based on the literature review summary in the context of public higher learning institution	No.

2.5 Goals of the Building Commissioning Process

The essential purpose of building commissioning is to provide a quality-based process with documented confirmation that building systems are planned, designed, installed, tested, operated, and maintained in compliance with the owner's project requirements (Shoop, 2006). Commissioning helps an owner to get what they have paid for (James, 2005). In this research, the standard forms of contract from the Public Works Department (P.W.D. Form) are to be used due to the fact that the government is the client for these projects for institutions of higher learning in Malaysia. Apart from this, the ultimate goal of the commissioning process is to obtain the Certificate of Practical Completion (CPC). Therefore, it is necessary to describe these clauses related to building commissioning. These forms are Standard Form of Contact P.W.D. Form 203 and 203A and Design and Build Contract P.W.D Form DB (Rev. 2007). These forms are referred depends on the procurement method being selected for that particular project.

2.5.1 Clauses in Standard Form of Contract P.W.D Form 203 and 203A (Rev. 2007) Related to Testing and Commissioning

The obligations of the contractor to carry out testing and commissioning and the completion of works are delineated in this standard form of contract. As specified in the Standard Form of Contract to be used where drawings and specifications form part of the contract P.W.D Form 203 and Standard Form of Contract to be used where bills of quantities form part of the contract P.W.D Form 203A (Rev. 2007), under Clause 10.1 (a), it is the obligations of the contractor to construct, complete, test and commissions the Works in accordance with the Contract. Besides that, for inspection and testing of materials, goods and equipment, Clause 36.2, the contractor shall carry out the inspection and tests as approved under Clause 36.5 or elsewhere in the Contract and such further tests as the Superintending Officer (S.O.) may reasonably require, including to open up for inspection any work covered up or to carry out any tests of any materials or goods (whether or not already incorporated in the Works or any executed works). However, under Clause 36.5, unless the Contract otherwise provides, the cost of making any test shall be borne by the Contractor if such test is proposed by the Contractor or clearly intended by or provided for in the Contract.

As specified in Clause 36.6, notwithstanding anything in Clause 36.5, if the Contractor carries out any further test as required by the S.O. pursuant to Clause 36.2 and the result of such test shows the workmanship or materials is not in accordance with the provisions of the contract, then the cost of such test shall be borne by the Contractor. But if the result of such test shows the workmanship or materials comply with the provisions of the Contract, and then the cost of such test shall be borne by the Government.

For completion of works, Clause 39.2, if the contractor considers that the works have achieved practical completion, the contractor shall notify the S.O. in writing to that effect. In accordance with Clause 39.3, within 14 days of receipt of such notice, the S.O. shall carry out testing/inspection of the works. Pursuant to such inspection/testing, the S.O. shall (a) issue the Certificate of Practical Completion to the contractor if in his opinion the whole works have reached Practical Completion and have satisfactorily passed any inspection/test carried out by the S.O. The date of such completion shall be certified by the S.O. and such date shall be the date of the commencement of the Defects Liability Period as provided in clause 48 hereof; or (b) give instruction to the contractor specifying all defective works which are required to be completed by the contractor before the issuance of the Certificate of Practical Completion. As stated in Clause 39.4, if the S.O. has given instruction pursuant to clause 39.3(b), no Certificate of Practical Completion shall be issued to the contractor until the contractor has effectively carried out the remedial work within reasonably period to the satisfaction of the S.O.

According to Clause 39.5, the works shall not be regarded as practically complete unless it has fulfilled the following:

(a) the works have been completed in accordance with the terms and conditions of this contract;

(b) the government can have full, proper and beneficial use of the works for their intended purpose, notwithstanding that there may be works of a very minor defects provided that such works do not prevent or diminish the full, proper and beneficial use as aforesaid;

(c) the works have passed any commissioning tests required in the contract document;

(d) the works shall be made available to the government in a condition fit for occupation; and

(e) all the essential services, including access roads, landscape, car parks, drains, sanitary, water and electricity installation, fire hydrant, sewerage and refuse disposal equipment and fire lifts specified in this contract.

In relation to Clause 39.6, when the whole of the works have reached practical completion to the satisfaction of the S.O., the date for such completion shall be certified by the S.O. and such date shall be the date of the commencement of the Defects Liability Period as provided in clause 48 hereof.

2.5.2 Clauses in Standard Form of Design and Build Contract P.W.D Form DB (Rev. 2007) Related to Testing and Commissioning

As outlined in the Standard Form of Design and Build Contract P.W.D. Form DB (Rev. 2007) Clause 13.3(a), from the commencement of the works to the date of the issuance of the Certificate of Practical Completion for the whole of the works the contractor shall, save as in Clause 13.3(b), take full responsibility for the care of the works for and for materials, plant and equipment for incorporation therein and shall at his own cost replace, repair and make good any damage, loss or injury to the same so that at completion the works shall be in good order and condition and in conformity in every respect with the requirements of the contract and the project director’s instructions. The contractor shall also be liable for any damage to the works occasioned by him in the course of any operations carried out by him for the purpose of complying with his obligations under Clause 47 hereof.

As referred to the same form Clause 13.3(b), if the project director issue a Certificate of Practical Completion or Certificate of Partial Occupation for any section or part of the permanent works the contractor shall cease to be responsible for the care of that section or part shall pass to the government. Provided always that the contractor shall remain responsible for any damage to such completed work caused by or as a result of his other activities on the site.

In Clause 15.2(b), the contractor shall carry out the inspection and tests approved under Clause 15.2(a) or elsewhere in the contract and such further test as the project director may reasonably require, including open up for inspection any work covered up or to carry any test of any materials or goods (whether or not already incorporated in the works or any executed works). Clause 15.3(e) specified that unless the contract otherwise provides, the cost of making any test shall be borne by the contractor if such test is:

(i) proposed by the contractor under Clause 14.1(e) or Clause 15.2(a); or

(ii) clearly intended by or provided for in the contract.

Clause 15.3(f) also stated that notwithstanding anything in Clause 15.2(e), if the contractor carries out any further test as required by the project director pursuant to Clause 15.2(b) and the result of such test shows the workmanship or materials is not in accordance with the provisions of the contract, then the cost of such test shall be borne by the contractor. However, if the result of such test shows the workmanship or materials comply with the provisions of the contract, and then the cost of such test shall be borne by the government.

Under Clause 42.0, for testing and commissioning of mechanical, electrical and other services. Clause 42.1 specified that where the works require the installation of any mechanical, electrical and other systems, the contractor shall carry out testing and commissioning of the installation to prove that the equipment has been properly adjusted and calibrated to produce the required guaranteed performance and that the system as a whole conforms to the specifications. This is further elaborated in Clause 42.2 that upon completion of the installation work at the site the contractor shall arrange for all necessary tests to be carried out on the equipment and installation as required by applicable laws. The contractor shall also perform all other tests which may be specified elsewhere in this contract. The costs of all tests including the provision of necessary equipment, tools, materials, labour and all other expenses shall be deemed to be included in the contract sum.

However, it is also stated in Clause 42.3 that in the event the equipment or system fails to achieve the required guaranteed performance or does not conform to the specifications, the contractor shall take all necessary measures to ensure that the equipment or system installed pass all the necessary tests. The installation work shall not be considered as completed until the equipment or systems have achieved the required guaranteed performance and have conformed to the specifications.

Besides that, Clause 42.4 also delineated that the contractor shall submit a test programme to and notifies the project director when these tests are to be conducted so that the project director or his representatives may be present to witness such tests. This is followed by Clause 42.5, which stated that the contractor should also carry out further adjustments to the controls whilst the building is occupied and the installation is in use, the Defects Liability Period. No additional cost shall be charged in carrying out these adjustments. Under Clause 42.6, a complete record of the tests and results of such tests (whether successful or otherwise) shall be kept up-to-date by the contractor. At the conclusion of all tests, these records shall be collated and two bound sets are to be provided to the project director. Again, as mentioned in Clause 42.7, on successful testing of the completed installation, the contractor shall arrange to commission the equipment in the presence of the project director or his representatives. The contractor shall demonstrate the correct operation of all mechanical and electrical aspects of the equipment, the correct operations of all controls and prove that the installation is complete.

For completion of the works as outlined in Clause 44.2, when the whole of the works have reached practical completion according to the provisions of this contract and to the satisfaction of the project director, and the contractor has obtained a temporary certificate of fitness for occupation/certificate of completion and compliance, wherever applicable, the date of such completion shall be certified by the project director and such date shall be the date of the commencement of the Defects Liability Period as provided in Clause 47. The certificate issued under this clause shall be referred to as the Certificate of Practical Completion (CPC). In addition, as mentioned in Clause 44.3, if the contractor considers that the works have achieved practical completion, the contractor shall notify the project director in writing to that effect. As stated in Clause 44.4, within 14 days of receipt of such notice, the project director shall carry out testing/ inspection of the works. Pursuant to such inspection/testing, the project director shall:

(a) issue the Certificate of Practical Completion to the contractor if in his opinion the whole works have reached practical completion and have satisfactorily passed any inspection/test carried out by the project director subject to the contractor giving a written undertaking to complete any outstanding work during the Defects

Liability Period (DLP). The date of such completion shall be certified by the project director and such date shall be the date of the commencement of the Defects Liability Period as provided in Clause 47.2 hereof; or

(b) give instruction to the contractor specifying all defective works which are required to be completed by the contractor before the issuance of the Certificate of Practical Completion (CPC).

As outlined in Clause 44.5, if the project director has given instruction pursuant to the abovementioned Clause. No Certificate of Practical Completion shall be issued to the contractor until the contractor has effectively carried out the remedial work within reasonable period to the satisfaction of the project director. As explained in Clause 44.6, the works shall only be regarded as practically complete if:

(a) the works have been completed in accordance with the terms and conditions of this contract;

(b) the government can have full, proper and beneficial use of the works for their intended purpose, notwithstanding that there may be works of a very minor nature still to be fully executed provided that such works do not prevent or diminish the full, proper and beneficial use as aforesaid;

(c) the contractor has given to the project director an undertaking to complete any outstanding work of a very minor nature;

(d) the works have passed any commissioning tests required in this contract;

(e) the works shall be made available to the government in a condition which is fit for the occupation; and

(f) all the essential services, including access roads, landscape (if applicable), car parks (if applicable), drains, sanitary, water and electricity installation, fire hydrant, sewerage and refuse disposal equipment and fire lifts where required, have been provided.

And most importantly, notwithstanding the provision of Clauses 45and 49, time shall be the essence of this contract.

2.6 Problems and Deficiencies in Building Commissioning

Without specialized training and attention in commissioning, problems would never have been caught in a timely manner until the project team was trying to finish up the systems. That early catch of problems could have saved the project from delays and potential change orders: once the ceilings are installed, going back and forth for troubleshoot of problems will incur more costs to be bear by the owner. Normally, contractors will simply submit report and to see if it gets spot-checked without conducting proper verification because the commissioning comes through once the construction works are done. If the commissioning has been done properly, there is no need to create as many punch lists when the Testing, Adjusting and Balancing Bureau (TABB) contractor tested a facility. This is because all those details have been hashed out before commissioning (Chichester, 2006).

These steps of commissioning such as design review, preparation of functional testing, implementation of functional tests, and review of trends and tests are part of an iterative process that must react to problems uncovered in the field of commissioning. No script can cover all of the contingences that include field installation, control sequences, equipment internal controls and configuration, unit delays and unanticipated issues uncovered in the commissioning process (Hydeman, 2005).

Commissioning is a valid means to ensure heating; ventilation and air-conditioning (HVAC) systems perform in building compliance with design intent, consequently to enhance the building sustainability. Heating, ventilation and air-conditioning (HVAC) systems seldom performs as well in practice as anticipated in design due to incomplete documentation for verification, insufficient information exchange among different roles (such as architects, consultants, suppliers, contractors and operators), improper equipment selection and installation, lacking of proper and prompt maintenance, poor feedback on operation performance, performance degradation and even complete failure of components, etc. (Xiao & Wang, 2009).

2.6.1 Risk of Delay and Building Commissioning

Commissioning enhances communication among project team members and ensures that they all understand the project goals. This allows the project team to detect the problems earlier, before these problems can affect later phases of the project and cause delays. To prevent the project and the commissioning work from being delayed, the project manager must tail the contractors to correct each deficiency (Oregon Office of Energy, 2000). In order to minimize potential delay, project participants should anticipate risk of delays in any project due to the occurrence of delays or problems in the building commissioning.

2.6.2 Project Efficiency and Delays

"Efficiency is a measure of units of work performed per units of resources consumed to perform that work. Inefficiency (also referred to as loss of efficiency or lost productivity) is a relative measurement. An operation is inefficient when it consumes more units of resources to perform a unit of work than should have been consumed or than were consumed by the same type of activity performed at another time" (Trauner, 2009: 205).

Project success was conceived by management using four a distinct dimension in which among these was project efficiency. This dimension expressed the short-term measure of efficiency wherein the project process has been managed and to inform whether the project was completed on time and within the specified budget. However, success in this dimension may indicate an efficient and well managed project but it may not indicate long term success nor benefit to the organization.

Therefore, enhanced of project efficiency should be seen as adding to product competitiveness with shorter product life-cycles, time to market (time from initial concept to market introduction) becomes a critical competitive components to increase competition. Nonetheless, all of these project success measures relate only to project successful implementation of project execution and not necessarily mean total success (Shenhar, Levy & Dvir, 1997). Thus, identification of problems in building commissioning which might cause delay in handing over is expecting to increase the project efficiency.

2.7 The Needs for Building Commissioning

Commissioning is an effective approach for system synergy because all building systems are interrelated and integrated in function and operation. Deficiency in one component can result in suboptimal operation and performance among other components. Some component deficiency may even lead to system failure and building shutdown. Therefore, the underlying forces of interdependence and synergy need to be harnessed and respected in the application of commissioning (Tseng, 2005). Some of the traditional factors supporting the need for a building commissioning programme and making the commissioning of buildings necessary are as follows (GSA Building Commissioning Guide, 1997):

- Unclear design intent;
- Complex building systems;
- Unclear standards and criteria for gauging system;
- Lack of functional performance testing;
- Conflicts between drawings/specifications and applicable codes;
- Inadequate system documentation;
- Maintainability and equipment accessibility problems;
- Inadequate provision for maintenance;
- Inadequate operation and maintenance manuals;
- Inadequate training of Operation & Maintenance staffs; and
- Numerous change orders and cost overruns (GSA Building Commissioning Guide, 1997).

With these factors as mentioned above, remedying of these deficiencies may results in a variety of benefits such as (Tseng, 2005).

- Improved occupant comfort and productivity;
- Important energy and operating cost savings;
- Significantly improved indoor environmental quality;
- Improved system and equipment reliability:
- Improved building operation and maintenance;
- Improved building and worker productivity; and
- Enhanced the market re-sale value for building owners (Tseng, 2005).

2.7.1 Benefits of Building Commissioning

Building commissioning is being increasingly recognized by owners as an effective means to reduce costs and ensuring quality as well as performance in building systems. The growth of the building commissioning movement is a long overdue effort to impart quality into this flawed process. This is mainly due to the plan-spec-bid-build process, which is typical and seriously flawed in most public, institutional, and private sector projects. The conventional plan-spec-bid process disperses responsibilities, muddies the performance measures, and does not allow for an integrated process for the delivery of the final product – a functioning, high performance building (Tseng, 1998). With the absence of an experienced commissioning providers in the Malaysian construction industry as compared with the overseas' practice, the benefits of commissioning might have to be re-emphasized. In view of this deficiency, it is of necessary to relook into the misconceptions of commissioning and what commissioning really is in the Malaysian construction industry.

Elzarka (2009) found that unqualified consultants without proper training, knowledge, and credentials in the commissioning market have had a negative effect on some owners' perceptions of the benefits of commissioning. For a building to produce the anticipated environmental benefits, the owner has to ensure the building actually operates as designed (Elzarka, 2009).

In the United States' scenarios, the need for verifying building operational performance has created a need for involving a party experienced in building operations during the design and construction phases of a building. This party is referred to as the commissioning agent. The involvement of the commissioning agent is a natural development of alternative project delivery systems that require a party knowledgeable in construction (the contractor) to participate during the design phase in order to perform constructability studies and develop realistic budgets and schedules. The participation of both the contractor and the commissioning agent during the design phase creates a project team with experience in design, construction, and operation that is capable of using integrated design techniques to improve both the constructability and operability of the new building (Elzarka, 2009).

Through the completion of construction, the direct and indirect benefits of buildings commissioning after taken into consideration the payback periods and returns on investment include (James, 2005):

- Savings in energy cost and improved building performance;
- Improved indoor-air quality and comfort and increased productivity on the part of building users;
- Early detection of potential problems (the sooner problems are resolved, the less expensive they are to fix);
- Fewer change orders during construction;
- Precise tune up and operation of systems and applicable controls;
- Better building documentation;
- Trained building operators and maintenance workers;
- Shortened occupancy-transition period; and
- Reduced maintenance, operation, and equipment – replacement costs (James, 2005).

The overall goals and benefits of the construction commissioning process included: improved occupant comfort (temperature and indoor air quality); sustained and increased energy and environmental efficiency; reduced maintenance burden and costs; and extended equipment life (Bowman & Wolpert, 2006).

2.8 The Relationship between Building Commissioning and Project Success

There is an absence of empirical studies which highlighted or portrayed the relationship between building commissioning and project success specifically. With the presence of this scarcity, it can be inferred that the revelation of this relationship between building commissioning and project success is highly noticeable. This relatively new insight can be significant to highlight the lack of attentiveness on building commissioning in the Malaysian construction industry. Empirically, no direct relationship is found between building commissioning and project success. However, from the reviews of literature, it can be postulated that there are relationship between building commissioning and project efficiency; and between project efficiency and project success. Therefore, the presence of this indirect relationship among building commissioning, project efficiency and project success have deduced the relationship of building commissioning and project success. The presence of relationship between building commissioning and project efficiency; and between project efficiency and project success are discussed in details in section 2.8.1 to 2.8.2. Combining these variables from literature reviews conducted will serves as base to yield a better insight on the possible influence of building commissioning on the project success.

2.8.1 Commissioning and Project Efficiency

It is essential to clearly define the roles and scopes of commissioning for all members of the design and construction team. By following recommendations from the commissioning authority, this will then lead to the most efficient, effective, and positive commissioning process for all project team members (Ellis, 2010). In the Malaysia's scenario, there is no commissioning authority for commissioning process.

2.8.2 Project Efficiency and Project Success

According to some researchers, the concept of success in a construction project is corresponding to the efficiency and effectiveness measures (Brudney & England, 1982; de Wit, 1988; Pinto & Slevin, 1988: 1989; Smith, 1998; Belout, 1998; Atkinson, 1999; Crawford & Bryce, 2003). Efficiency is broadly known as the maximization of output for a given level of input or resources (Takim & Adnan, 2008). Efficiency measures refer to internal organizational structures (adherence to schedule and budget, and basic performance expectations) and strong management. In other words, efficiency measures deal with 'time, budget and specifications'. The efficiency of a project would only be achieved by having a standard system and methodology put in place (George, 1968). This is in alignment with what have been found by Smith (1998) and Nyhan and Martin (1999) that project efficiency are concerned with the ***utilization of equipment*** and workforce. Maloney (1990) also emphasized that the construction projects' efficiency entailed the utilization of resources, which may be represented by the ratio of the resources expected to be consumed divided by the resources actually consumed.

According to Crawford and Bryce (2003), project efficiency ("doing the thing right") is concerned with cost and process management (i.e. the efficient conversion of inputs to outputs within budget and on schedule) and a wise use of human, financial and natural capital.

2.9 Variables of Building Commissioning

From extensive review of literatures, it is found that there are interrelationships among building commissioning and productivity, functionality, integration and quality assurance as illustrated in Figure 2.3. Therefore, building commissioning is utmost important to enhance productivity, functionality, integration and quality assurance in construction projects. These interrelationships will be discussed in details in the following section.

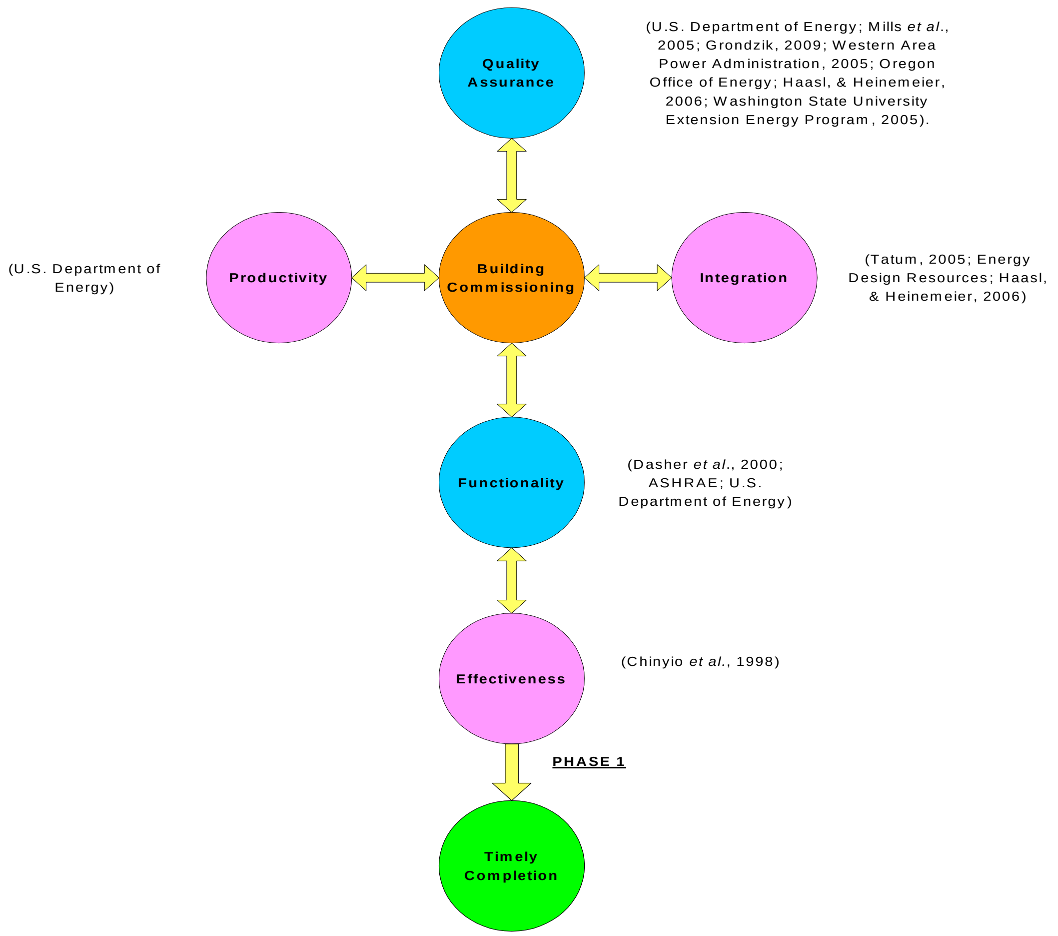


Figure 2.3: Variables of Building Commissioning in the Malaysian Construction Industry

2.9.1 Building Commissioning and Productivity-Related Variable

Hanna, Russel, Gotzion, and Nordheim (1999); Hanna, Russel, Nordheim, and Bruggink (1999); Hanna, Camlic, Peterson, and Nordheim (2002); Hanna, Camlic, Peterson, and Lee (2004); Hanna, Taylor, and Sullivan (2005) conducted a series of detailed studies on the impact of project productivity and efficiency concluded that the loss of productivity due to change was caused by the loss of learning curve effect, site congestion, trade stacking, schedule compression, overtime, overmanning, multiple-shift work, staff morale and motivational problems, and resource problems. One of the reasons for the loss of learning curve might be due to the instability of employment of craftsmen in the construction industry. Uwakweh and Maloney (1991) postulated that these workers are normally hired by the contractors to work on a specific project that has a finite duration. These workers are normally laid off when the project is completed. In lieu of this, it could be inferred that there are two types of loss of learning curve which are inter and intra construction projects. Thus, this study is directed to identify enablers for loss of "intra" learning curve within project towards the project completion or to identify outstanding works that hinder the project handing over.

Buildings are created to provide a productive and healthy indoor environment (Scott, 2010). The increment of productivity on the part of building users is one of the direct and indirect benefits of commissioning. The benefits of building commissioning which can be factor into return of investment and pay back periods such as the improvement of indoor air quality and comfort of the building (James, 2005). Besides that, the benefits of post-occupancy commissioning also include the increased productivity of facility staff by reducing their burden (Bowman & Wolpert, 2006).

Existing building commissioning is to ensure the quality of building and its operational characteristics with regard to productivity, occupant health and energy use, and equipment and structural reliability and longevity studied (Wilkinson, 2009). Another most cited reason for conducting building commissioning for existing building is due to non-energy reasons to improve productivity in which very little publicly available documents detailed about this (Poulos, 2007). Remedying deficiencies of building systems may result in a variety of benefits in which one of them is to improve productivity and occupant comfort and on the other hand to improve building and worker productivity (Tseng, 2005). Apart from these, owners are beginning to realize the benefits of procuring commissioning does offer significant opportunities to increase occupant productivity (U.S. Department of Energy, 1998; Mauro, 2005; Nicholson & Molenaar, 2004).

2.9.2 Building Commissioning and Project Functionality and 'Fitness for Purpose'

Chan (2000); Chan, Scott and Lam (2002) considers project 'functionality' as one of the success measures in the post-construction phase when the project is completed and delivered. According to Chan (2000); Chan, Scott and Lam (2002), project functionality with expectations of project participant and can be best measured by the degree of conformance to all technical specifications. In addition, it was argued that both financial and technical aspects implemented to technical specifications should be considered, achieving the ‘fitness for purpose’ objective. Kometa *et al.*, (1995) regard client satisfaction in terms of the functionality of the finish product, meeting safety requirements, flexibility, time, and quality. A study conducted by Chinyio *et al.*, (1998) reckons project functionality as building to be operationally efficient with its intended purpose, durable and keeping existing buildings operational during construction. Hence, taking these points mentioned by those authors, it seems most likely that project functionality and fitness for purpose could be associated with project effectiveness measures.

Projects are formed to accomplish objectives and success is measured in terms of how well these objectives have been met. Criteria such as meeting project time, budget, technical specification and mission to be performed are the top priorities of project objectives.

The competent design and construction management teams should be able to deliver these services with minimal or no oversight if the commissioning scope of work is defined clearly in the contract document but apparently not all design teams or construction management teams have the necessary experience (Kjelgaard, 2005).

2.9.3 Building Commissioning and Integration

‘‘Integration is the act or process of making something whole and entire’’. By referring to integration, we thus mean bringing or joining together a number of distinct things so that they move, operate and function as a harmonious, optimal unit (Sun & Meng, 2009). According to PMI (1996/2000), integration is understood as the processes required ensuring that the various elements of the project are properly coordinated. This definition is seen as an accepted view on project integration at that time. In the context of services and products, when a supplier integrates services and/or products to deliver an outcome is referred to as integration (Foote, Galbraith, Hope & Miller, 2001; Miller, Hope, Eisenstat, Foote & Galbraith, 2002). In other words, project integration could be deduced as an analogous to building commissioning in construction.

A construction program, or project plan, comprises of a series of interrelated and sometimes inter dependent processes or activities. Every process requires a set of inputs and produces a set of outputs (Sun & Meng, 2009). This is most similar to the function of commissioning wherein the main purpose of commissioning is to integrate all elements together (Energy Design Resources, Building Commissioning Guidelines: A Source Book on Building Systems Performance).

The commissioning process integrates and enhances the traditionally separate functions of design peer review, equipment start-up, control system calibration, testing, adjusting and balancing, equipment documentation and facilitates staff training, and adds the activities of documented functional testing and verification. Testing, adjusting and balancing measures building air and water flows, but commissioning encompasses a much broader scope of work. Although commissioning can begin during the construction phase, owners receive the most cost-effective benefits when the process begins during the pre-design phase at the time the project team is assembled. Commissioning also assures that the building's operational staff is properly trained and that the operations and maintenance manuals are compiled correctly at project handing over.

Commissioning provides a means of linking the traditionally fragmented phases of the design and construction process, because it encourages the project team to view the process holistically. Commissioning allows for a broad perspective and consistent focus throughout the design and construction process on whether the building will function as intended and identifies the best long-term solutions for problems that arise during project. Commissioning can facilitate improved integration and communication among team members throughout these phases and can ensure that correctly sized systems function as intended and specified.

Commissioning brings a holistic perspective to the design and construction process that integrates and enhances its traditionally separate functions. The commissioning process brings project team members together on a regular basis and encourages the group to work together to solve problems (Haasl & Heinemeier, 2006).

Research that contributed to increase understanding of technical support activities included investigations of integration and innovation in construction. The integration research included improving constructability (Tatum 1987, 1989a), and construction knowledge to consider in design (Fischer & Tatum 1997; Tatum & Korman, 2000).

2.9.4 Building Commissioning and Quality Assurance

Three key attributes about commissioning need to be emphasized. First, commissioning is a process. Second, commissioning is about quality. Third commissioning focuses on performance. Two adages about the commissioning and quality assurance process are: quality cannot be inspected into a product. Quality must be infused throughout the formation and construction phases of a project. Commissioning also means to shift away from inspection mode to quality integration (Tseng, 2005).

"Commissioning refers to the formalization of each of these quality control processes into a phased quality assurance program with supporting documentation and accountability, ideally by an objective third-party entity" (Rodgers, 2005: 621). Fortunately, an emerging form of quality assurance— building commissioning—can detect and remedy most deficiencies. The ultimate impact of energy efficiency research-and-development portfolios, deployment programs, and in-house energy-management initiatives lies in no small part in the extent to which they are coupled with cost-effective quality assurance (i.e.: commissioning) (Mills, Bourassa, Piette, Friedman, Haasl, Powell & Claridge, 2005).

The premise that the usual quality assurance processes needed further development was derived mainly from the dissatisfaction of building owners resulting from that fact that their buildings rarely fulfilled their initial requirements or operational needs and the time it took to work out the faults that were overlooked in the building process (Grondzik, 2009). In order to achieve this, commissioning needs to be emphasized.

Commissioning is a quality assurance process. It is distinctive from construction inspection, code compliance or construction administration visits by designers. Its emergence is the result of the needs of building owners. Its growth is a reaction to an industry wide problem of failed performance in newly constructed buildings and a response to the increasing complexity of building systems and their interdependency. The fledgling field of commissioning provides great opportunity to owners in substantial improvements in the quality and the performance of their building stock (Tseng, 2005).

2.10 Summary of Chapter

From the extensive literature reviews that have been carried out, it was found that commissioning of buildings in the construction industry are worth to be studied to add merit to the existing literatures. The effects of poor building commissioning can affect construction projects in terms of time, cost and quality. Thus, reviews of literature on remedies to mitigate this problem were described in this chapter. Firstly, the existing literature indicates the relevance and significance of this research to deal with this problem and to address the vagueness which has caused these problems in the following aspects:

1. Some of the previous researches on building commissioning have overlooked the essentiality of commissioning as an integral part of the project in the construction industry;
2. Most of the existing literatures merely identified that construction delays are among the most common causes of delay in construction projects and span throughout the project life-cycle;
3. What is considered as building commissioning from the contractors' and consultants' perspective? Do they perceived the essentiality of commissioning or merely commissioning is just treated as a pre-requisite to obtain the Certificate of Practical Completion (CPC)? Why?
4. How does this problem of poor commissioning and construction problems affect the project performance and the project timely completion?; and
5. Do problems or delays from construction affect the commissioning of the construction projects? How?
6. How does commissioning affect the project performance? How do they interrelate?

Secondly, from the extensive review of previous empirical studies, the following aspects have shaped to become the objectives of this research:

1. To redefine the scope and understanding of building commissioning from the contractors' and consultants' perspective;
2. To identify problems during commissioning and the relationships of these problems with other phases of the project life-cycle;
3. To determine the underlying causes of identified commissioning problems;

4. To measure the importance of building commissioning and its effect on project completion by using Earned Value Analysis; and
5. To develop a conceptual model to improve building commissioning for construction projects in the public institution of higher learning in Malaysia.

RESEARCH DESIGN AND METHODOLOGY

CHAPTER 3

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

This chapter elaborates the research methodology section which begins with the introduction of the chapter. This is followed with the research process of the study and rationale for the selection of research method. In the next sub-chapter, justification of selecting qualitative research approach is described and explained. The outline of this chapter is as illustrated in Figure 3.1. This chapter aims to present the flow of research design and the methodology adopted in this research.

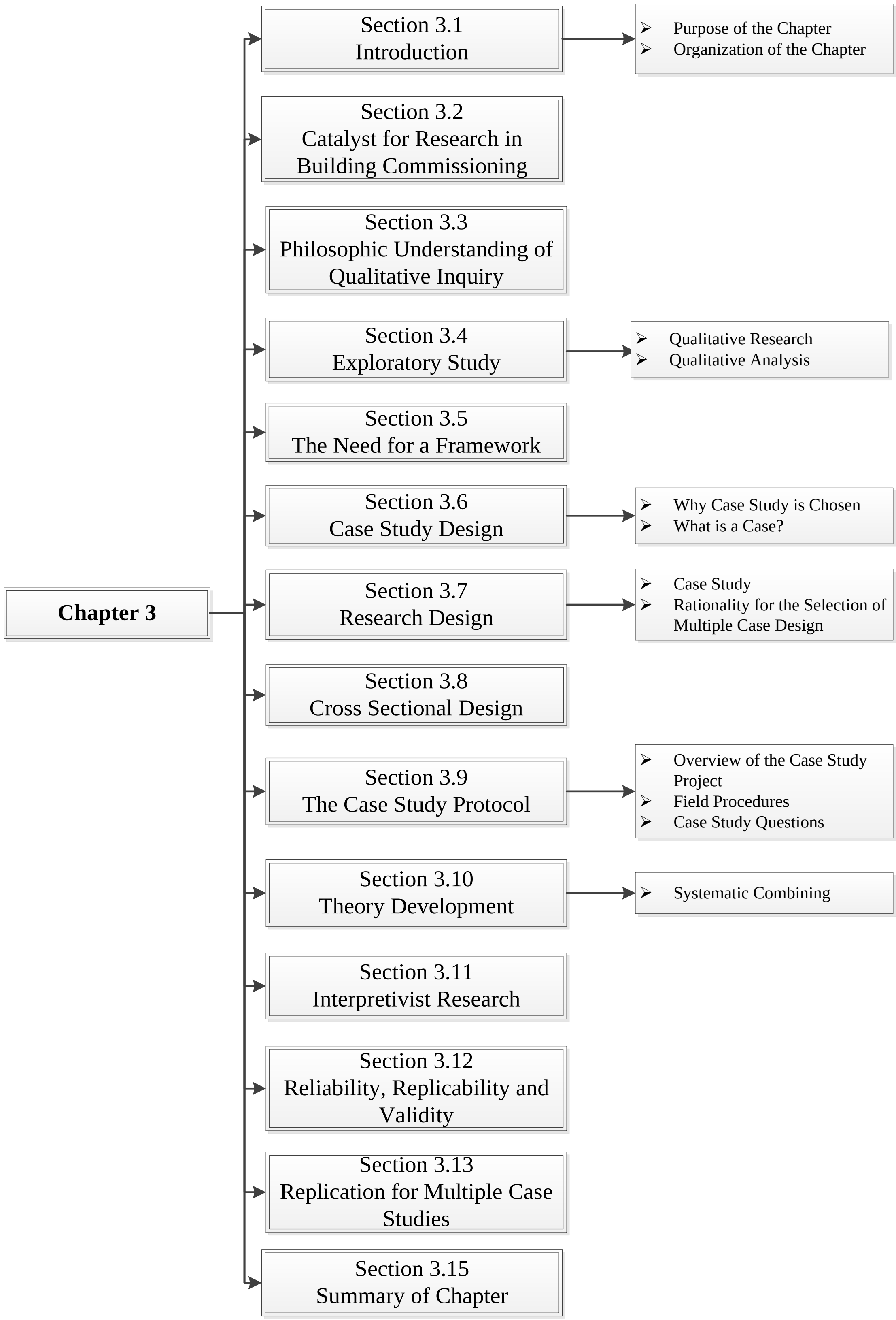


Figure 3.1: The Framework of Research Design and Methodology Section

3.2 Catalyst for Research in Building Commissioning

There is a conceptual basis that needs to be tightened in this study (Cavana, Delahaye & Sekaran, 2001). Currently, building commissioning might be broadly defined as merely a pre-requisite to obtain Certificate of Practical Completion (CPC). In practice, however, problems inherited from construction phase such as uncompleted work, might also be an uncovered scope that was part of the additional elements while conducting building commissioning. Thus, this research intended to re-define the understanding of building commissioning in the Malaysian construction industry and expand the definition of term to suit this context. This study is a clear case for a better understanding and definition of the concept itself. The issue of perceived understanding of building commissioning is explored empirically to answer the research question.

3.3 Philosophical Understanding of Qualitative Inquiry

Phenomenology is an overarching perspective that shapes our understanding on research (Maykut & Morehouse, 1994). A focus on understanding of meaning events have for person being studied is coined as phenomenological approach (Patton, 1991).

The answers to these questions of ontology and epistemology postulate the research paradigms. Before examining these postulates, two other words need clarification which are paradigm and postulates. "*A paradigm means a set of overarching and interconnected assumptions about the nature of reality*" *(Maykut & Morehouse,* *1994: 5).* The word “assumptions” is the key as one must make assumptions about the nature of reality. Anything that a researcher might do to test what reality is must be based on some understanding of that reality. A philosophic assumption cannot be proved but may be stipulated; these stipulations are called postulates. Our definition of a postulate is an assumption stated positively. A set of postulates make up a paradigm. The paradigm, based on these postulates, cannot be self-tested but it provides the basis on which verifiable knowledge is built (Maykut & Morehouse, 1994). As referred to Table 3.1, the word epistemology derives from two Greek words: “episteme” which means knowledge or science; and “logos” which means knowledge, information, theory or account. This aetiology demonstrates how epistemology is usually understood as being concerned study of the criteria by which we can know what does and does not constitute warranted, or scientific, knowledge. Therefore it would seem that epistemology assumes some vantage point, one-step removed from the actual practice of science itself. At first sight, this promises to provide some foundation for scientific knowledge: a methodological and theoretical beginning located in normative standards that enable the evaluation of knowledge by specifying what is permissible and hence the discrimination of warranted belief from the unwarranted, the rational from the irrational, and the scientific from pseudoscience. In other words, epistemology is the study of the criteria by which we can know what does and does not constitute warranted, or scientific, knowledge (Johnson & Duberley, 2000). Therefore, the epistemology for this study is knowledge, information, or theory in relation to building commissioning.

Ontology is derived from the Greek words “ontos” (being) and “logos” (theory or knowledge). It is a branch of metaphysics dealing with the essence of phenomena and the nature of their existence. Hence, to consider the ontological status of something is to ask whether it is real or illusory. Here, the primarily concerned is the ontological status of social and natural reality (Johnson & Duberley, 2000). The ontology to be dealt with in this study is the phenomena of building commissioning and the nature of its existence.

Table 3.1: Framing Research within Philosophy

	Areas of Philosophy to Relate With Research	**Questions**
1.	Ontology raises questions about the nature of reality	What is the nature of the world? What is real? What counts as evidence?
2.	Epistemology is interested in the origins and nature of knowing and the construction of knowledge	What is the relationship between the knower and the known? What role do values play in understanding?

(Developed from Maykut & Morehouse, 1994: 4)

3.4 Exploratory Study

According to Yin (2009), this empirical study on building commissioning is likely to assume the characteristics of an exploratory study. This is because the available literature on building commissioning provide little conceptual framework or hypotheses and the existing knowledge base of building commissioning is poor. When little is known about the situation at hand or when no information is available on how similar problems or research issues have been resolved in the past, an exploratory study is undertaken. Exploratory study is undertaken to better understand the nature of the problem that has been the subject of very few studies.

3.4.1 Qualitative Research

Qualitative research aims to discover how humans construct meanings in their contextual setting to reveal people's values, interpretative schemes, mind maps, belief systems and rules of living so that the respondents' reality can be comprehend. In an attempt to understand how participants experience and explain their own world by emphasizing on careful and detailed descriptions of social practices rather than concerning itself mainly with representative samples (Jackson, 1995). To emphasis on understanding through closely examining people's words, actions and records rather than assigning mathematical symbols to these words, actions and records (Maykut & Morehouse, 1994). Rather than an objective stance, qualitative research is interested in the subjective perception of the respondent – that is to examine the perspective of the respondent's beliefs and interpretation of the phenomena being researched in a perspectival view (Ticehurst & Veal, 1999). According to Polanyi (1997), qualitative research is the best instrument to surface the hidden tacit knowledge of the respondent as tacit knowledge is known as "We know more than we can tell" (Polanyi, 1997: 136). Qualitative research tends to concentrate on collecting a great deal of 'rich' information from relatively few people and recognizes a more fluid and recursive relationships among the various elements of the research (Ticehurst & Veal, 1999: 95). The two schools of thoughts have been at loggerheads due to the contrasting nature of the belief systems.

In qualitative research, certain phenomena are observed and the process to arrive at certain conclusion is termed induction (Cavana *et al.*, 2001). Qualitative research, on the other hand, generally examines people's words and actions in narrative or descriptive ways more closely representing the situation as experienced by the participants. It is also based on a phenomenological position. As shown in Figure 3.2 is an inductive reasoning for this research.

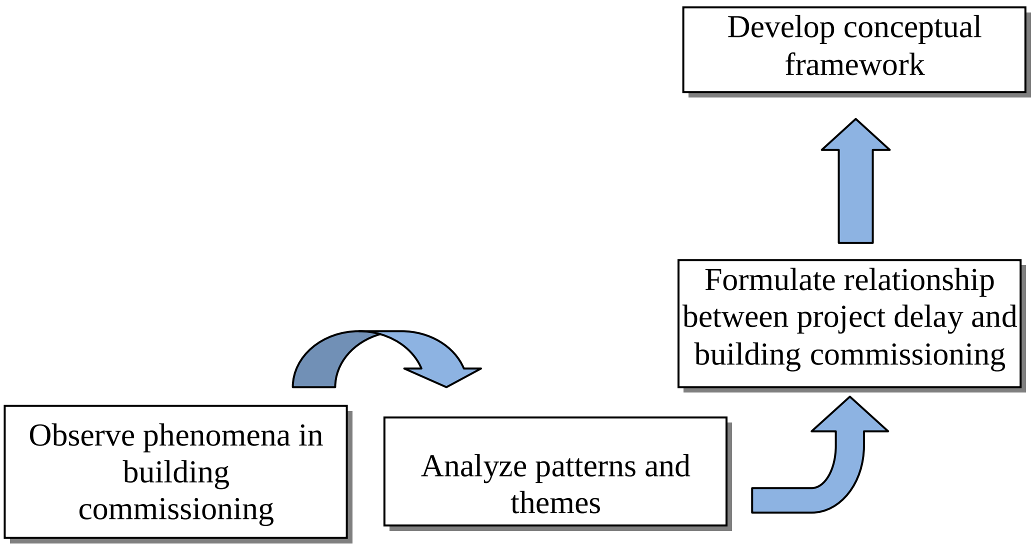


Figure 3.2: Inductive reasoning
(developed from Cavana et al., 2001: 36)

Qualitative research therefore is seen as:

The systematic analysis of socially meaningful action through the direct detailed observation of people in natural settings in order to arrive at understandings and interpretations of how people create and maintain their social words (Neuman, 1997: 68).

3.4.2 Qualitative Analysis

Understanding the studied phenomena is the overall purpose of analyzing qualitative data. Content analysis is the process of identifying, coding and categorizing the primary patterns in data (Patton, 1990). Content analysis allows the themes to emerge from the raw data and to describe the main focus of the qualitative analyst. Each them will then has a separate identity from the other themes and the term content analysis can refer to the statistical analysis of key word or phrase occurrences (Krippendorff, 1980).

3.5 The Need for a Framework

A framework offered a model of how to make logical sense of the relationships among the several factors that have been identified as pertinent to the commissioning problems in Malaysian construction industry. These relationships flow logically from the documentation of previous research in the problems area of construction delays. The framework discussed the interrelationships among the concepts and/or variables that were deemed to be integral to the dynamics of the problem being investigated. By developing this framework, it helped to formulate research questions to improve understandings of this problem. This framework formed the basis for the rest of the research in this study. The framework defined the concepts, explained the theory underlying these concepts, elaborated the relationships and described the nature and the direction of the relationships which in turn provide logical base for the development of research objectives. To define the building commissioning issues as clearly as possible in a conceptual framework can assist to shape a clearer view on the research topic. From the information gathered from preliminary investigation, the description for each concept might be incomplete and there may be other concepts that have not yet been discovered. Therefore, the emphasis of this research was based on a qualitative design using case study approach. This was adopted to allow for investigation, identification and to describe the concepts in a more distinct form.

The relationship form that was mutually coupled reflects the complex relations among the activities in the objective world have been researched quite a lot by overseas scholar (Smith & Eppinger, 1997a, b). These activities referred to the issues to be addressed in this study. The information coupling among the activities via activity of construction project life-cycle requires the information of commissioning problems. The same applied to the activity of commissioning problems which required the information of construction project life-cycle to form the circular relation forms (Xiao & Si, 2003). The relationship for this is as shown in Figure 3.3. According to (Yin, 1981), though case studies might start with little conceptual framework, the narrative must nonetheless be organized around specific questions or activities on building commissioning with flexibility in modifying this topic as analysis progresses.

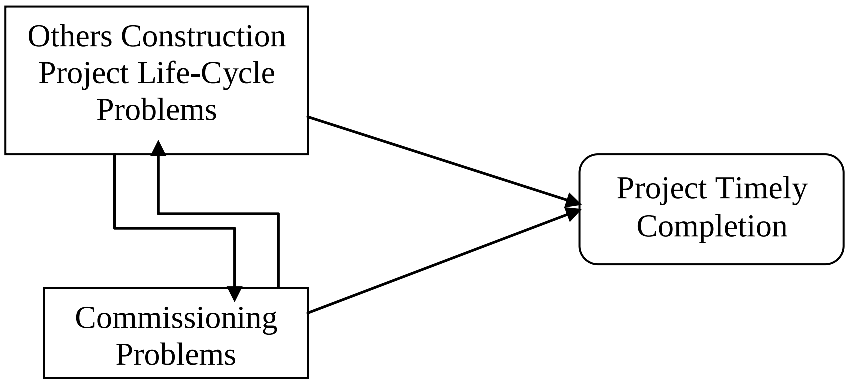


Figure 3.3: The Influence of Commissioning Problems on Project Timely Completion

Five basic features that should be incorporated in any theoretical framework (Cavana *et al.*, 2001).

1. The variables considered relevant to the study should be clearly identified and labeled in the discussions;

2. The discussions should state how two or more variables are related to one another. This should be done for the important relationships that are theorized to exist among the variables.
3. If the nature and the directions of the relationships can be theorized on the basis of the findings from previous research, then there should be an indication in the discussions as to whether the relationships would be positive or negative.
4. There should a clear explanation of why we would expect these relationships to exist. The arguments could be drawn from the previous research findings.
5. A schematic diagram of the proposed theoretical framework should be given so that it can be seen and the theorized relationships are easily comprehended.

3.6 Case Study Design

3.6.1 Why Case Study is Chosen?

Case studies is a method of solving problems, or of understanding phenomena of interest and generating additional knowledge in that area by examining studies done in other similar organizational institutions. Case studies are qualitative in nature and are useful to apply solutions to current problems based on past problem solving experiences. Case studies are also useful to understand certain phenomena and to generate further theories to be tested empirically (Cavana *et al.*, 2001). There is no formula for the use of case study method, but the choice to use this method depends in large part on the research questions. The more one questions seek to explain some present circumstance such as "how" or "why" some social phenomenon works, the more the case study method will be relevant (Yin, 2009). As tabulated in Table 3.2 is rationality for the selection of case study.

Most importantly, case study research is enquiry which focuses on understanding, describing, predicting, and/or controlling the individual (i.e.: process, person, organization, industry, group, culture or nationality) (Woodside & Wilson, 2003). One of the research objectives of this study is to redefine the understanding and scope of building commissioning.

Furthermore, case research may be better suited for questions addressing causality than survey research. Survey research addressing this same question would require multiple surveys conducted over the course of several months or even for years (Johnston, Leach & Liu, 1999). Among the research objectives of this study are to determine the causality for the identified commissioning problems and the relationships of these problems with other phases in the project life-cycle.

The universality and importance of experiential understanding and because of their compatibility with such understanding, case studies can be expected to persist to have an epistemological advantage over other inquiry methods (Stake, 1978). Therefore, case study approach is chosen in this research.

Table 3.2: Rationality for the Selection of Case Study

	When to Use Case Study?	Conditions	Applicability to the Study
1.	Form of research question?	How, Why?	The research questions for this study are mainly directed to "Why" and "How" questions as follows: a) ***How*** someone would have perceived building commissioning in the Malaysian construction industry? b) ***Why*** project commissioning is not considered as an integral part of the project life-cycle? c) ***Why*** problems in building commissioning has not been drawing equal attention as in comparisons with problems arise in others phase of the project life-cycle? d) ***Why*** problems in building commissioning can eventually leads to delay in construction projects? e) ***How*** will building commissioning affects the project completion?
2.	Requires control of behavioral events?	No.	Does not require control of behavioral events.
3.	Focuses on contemporary events?	Yes.	Focuses on the contemporary issues pertinent to building commissioning in the Malaysian construction industry.

(Source: COSMO Corporation, 1983)

3.6.2 What is a Case?

A case can be a single location, such as factory, production site, or office building (Pollert, 1981; Linstead, 1985; Milkman, 1997) and a single event (Vaughan, 1990). For this study, the location selected is construction projects in a public institution of higher learning in Malaysia which are scheduled to have testing and commissioning regardless whether these projects are behind schedule. The case need not be a person or enterprise. It can be whatever "bounded system" is of interest. An institution, a program, a responsibility, a collection, or a population can be the case (Stake, 1978). Knights and McCabe (1997) proposed that the case study gives a vehicle through which several qualitative methods can be combined to avoid too great a dependence on one single approach. In a study of quality management in a United Kingdom (UK) retail bank, participant observation, semi-structured interview and documentation of company reports, and total quality management guides were combined. Knights and McCabe (1997) also suggested that case study's findings can be used to identify insights into why so many quality management programmes have failed. Thus, the findings of this study can be used to identify insights why these projects have commissioning problems. Are these problems caused by problems that occurred during planning, design or construction stage? Alternatively, why building commissioning is not considered as an integral part of the project life-cycle?

According to Bryman and Bell (2007), with a case study, the researcher aims to provide an in-depth elucidation of it and the case is an object of interest in its own right. It becomes almost impossible to differentiate the case study as a special research design because almost any type of research can be construed as a case study. What distinguishes a case study is that the researcher is usually concerned to explain the unique features of the case which is known as an idiographic approach.

3.7 Research Design

Research design is a plan that guides the investigator in the process of collecting, analyzing and interpreting observations. It is a logical model of proof that allows the researcher to draw inference concerning causal relations among the variables under investigation (Nachmias & Nachmias, 1992: 77).

1. The study's question of this study are as follows:

a) How does building commissioning being perceived in the Malaysian construction industry from the contractors' and consultants' perspectives?

b) How are problems during commissioning stage are related to planning, design and construction stages?

c) How do the underlying causes for these problems affecting the conduct of building commissioning? Or are these problems derived from commissioning stage itself?

Specification of these research questions accurately could then resulted in the selection of the appropriate unit of analysis.

2. Proposition of the study is:

a) Commissioning problems could affect the project timely completion.

3. Its unit(s) of analysis

The entity for this study is the projects as a case. Contractors and consultants (individual) who's involved in these construction projects in a public institution of higher learning in Malaysia are interviewed. According to Yin (1994), without such suggestions, the researcher would be attracted to collect “everything”. Therefore, the proposition serves as a demarcation to direct the research towards achieving the purpose of study and within feasible limit without deviated from the research objectives.

4. The logic linking the data to the propositions, and the criteria for interpreting the findings.

These components represent data analysis steps in case study research. In relating the data to the propositions, the pattern-matching technique is a way. Detailed guidance on this step is not provided by the current state of the art but the complete research should not only specify what data are to be collected (Yin, 1994).

5. Criteria for matching and interpreting a study’s findings.

The identification and to address rival explanations of the findings is a major and important strategy (Yin, 2009).

3.7.1 Case Study

A case study may be understood as the intensive study of a single case where the purpose of that study is partly to at least shed light on a larger class of cases (a population). However, the term “case study” also has an additional implication that the unit(s) under special focus is not perfectly representative of the population. However, this shortcoming is generally acceptable as sometimes, in-depth knowledge of an individual example is more helpful than fleeting knowledge about a larger number of examples. By focusing on a key part, someone can gain better understanding of the whole (Gerring, 2007). Therefore, by focusing on project termination phase in a public institution of higher learning in Malaysia, someone can gain better understanding of building commissioning.

Platt (1992) observes that “much case study theorizing has been conceptually confused, because too many different themes have been packed into the idea ‘case study.” According to Yin (2009), a common flaw about case study is to consider it as the exploratory stage of some other type of research method. A case study is logic of design (Platt, 1992) and it should be defined as an empirical enquiry that investigates a contemporary phenomenon in depth and within its real-life context especially when the boundaries between phenomenon and context are not clearly evident. The case study inquiry relies on multiple sources of evidence and copes with technically unique situation in which there will be many more variables of interest than data points as one result. The case study benefits from the prior development of theoretical propositions to guide data collection and analysis (Yin, 2009).

Case studies represent another type of qualitative research and are different from other types of research approach. Case studies are intensive analyses and descriptions of a single unit or system bounded by space and time. Topics often examined in case studies include individuals, events, or groups. The researcher hopes to gain in-depth understanding of situations and meaning of building commissioning for those involved through case studies. Although case studies are discussed extensively in the literature and employed frequently in practice, little has been written regarding the specific steps one may use to successfully plan, conduct, and share the results of a case study project (Hancock & Algozzine, 2006).

As tabulated in Table 3.3 refers to what a work as a "case study" might mean:

Table 3.3: Meaning of a Case Study

	Options	**Explanations**	**Applicability with the Current Study (√)**
a)	its method is qualitative, small-N (Eckstein, 1975; George & Bennett, 2005; Lijphart, 1975; Orum, Feagin, & Sjoberg, 1991: 2; Van Evera, 1997: 50; Yin, 1994)	Eight cases are selected for this study which will be explained more details in section 4.6.2.	√
b)	the research is holistic, thick (a more or less comprehensive examination of a phenomenon) (Goode & Hart, 1952: 331; quoted in Mitchell, 1983: 191; Queen, 1928: 226; Ragin, 1987, 1997; Stoecker (1991: 97; Verschuren, 2003).	A comprehensive examination of the issues on building commissioning in the Malaysian construction industry.	√
c)	it utilizes a particular type of evidence (e.g., ethnographic, clinical, non-experimental, non-survey-based, participant-observation, process-tracing, historical, textual, or field research) (George & Bennett, 2005; Hamel, 1993; Hammersley & Gomm, 2000; Yin, 1994).	Utilization of non-experimental, non-survey based, participant observation evidence by conducting semi-structured interviews, attending site meeting, review of documentations and etc.	√
d)	its method of evidence gathering is naturalistic (a "real-life context") (Yin, 2003: 13).	Gathering of evidence based on real-life context from the construction projects.	√
e)	the topic is diffuse (case and context are difficult to distinguish) (Yin, 1994: 123).	The case and context of the study are hard to be differentiated.	√
f)	it employs triangulation ("multiple sources of evidence") (Yin, 1994: 123).	Non-survey based method, participant observation and reviews of documentations for these cases to collect evidence.	√
g)	the research investigates the		√

Table 3.3: Meaning of a Study (Cont'd)

	Options	Explanations	Applicability with the Current Study (√)
g)	properties of a single observation (Campbell & Stanley, 1963: 7; Eckstein, 1975: 85).		
h)	the research investigates the properties of a single phenomenon, instance, or example (George & Bennett, 2005; Odell, 2001: 162; Thies, 2002: 353; Platt, 1992: 37;48).	The single phenomenon being investigated for this study was problem during building commissioning.	√

3.7.2 Rationality for the Selection of Multiple Case (Holistic) Design

According to Yin (2009), multiple-case design is preferred over single-case designs as the benefits of doing two-case study will be better than using a single-case design. This study employed a holistic design as it only examined the issue of building commissioning for the institutions of higher learning in Malaysia (Yin, 2009). More essentially, the analytic benefits from having two or more cases would be substantial and is potential for direct replication. According to Szanton's (1981) who used eight case studies in showing how different universities group all failed to help cities. According to him, eight case studies are sufficient replications to convince the reader of a general phenomenon. Besides, more than two cases will aid to neutralize the criticisms that might turn into skepticism on the ability of doing empirical work by having only one case study. Having two or more cases will produce an even stronger effect. Thus, for instance, Derthick (1972) reported on seven case studies from a site in a prominent federal program. When the lessons from each case study were compared, a common explanation emerged was used to characterize the problems of federal program implementation.

Finally, while there is no ideal number of cases, a number between four and ten cases will usually work out well (Eisenhardt, 1989). According to Herriott and Firestone (1983), the evidence from multiple cases is often considered more compelling, and the overall study was regarded as being more robust. Thereafter, this research opts to select eight cases for the multiple-case deigns. This study covers several construction projects in a public institution of higher learning in Malaysia. Each of these construction projects is the subject of an individual case study. Lessons from each case study are compared and common explanation emerged are used to characterized building commissioning problems for construction projects in a public institution of higher learning in Malaysia.

Rationality of the selection of case studies in a public institution of higher learning in Malaysia was that these cases were not selected because of their distinctive technologies or for any other substantive reason (Yin, 2009). The main criterion besides proximity (Yin, 2009) was the fact that access to these cases was made easy. Commissioning is underutilized in public-interest deployment programs and research-and-development activities (Mills *et al*., 2005). The scope of research was on-going construction projects in one of the public institutions of higher learning in Malaysia (as illustrated in Figure 3.4) during the candidature period of the researcher. Several candidates for case studies were initially identified from these projects (Nitithamyong & Skibniewski, 2010).

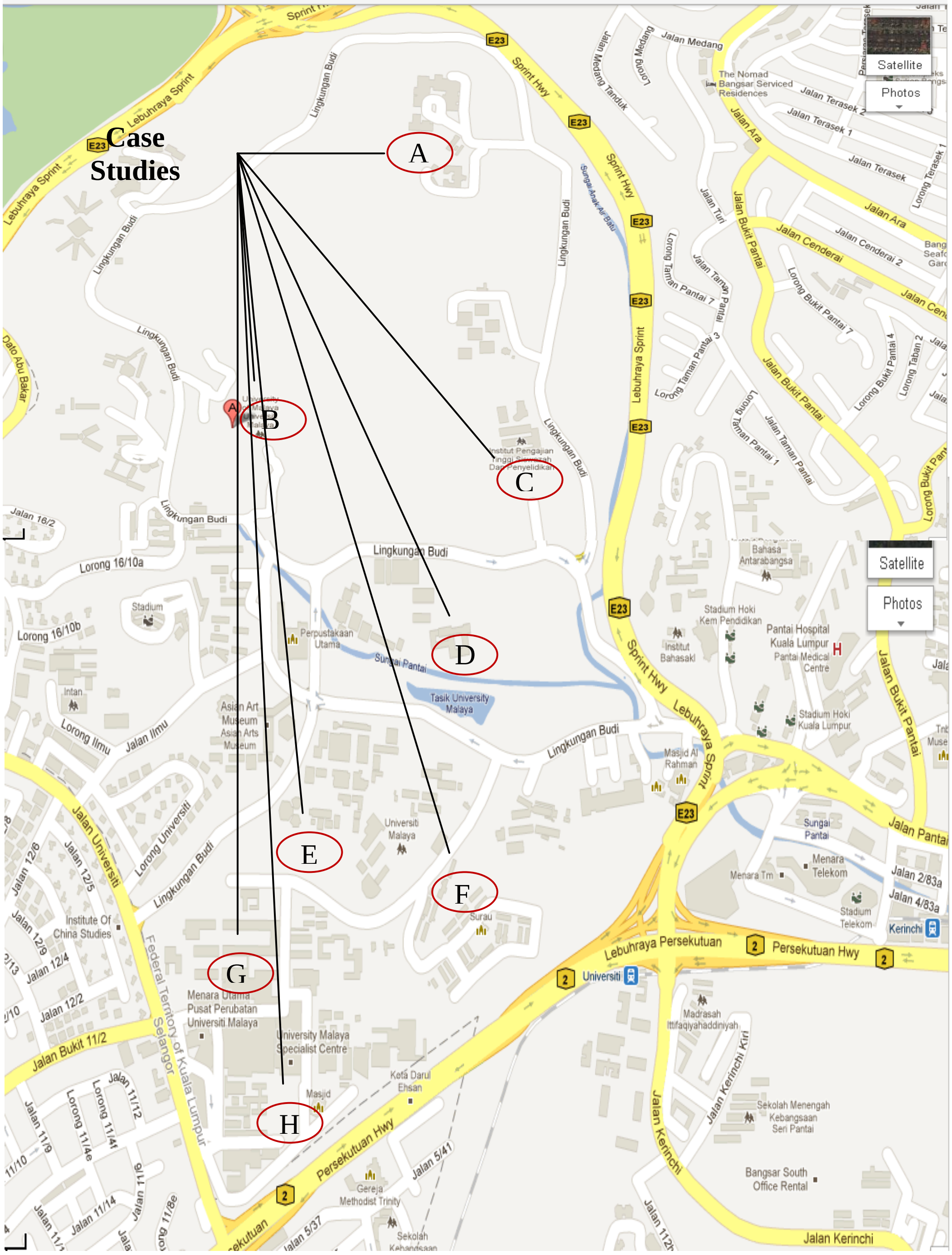


Figure 3.4: Map for the Selection of Case Studies for a Public Institution of Higher Learning in Malaysia

3.8 Cross Sectional Design

This was a cross-sectional study which involved observation of a sample of on-going construction projects in a public institution of higher learning in Malaysia from year 2011 till 2012. The phenomenon and problems of commissioning for some of these projects during the candidature period for the researcher was studied.

3.9 The Case Study Protocol

The protocol is directed at a single data point. In this study, the single data point is the project which is part of a multiple case study. The protocol not only encloses the instrument but also enfolds the general rules and procedures to be followed. The protocol aims to guide in carrying out the data collection and to increase the reliability of case study research. Firstly, the case study protocol keeps the topic of the case study targeted. Second, preparation of the protocol enables the anticipation of several problems and the ways the case study reports are to be completed (Yin, 2009).

The case study protocol as shown in Table 3.4 is used to guide the researcher in collecting data from the projects. The protocol started with the delineation of the purpose of the case study, and then followed with the data collection procedures, outline of the case study report and lastly the case study questions. The protocol as recommended by Yin (2009) is followed in this study to focus on the effect of the mind and to ensure the research process is organized. This protocol also helps to keep track of the research activity due to the complexity of the material in case study research.

To adhere to this protocol as recommended by Yin (2009) in Table 3.4, each of these potential interviewees identified for this study will be contacted to introduce the case study to them when they are contacted by the researcher through telephone. If the interviewee agreed to participate, the researcher will follow up with them closely from time to time till an actual appointment has been fixed with the interviewee or with their personal assistance or secretary. Sometimes, if required by the interviewee or when necessarily, the case study questions will be emailed to them beforehand. Besides that, an approval letter issued by the researcher's university to obtain information will be attached together with the case study questions as a formality for data collection. If the interviewee replied to the email and agreed to be interviewed, the researcher will do the necessarily preparation prior to the site visit. This expectation and preparation prior to site visit is important to avoid missing out of any important information during the conduct of the actual case study.

As a general matter as mentioned by Yin (2009), a case study protocol should have an overview of the case study project which comprises of the project objectives, case study issues and relevant readings on building commissioning. Another section which should be incorporated in the protocol is the field procedures such as the presentation of credential, access to the case study site, language used, sources of data and procedural reminder. For this case study of the public institution of higher learning in Malaysia, first of all, access to this site must be obtained from the respective university's development department. With this credential, the researcher will proceed to identify those persons-in-charge for these projects to gain their approval to conduct case study research on building commissioning. The language used will be English but interchangeably with Bahasa Malaysia if necessarily to explain the issues concerned in a clearer manner. Sources of data to be obtained from the site are not easy as most of this information is deemed confidential. To counter this problem, the researcher will request the interviewee to provide verbal information or the researcher will only review this document or information on site. The researcher will ask permission from the interviewee to take note of this information. Procedural reminder for this case study will be not to emphasize too much on the problems of building commissioning in the beginning of the case study. The researcher will begin the session with an overview of the case study before going deep into certain issue on building commissioning. After the field procedures, the researcher must keep in mind of this case study questions when collecting data. Case study questions for this research are presented in a table for specific arrays of data on building commissioning and the possible sources of information to answer each question (referred to Appendix A). Lastly, the protocol should have a guide to present the case study report.

Table 3.4: Case Study Protocol

A. Introduction to the Case Study and Purpose of Protocol

1. Case study questions

   a) How someone would perceived building commissioning in the Malaysian construction industry?
   b) Why project commissioning is not considered as an integral part of the project life-cycle?
   c) Why and how problems in building commissioning can eventually leads to delay in project completion?

2. Role of protocol in guiding the case study

The protocol also directed at an entirely different party than that as compared to survey questionnaire and to increase the reliability of

Table 3.4: Case Study Protocol (Cont'd)

case study research. Most importantly, the protocol guides carrying out the data collection by being able to anticipate problems. By having such forethoughts will aid to avoid mismatches. B. Data Collection Procedures a) Names of sites to be visited and contact persons These are specified in each of the table of case studies' questions as attached in Appendix A. b) Data collection plan i. covers the types of evidence to be expected from the respondents such as their consensus to be interviewed and any relevant information found from the case study, The researcher should search for different kinds of evidence: what people say, what you see them doing, what they make or produce, what documents and records show. The main types of evidence for this study are interviews, documents, and participant observations (if possible). ii. the roles of people to be interviewed are to provide feedbacks and information required to achieve the objectives of this study; It is also hopes that these interviewees will provide valuable insight on how to improve the study being conducted. iii. the events to be observed at the construction site for this study are the physical progress at site and to observe any uncompleted works or outstanding work at site when the interview is conducted, and iv. document to be reviewed when on site (if available) is information related to the site visited such as the project's progress report, milestones for testing and commissioning programme, and minutes of meeting for testing and commissioning meeting (if available). c) Expected preparation prior to site visits (Identifies specific information and issues of building commissioning to be covered prior to going on site). C. Outline of Case Study Report a) Background of the Case Study b) Other Issues of the Case Study c) Discussions of the Case Study

(Source: Yin, 2009: 80)

3.9.1 Overview of the Case Study Project

The overview covers the background information about the project, which will be further elaborated in Chapter 5, and relevant readings about building commissioning issues which have been described in Chapter 1 and 2. Every project has its own context and perspective and may form the basis for the background to the final case study report. This case study project focuses on the institutions of higher learning in Malaysia which is conducted by the researcher herself. Building commissioning issues being investigated, the rationale for selecting the case(s), the case study's purpose, the broader or theoretical or policy relevance of the inquiry and the relevant readings about the issues are presented.

3.9.1.1 Selection of Cases

In case study research, random sampling is inappropriate as a selection method because there is no guarantee that a few cases chosen randomly could provide leverage into the research question that animates an investigation. Besides, the sample might be representative but uninformative as in case study research the sample is small (by definition) which caused randomization problematic. The goals of case selection remain the same regardless of the size of the chosen sample. The selection of cases aims to identify cases that reproduce the relevant causal features of a larger universe (representativeness) and provide variation along the dimensions of theoretical interest (causal leverage). However, in case study research, this goal must be achieved through purposive (non-random) selection procedures (Gerring, 2007).

Hence, this study used purposive sampling wherein the case study focuses on the institutions of higher learning in Malaysia.

3.9.1.2 Rationale for the Selection of Case Studies in a Public Institution of Higher Learning in Malaysia

The case can be whatever "bounded system" of interest such as an institution, a program, a responsibility, a collection. This is not to trivialize the notion of "case" but to note the generality of the case study method in preparation for noting its uniqueness (Robert, 1978). Intrachooto and Arons (2002) stated that the current process for the construction of buildings on campus for institutions of higher learning was generally inefficient. Both of these claims by Robert (1978) and Intrachooto and Arons (2002) complemented each other to explain rationality for the selection of institutions of higher learning in Malaysia as the case. Case studies conducted by Environment Design and Construction ("Collaborating on Commissioning," 2007) further supported this rationale as universities are amongst the case selected to show the benefits of commissioning in a diversity of environments.

Besides that, the ease of accessibility of information to these construction projects was one of the criteria for selecting construction projects in the institutions of higher learning in Malaysia. These construction projects were selected as these projects were actually managed and participated by various external construction teams, such as: external client’s representative from the government, external architect, engineers and contractor. Therefore, by studying these projects would enable an effective use of non-campus expertise and knowledge simultaneously. Most importantly was no study has been done on commissioning for public institutions of higher learning in Malaysia. Building construction in public buildings employ the same method and process in procurement, design, construction and commissioning stage. Therefore, we can show the trend or pattern using samples taken from the institutions of higher learning in Malaysia as the case study.

Commissioning provides American Society of Heating, Refrigerating and Air-Conditioning Engineers' (ASHRAE) members a potentially profitable revenue stream, and an opportunity to be a substantive player along with the architects, in delivering high performance building systems (Tseng, 2005). An Exterior Enclosure Commission (EEC) is defined as an assessment plan for the entire construction process and insures realization of performance goal. This commissioning involves architects, designers, contractors, sub-contractors, suppliers, and the owner in agreeing to, and to set a path in meet energy goals (Anis, 2010). The approached interviewees were those working for the contracting companies and consultants, who are contractors and consultants such as: construction manager, engineer, project manager and architect with a minimum of ten to more than forty years of experience. These disciplines among interviewees which comprised of the contractors and consultants enabled a more compelling comparison to be made among those who are in the realm of commissioning.

3.9.2 Field Procedures

Case study is a study of events within their real-life context on which properly defined field procedures are essential. Data will be collected from people and institutions in their everyday situations. Therefore, it is necessarily to integrate real-world events with the needs of the data collection plan. The field procedures of the protocol needs to highlight these major tasks, such as: gaining access to key organizations or interviewees, having sufficient resources while in the field i.e. writing instruments, voice recorder and pre-established answer sheets. Besides that, it is also important make a clear schedule of the data collection activities to be completed within a specified periods of time. The researcher should also anticipate changes in the availability of the interviewees or changes of the appointment made to cater the interviewee's schedule and availability (Yin, 2009).

3.9.3 Case Study Questions

The protocol's questions are reminders concerning the information that needs to be collected to answer the research objectives. The protocol is for the data collection from a single case even when the case is part of a multiple-case study. These questions in the protocol also serve as a prompts in asking questions during a case study interview. The main purpose of the protocol's questions is to keep the researcher on track as data collection proceeds. These questions also allow the researcher to quickly review the major questions that the data collection should cover (Yin, 2009) before starting the interview session. With these key questions in mind, the researcher will be reminded to stay focus on the purpose of the case study and not to deviate or carry away by the interviewee to discuss on other issues irrelevant to the case. Therefore, it is utmost essential to bear in mind of these case study questions, as the interviews will proceed in accordance with the case study questions. The table for case study questions can be found in Appendix A.

3.10 Theory Development

Development of theory as part of the design phase is vital for case studies (Yin, 1994). The complete research design will increasingly cover the five components of the needed research design such as the questions, propositions, units of analysis, logic connecting data to propositions and criteria for interpreting the findings. It also embodies a theory of what is being studied. Theory development prior to the collection of any case study data is a vital step in doing case studies (Yin, 2009). The simple goal of theory development is to have sufficient blueprint of the study which requires theoretical propositions (Yin, 2009) and this is noted by Sutton and Staw (1995) as "hypothetical" story about why acts, events, structures and thoughts occur. Literature reviews related to building commissioning are reviewed in preparing the case study for theory development. For the multiple-case study, the mode of generalization is analytic generalization. Previously developed theories are used as a guide to compare the empirical results of the case study in this kind of generalization (Yin, 2009). Details for this are described further in the following section.

3.10.1 Systematic Combining

A multiple method approach was used to permit a "triangulation" (van Maanen, 1979) of data collection to provide valid observations of coordinated purchasing activities and decisions. Data from direct observation, a review of company records, personal interviews, and a literature review were compared and contrasted in an attempt to produce clarity in understanding information processing and decision making in corporate purchasing agreements.

As demonstrated in Figure 3.5, the main characteristic of systematic combining is a continuous movement between an empirical world and a model world. During this process, the research issues and the analytical framework are successively reoriented when they are confronted with the empirical world. Systematic combining is a process where theoretical framework, empirical fieldwork, and case analysis evolve simultaneously. The proposed systematic combining is an argument for a stronger reliance on theory than is suggested by true induction (Dubois & Gaide, 2002).

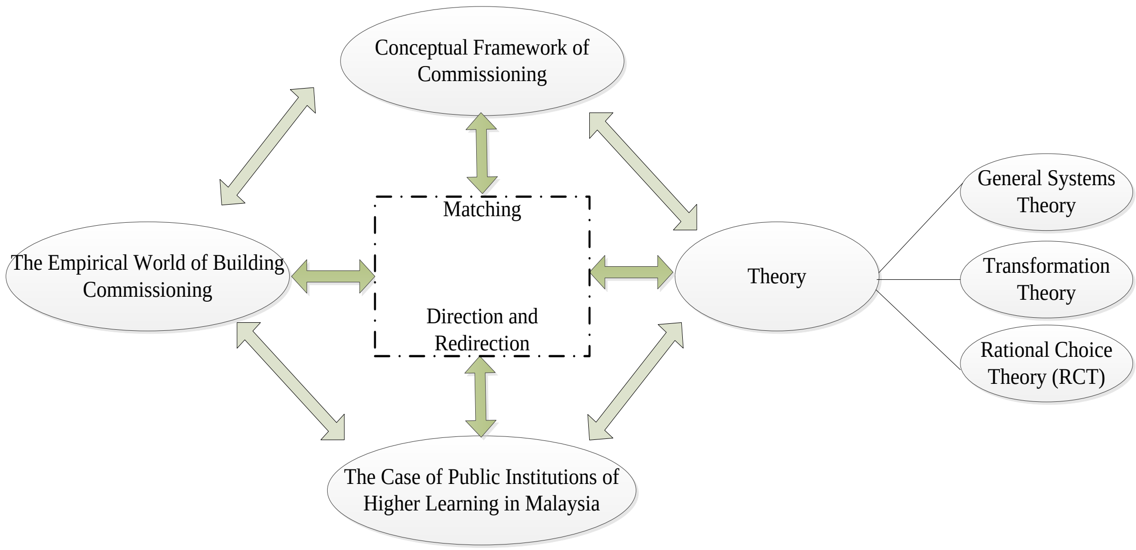


Figure 3.5: Systematic Combining
(Source: Developed from Dubois & Gaide, 2002: 555)

Some case studies are simply rich descriptions of events from which the readers are expected to come to their own conclusions (Easton, 1995: 379). Weick (1979) suggested solving this problem by "invest in theory to keep some intellectual control over the burgeoning set of case descriptions".

The Embedded Commissioning Model (ECM) by Turkaslan-Bulbul and Akin (2006) was used as general theoretical foundation focusing on building information exchange. The Embedded Commissioning Model (ECM) illuminated the combination of commissioning process and the building life-cycle to manage the information exchange among them. But, this are not yet fully utilized at this point because commissioning is not considered as an integral part of the project life-cycle (Pinto & Slevin, 1987; Tishler, Dvir, Shenhar & Lipovetsky, 1996; Bennett, 2003).

The focus on building commissioning brought efficiency into the picture. One problem was that the commissioning concepts found in the literature required the object scrutinized to be somehow delimited. Already at this stage, this was perceived as a problem because commissioning activities were interrelated with the project life-cycle in so many ways. Moreover, identifying problems and interdependencies of commissioning activities appeared to be more interesting than only measuring factors of delay per se. Data collection continued in a similar way, but with the new research focus. As a result of these efforts, the picture of the setting to search for a commissioning model grew stronger. The new view of reality illuminated the connections between commissioning and other problem areas in the project life-cycle. Particularly the understanding of the commissioning matters grew stronger during this period.

Parallel to the data collection, the search for complementary theories continued and guided by the findings in the empirical world. A particularly useful theory would be one that solved the problem of how to analyze commissioning issues without setting clear boundaries. The single most important reference found during this process was “the general systems theory” (Kast & Rosenzweig, 1972). Concepts and models from this article contributed to a rearticulation of the research problem. The conceptual framework now developed in a direction where integration of commissioning problems with the project life-cycle became the central issue. This, in turn, put commissioning activities among projects into focus. These insights from theory affected the discussions with people in the projects and were the starting point for the redirection.

In the case study initially described, the researcher set out to analyze the activity dimension/practice/defined understanding of building commissioning to explain the effects on the project life-cycle. The commissioning conceptual model functioned as a rather general initial framework when the fieldwork was initiated. Parallel to the data collection the search for useful theories, complementary to the general framework, was ongoing, guided by the fact that the empirical observations and the current theoretical framework did not match. For this endeavor, an Embedded Commissioning Model was found (Turkaslan-Bubul & Akin, 2006) that could explain some of the interdependencies between these antecedent activities that had been empirically identified. Thereby, the empirical fieldwork continued from a revised theoretical platform. This is an illustration of what we mean by the matching process.

Systematic combining builds more on refinement of existing theories than on inventing new ones. In studies relying on abduction, the original framework is successively modified, partly as a result of unanticipated empirical findings, but also of theoretical insights gained during the process. This approach creates fruitful crossfertilization where new combinations are developed through a mixture of established theoretical models and new concepts derived from the confrontation with reality (Dubois & Gaide, 2002). By adopting the Embedded Commissioning Model (ECM) by Turkaslan-Bulbul and Akin (2006) as a fundamental basis, Figure 3.6 illustrates the conceptual framework for building commissioning developed from this initial model of Embedded Commissioning Model (ECM).

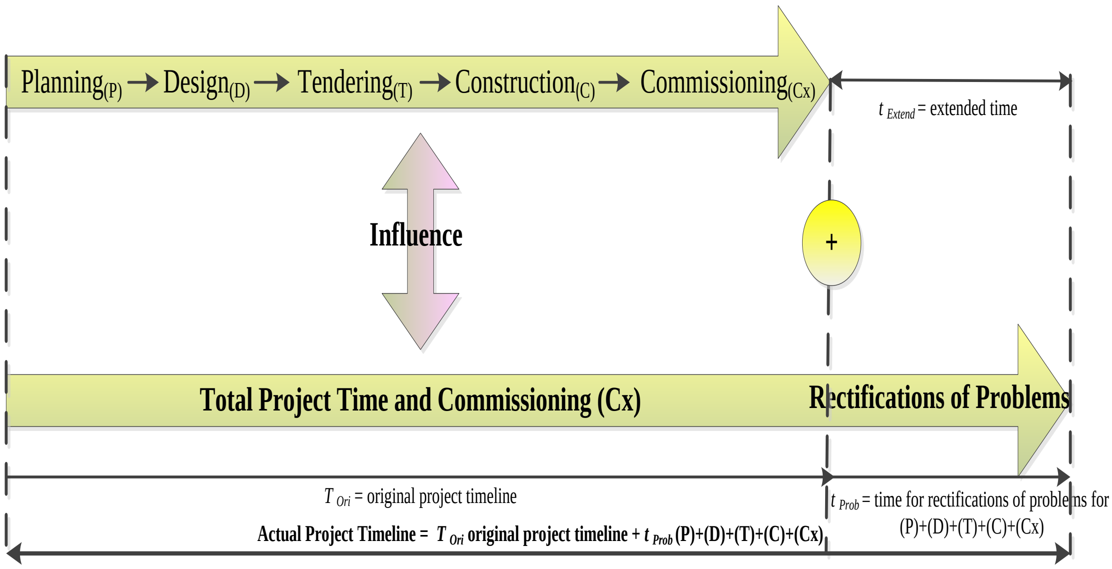


Figure 3.6: Conceptual Framework of Building Commissioning for Public Institutions of Higher Learning in Malaysia

3.10.1.1 General Systems Theory

General systems theory emphasizes that systems are organized and composed of interdependent components in some relationships. All systems may be considered to be organized but these systems do not have purposeful entities. The concern of general systems theory is mainly the way organism responds to the environmentally generated inputs. The concepts of feedback and the maintenance of a steady state are based on internal adaptations to environmental forces. What about those changes and adaptation which occur from within social organizations? Purposeful elements within the social organization may initiate activities and adaptations which are hard to be included under feedback and steady state concepts. Therefore, it is the interest of this study to identify those changes of commissioning which occur within the construction project (Kast & Rosenzweig, 1972).

3.10.1.2 Transformation Theory

Current theories of the design and construction processes suggest significantly different progressions, with design perceived as being generally iterative and cyclical in nature (Austin *et al*., 1999a; Brawne, 2003: 33), and construction as being linear and sequential in nature (Koskela, 2000: 257). This view of construction is based on ***transformation theory***, which describes the process by which inputs are changed into outputs. It is the theoretical model that underlies the current understanding of the production process and thus of the construction process (Koskela, 2000: 38). The important interface between the design process and the construction process is complex to manage due to the contrasting cyclical and linear characteristics between them. They also make it difficult to find one tool that will cope with planning, design and construction (Mitchell, Frame, Coday & Hoxley, 2011).

It is postulated in this study that in the process to change inputs into outputs; there is lack of attentiveness on building commissioning problems as in comparisons with problems on construction delays. Different phases in a construction project might have different characteristics which might then affect the production process in construction. It is hypothesized in this study to portray the double-effect of construction and commissioning problems on the project timely completion. Different factors of delay in different phases will have a different impact on the project.

Processes are the place in which resources, assets, and competencies of an organization are put together to produce a desired output (Hammer & Champy, 1993; Hammer & Stanton, 1999; Crowston, 1997). The adoption of a process view allows the identification and addressed of structural inertia by looking into these resources, assets, and competencies of an organization. This has indirectly supporting a type of organizational cognitive re-orientation. For these reasons, the adoption of a process view is proposed as a means to sustain and understand information and knowledge intensive processes, such as the development of new services, the formulation of operative strategies, and the implementation of information systems (van de Ven & Poole, 1990).

The preceding of rapid and superficial survey tend to show that the problems concerned under the term system nowadays were not born yesterday out of current questions of science, mathematics, and technology. Rather, they are a contemporary expression of perennial problems which have been recognized for centuries and discussed in the language available at the time. The second maxim of Descartes's Discours de la Methods was to break down every problem into as many separate simple elements as might be possible. This, similarly formulated by Galileo as the resolutive method, was the conceptual paradigm (Kuhn, 1962) of science from its foundation to modern laboratory work: that is, to resolve and reduce complex phenomena into elementary parts and processes. It is postulated in this study that the project close-out phase towards handing over process was studied to sustain and gain more information and knowledge in this ultimate process to improve timely completion of the project.

3.10.1.3 Rational Choice Theory (RCT)

The purpose of the current study is to apply one of the leading sociological explanations of deviant behaviors, namely Rational Choice Theory (RCT) (Bachman, Paternoster & Ward, 1992; Paternoster & Simpson, 1996), to building commissioning problems and delays in the construction industry. The current undertaking can make an important contribution to understand the essentiality of compliance with building commissioning. In this study, the rational choice perspective was employed to examine the influence of commissioning problems on project timely completion.

Rational choice theory was originally developed by Becker (1968) with the central proposition that offenders weigh the costs and benefits of deviant behaviors in deciding whether to offend. Most adherents of rational choice theory envision exclusively the second possibility. For example, by proposing "a rational choice perspective" - that "takes as its central core the idea that persons act rationally to satisfy preferences, or to maximize utility" (Coleman, 1994: 166).

As developed here, it is one of stimulus competition, with richer environments and greater interludes providing more opportunities for interference. A stimulus-sampling model of acquisition (Bower, 1994; Estes & Suppes, 1974; Neimark & Estes, 1967;

Estes, 1950) provides the basis of a model of acquisition in the face of such contingencies degraded by delay and distraction (Killeen, 2001a). Thus, inference was made based on these previous studies by putting forward the impacts of these interruptions in the construction industry. In relation with these distractions of delays in construction; it may then interlude the execution of planned commissioning and subsequently further magnifying the magnitude of delay. It is believed that the mitigation of this interruption caused by building commissioning will improve the project timely completion.

This comprehensive model of choice leaves unanswered the question of why we often make choices that defeat our own plans—that is, why impulses or temporary preferences arise for alternatives that usually seem inferior. The diagnosis of impulse which control disorder covers a wide range of behaviors that lie at the extremes of ordinary bad habits, including pathological gambling, compulsive shopping, intermittent explosive disorder, binge eating, and problematic internet use (Hollander & Stein, 2006).

3.11 Interpretivist Research

Interpretivist research believes that it is more likely that people experience physical and social reality in different ways. The interpretivist research assumes that the world is largely what people perceive it to be and interested to understand the lived experience of human beings. Nevertheless, interpretivist research received some criticisms as: 1) it is too subjective; 2) it focuses on local and micro-level or short-term events; and 3) it does not seek to initiate change. (Cavana *et al*., 2001). In the development of theory, the interpretivist seeks to comprehend the nature of multiple influences of a phenomenon through case studies. The search for multiple influences means focusing upon the intrinsic details of individual cases and the differences between diverse classes of case. This aids the interpretivist to describe phenomena and hopefully put on new and creative insights to realize ultimately the nature of one's behaviour in its fullest sense (Malhotra & Birks, 2007).

The involvement of the researcher with these individual subjects allows the researcher to uncover the socially constructed meaning of building commissioning as it is understood by an individual or a group of individuals. Interpretivist research produce a rich and complex description of how people think, react and feel under certain contextually specific situations rather than producing general or predictive laws about human behavior on building commissioning for the Malaysian construction industry (Cavana *et al.*, 2001).

In interpretivist research, an area of enquiry is identified, but with little or no theoretical framework. Theoretical framework is seen as restrictive, narrowing the researcher's perspective and an inhibitor to creativity. However, broad themes are identified for discussion, with observation, probing and in-depth questioning to elaborate the nature of these themes. The researchers develop their theory by searching for the occurrence and interconnection of phenomena. They seek to develop a model based upon their observed combination of events. Such a process means that interpretivists reach conclusions without 'complete evidence' (Malhotra & Birks, 2007).

3.12 Reliability, Replicability and Validity

It is important to know that it is impossible to identify typical cases that can be used to represent a certain class of objects such as managers, factories, or critical events or to put it in another way that case study is not a sample of one. Although it is emphasized that many researchers are interested in the detail of a single case, however, they do sometimes assert a degree of theoretical generalizability on the basis of it (Bryman & Bell, 2007). However, Yin (1984) claimed that there are appropriate criteria and propose ways to develop case study research to enhance its ability to meet the criteria like this. Case study research has restricted external validity, as it is not the purpose of this research design to generalize to other cases or to populations beyond the case. As an alternative, case study research aims to generate an intensive examination of a single case (Bryman & Bell, 2007). It is not whether the case study findings can be generalized to a wider universe, but how well the researcher generates theory out of the findings (Mitchell, 1983; Yin, 1984).

3.12.1 Replication for Multiple Case Studies

Each case of multiple case study must be carefully selected so that it either predicts similar results (a literal replication) or predicts contrasting results but for anticipatable reasons (a theoretical replication). If all these six to ten cases turn out as predicted, in the aggregate, would have provided compelling support for the initial set of propositions (Yin, 2009). Literal replication is selected to be achieved in this study, and analogously, the designated number of replications depends upon the desired certainty to be derived from multiple-case results. In this research, eight cases of construction projects are selected within a multiple-case design from a public institution of higher learning in Malaysia from year 2011 till 2012. According to Szanton (1981), eight cases are sufficient "replication" to convince the reader of a general phenomenon in showing how different universities groups all failed to help cities.

This kind of case study research allows the researcher to compare and contrast the findings deriving from each of the cases. Multiple case studies also encourages researcher to consider what is common across cases and what is distinctive, and to promote theoretical reflection on the findings. Comparative design embodies the logic of comparisons. It also implies the importance to better understand social phenomena when these cases are compared in relation to two or more meaningfully contrasting cases or situations. The comparative design aims to gain a greater awareness and a deeper understanding of social reality in difference national contexts or to seek explanations for similarities and differences (Bryman & Bell, 2007).

An embedded design is chosen because surveys of the consultants or examinations of the projects' progress archival records are needed to address the research questions about the performance of the construction projects. With an embedded design, each individual case study may include the collection and analysis of quantitative data via the use of surveys within each case (Yin, 2009).

3.13 Summary of Chapter

It is important to understand that there is no single research approach or methodology that is appropriate for every research question. Therefore, qualitative research is adopted to provide a holistic understanding of research participants' views and actions in the context of institutions of higher learning in Malaysia.

CHAPTER 4

CASE STUDIES REPORT

CHAPTER 4

CASE STUDIES FINDINGS

4.1 Introduction

In this chapter, case studies' findings are presented to highlight the issues of building commissioning pertaining to the Malaysian construction industry. The outline of the findings is illustrated in Figure 4.1.

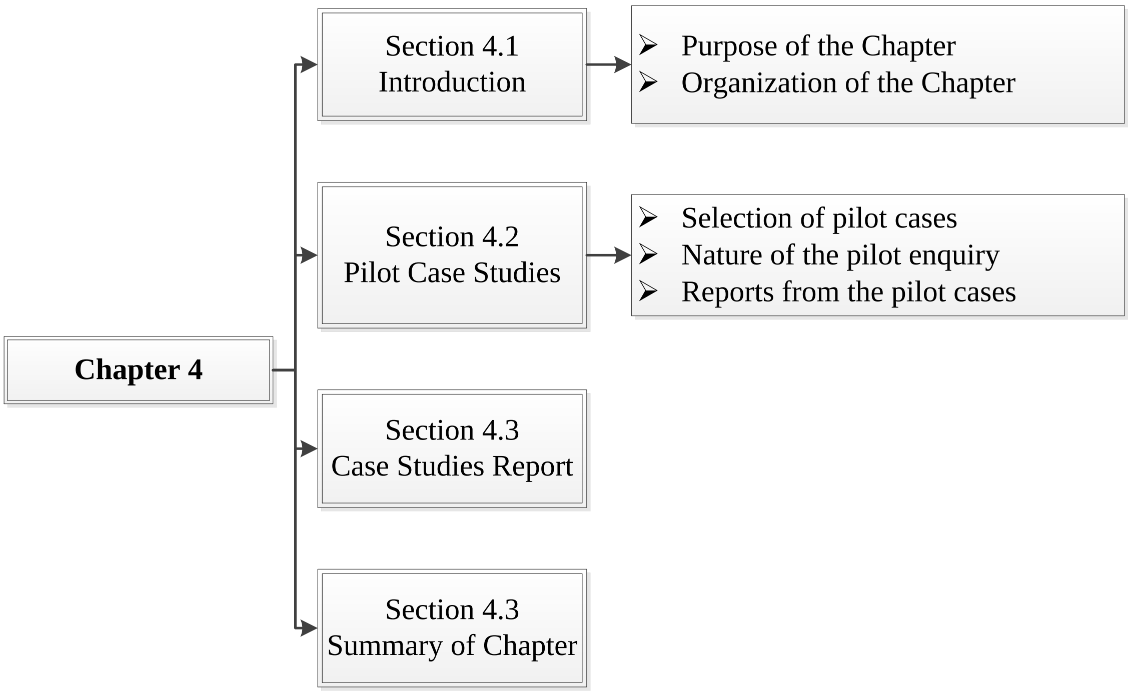


Figure 4.1: Outline of Chapter 4

4.2 Pilot Case Studies

Pilot case studies are conducted for several reasons but these reasons are unrelated to the criteria for selecting the final cases in the preparation of case study. Even though these pilot case studies does not represent the most complicated cases but the issues found are important in refining the data collection plan. This data collection plan includes the contents of the data and the procedures required. The aim of this pilot case study is to assist in the development of relevant questions and to study in depth actual cases. Pilot case study is also helpful in detailing the case study protocols for different phenomenon of commissioning from different angles on a trial basis (Yin, 2009).

4.2.1 Selection of Pilot case studies

For this thesis, the relevant case studies were selected due to access, convenience and geographic proximity. Besides that, the interviewees concerned were congenial to the notion that the researcher did not have a fixed agenda during the early stage of her research. In this study, four cases were selected from the construction projects located in the vicinity of Klang Valley, Malaysia as the pilot case studies regardless of the size of and the percentage of completion for these projects. Four cases were deemed sufficient for this study because there were not much amendment in the design of the interview questions from the transition of this case study from one to another.

4.2.2 Nature of the Pilot Enquiry

The pilot case's scope of inquiry is much broader and less focused than the ultimate data collection plan. The pilot data provides considerable insight into the basis issues of building commissioning and to improve its conceptualization. This information is used in parallel with an ongoing literature reviews. Hence, the final design is informed both by a fresh set of an empirical observations and prevailing theories to ensure the actual study reflected the significant theory or policy issues. These pilot case studies also provide information on the relevancy of the field questions and about the logistics of the field inquiry. Eventually, the conduct of pilot case studies developed a satisfactory procedure for the formal data collection plan later on (Yin, 2009). The purpose of the pilot study is to check the clarity of interview questions (Fellows & Liu, 2003).

4.2.3 Reports from the Pilot case studies

The pilot report should be explicit about the lessons learned for both research design and field procedures. The conduct of sufficient pilot case studies, the final agenda derived from these pilot case studies may actually become a good prototype for the final case study protocol. The pilot case was conducted by using open-ended question to gain broader views on the relevant subject on commissioning in the Malaysian construction industry. This pilot case study managed to portray the relevancy and the logistics of the field questions asked. The case studies were done by posting different questions to the interviewee. During the pilot case study, issues pertaining to building commissioning and other questions relevant to the researcher's line of inquiry were asked to the interviewee. Profile for the interviewees for pilot case study is shown in Table 4.1. These interviewees were randomly selected to confirm the significance and the persistence of commissioning problems in this study. The interviewees selected for this pilot case are those with at least 7 years of experience in the construction industry. The interviewees are from a diverse field. This is to help the research to cover view points from different angles. This will aid the comprehensiveness of the actual case study.

Table 4.1: Profile of the Interviewees

Interviewees	Position held by the interviewees	Year of Experience
Interviewee I	Civil Engineer	9++
Interviewee II	Contract Manager	15++
Interviewee III	Mechanical and Electrical Engineer	7
Interviewee IV	Construction Manager	16

The interview questions are tabulated in Table 4.2. These questions were asked during the pilot case study. The pilot case study was conducted to determine the understanding of interviewees on building commissioning. This approach is to gain a rough idea on the current scenario and potential problems of building commissioning in the Malaysian construction industry. The aim of this pilot case study is to acquaint with issues in building commissioning and problems during commissioning. These commissioning problems need to be examined as consequently, these problems will affect the completion and performance of construction projects in the Malaysian construction industry. Various understanding was derived from the interview findings on building commissioning. This finding further strengthens the need to conduct this research study. This research importance is further complemented by the need to identify the importance of building commissioning to ensure the building is functioning well and to further identify the possible influence of commissioning problems on project completion. The aim of this pilot case study is to improve the instruments to be used for actual case study later on. Questions that were unclear and ambiguous might be modified or eliminated before proceeding to the fourth pilot case study.

Table 4.2: Interview Questions for Pilot Case Study

No.	Question asked	Answer	Reasons
1	Are there any problems during commissioning?	Yes.	• Work progress is hurried to close-out the project; • Poor management of commissioning and poor workmanship; • Due to problems during construction and installations of architectural elements. • Local authority's inspection – to change the design for safety purpose.
2	What is your understanding of building commissioning in the Malaysian construction industry?	Varies understanding found from the interviewees.	• Commissioning will be interchangeably used throughout the contract and not just during the final stage of the project • Commissioning is done to ensure the deliverables of the project; • Commissioning should be given more attention to ensure the workability or functionality of the project; • More towards services.
3	Will commissioning affect the construction project? Why?	Yes.	• To do testing and commissioning, stop work order must be issued; • Additional test requirement from dissatisfied client; • Underestimate the duration needed for testing and commissioning in the original contract duration. • Possible to delay the handover of the project. In referring to the Critical Path Analysis, predecessor will affect the successor. Therefore, any activities before an item will affect the descendant.
4	Do you think commissioning is important?	Yes.	• If no commissioning is performed, there will be defects and commissioning ensures the building is functioning well; • Need to capture the problems from the beginning to avoid delay. • If not, the building will be deemed

Table 4.2: Interview Questions for Pilot Case Study (Cont'd)

No.	Question asked	Answer	Reasons
4			incomplete. To measure the functioning of the services and not just completion. 10% of the problems in a project are caused by commissioning problems.
5	What are the problems in construction that will cause delay in the execution of commissioning?	Structural works, discrepancies between drawings and rushing to hand over the project towards the end.	• If the structural works is not completed and there is only one month left to complete the project, the project will be rushed. Therefore, mechanical and electrical engineer will have to compress their schedule in order to make up for the delay in previous stages. Consequently, rescheduling the whole time frame is needed to follow-up closely with the monthly progress and to cut-off others department's duration. Actually, around 6 months till 1 year prior to the completion date, the chances of delay in completing the project will unveil; • Discrepancies of drawing between as-built drawing and the local authority's approved drawing. For example: the casting for roofing in drawing was 4m but the constructed roofing was 6m; • Besides, towards the end of the project, any delay is unavoidable as everyone is rushing to complete the project; • Time is not enough for commissioning of services and troubleshooting of problems. This is because there are too many items in commissioning. Just for electrical supply alone, there are more than 100 items to be tested and commissioned.
6	What are the aspects to be commissioned in this stage?		• Mechanical and electrical; • Fire and Rescue Department of Malaysia's (Bomba) inspection; • Building inspection; a) For safety wise such as staircase and signage; b) Non-compliance with

Table 4.2: Interview Questions for Pilot Case Study (Cont'd)

No.	Question asked	Answer	Reasons
6			specification such as no railing for staircase; • Electricity – Tenaga Nasional Berhad (TNB); • Water authority; • Services such as plumbing, air-conditioner, electricity and gas supply; • Architectural; • Structural. • Landscape. • Failing to get approval from these related personnel will affect the approval of Certificate of Practical Completion (CPC).
7	Which aspect has the most significant impact on the project completion?	Mechanical and electrical parts.	• The mechanical and electrical part such as lift and electricity are prone to delay. Failure to obtain authority approval for railing, power cut and fire mode will lead to delay in project completion. • For railing of lift, the work must begin from bottom up, if the railing at ground floor is not completed, the railing at first floor cannot be started. This is because the alignment of the railing must proceed continuously from bottom up. • Sometimes, the cable for electric outlet at the switch box and air-conditioner are not tightened properly. This can cause short circuit and other safety issues.
8	Is proper inspection being done during commissioning or commissioning is merely an administrative task?	Yes.	• Proper commissioning is utmost important to ensure functioning and performance of constructed building and facilities. For instance: lighting at car park. Testing for the wiring and timer have to be done during commissioning to check whether all lights can be light up and whether the quantities of light points are installed correctly as specified in the specifications. The adequacy of brightness at that area during night time must also be

Table 4.2: Interview Questions for Pilot Case Study (Cont'd)

No.	Question asked	Answer	Reasons
8			checked to see whether additional light points should be added to light up that particular area. • Quality of work and materials being used must also be commissioned. For instance, plastering is done in a hurry without waiting for the previous plaster to be hardened. This will cause defects to occur later on. • No testing is done for electricity and once the house owner turn on the air-conditioner, the electricity will drip; • Yes because this is crucial to obtain Certificate of Practical Completion (CPC). The ultimate goal for the project team wis to obtain the CPC.
9	Is delay in commissioning derived from previous phases of the project life-cycle? If yes, which stage and why?	Yes.	• All activities in the construction projects are interrelated to each other. • All activities in the construction projects are important for handing over of the project.
10	What are the problems in construction phase that will cause delay in commissioning phase?	Structural problem.	• Structural problem such as: lift shaft which has not been installed and will hinder the subsequent activities to install motor and cable for the lift.

4.3 Case Studies Report from the Contractor's and Consultant's Perspectives

This research is to identify the main causes for commissioning problems and to define the areas for commissioning, as well as to identify occurrences of inhibitor and the causes for these impediments to deliver building projects in a timely manner. This research has ignited the emergence of the question of 'why' and 'how' in context of commissioning research. The emergence of ‘why’ and ‘how’ questions resulted in the selection of interviews, review of documents, and observations as the research method.

Each of these eight cases were handled by different contracting companies who are in-charged to construct buildings with different functions as required by the end-user for an institution of higher learning in Malaysia. The interviewees were practitioners in these construction projects and were selected and appointed by the Ministry of Works Malaysia to participate in these projects. These interviewees were chosen for their specific knowledge in commissioning and experience to provide relevant information about commissioning. The interviewees whom participated in this research are practitioners with at least 10 years of working experience in the construction industry with some of them are practitioners with more than 40 years of experience in the field. These projects cost ranges from Ringgit Malaysian (RM) 36Million to 200Million. Table 4.3 is the summary list of case studies selected for this study. The first purpose of these case studies is to explore the current scenario of building commissioning and to determine the perceived understanding of building. The second purpose is to determine the performance rate for commissioning using Earned Value Analysis. This performance rate for commissioning is then compared with the performance rate for construction to deduce derivation for these case studies.

Table 4.3: List of Selected Case Studies

Project	**Contract Value (RM Million)**	**Contract Duration (Months)**	**Expected Completion Date**	**Interviewees**
A	61	24	August 2011	Contractor; Consultant
B	55	24	April 2011	Contractors, Consultant
C	46	24	December 2011	Contractors
D	70	30	December 2011	Contractor
E	47	18	April 2011	Contractor; Consultant
F	200	Abandoned since 2001	June 2011	Contractor, Consultant
G	53	24	August 2012	Contractor; Consultant
H	36	36	April 2012	Contractor, Consultant

The purpose of an in-depth interview study is to understand the experience of those who are interviewed, not to predict or to control that experience (van Manen, 1990: 22). In qualitative research, the researcher is trying to understand the speech patterns and behavior of actors or agents and the specific context in which these behaviors occur. The purpose of qualitative research is to get at the world of the agent or subject. The goal of qualitative research is to discover patterns which emerge after close observation, careful documentation, and thoughtful analysis of the research topic. What can be discovered by qualitative research is not sweeping generalizations but contextual findings. From the point of view of the phenomenological perspective, to the question of how one finds out about the complexities of problems and persons is indwelling; the proposed research framework is the posture taken by a qualitative researcher, by the human-as-instrument (Maykut & Morehouse, 1994).

Rather than decrying the fact that the instrument used to gather data affects the interview process, it is says that the human interviewer can be a marvelously smart, adaptable, flexible instrument who can respond to situations with skill, tact, and understanding. The human instrument is the only data collection instrument which is multifaceted enough and complex enough to capture the important elements of a human person or activity (Lincoln & Guba, 1985: 107). For project C and D, though only contractors were interviewed, but, the interaction between the data gatherers and the participants is inherent in the nature of interviewing. Instead the researcher's task is to present the experience of the people being interviewed in compelling enough detail and in sufficient depth that those who read the study can connect to that experience, learn how it is constituted, and deepen their understanding of the issues it reflects. Because the basic assumptions underlying an interview study are different from those of an experimental study, selecting participants is approached differently (Seidman, 2006). Therefore, this study presumes that the participation of merely contractors in these two projects do not affect the reliability of the study.

4.3.1 Case Study 1 (IE1ab1-5)

IE1ab1-5 is a source code for each of these interviews so that any future reference can be traced easily to each piece of raw data. The first code segment refers to the type of data (I for interview). The second segment, for example E1a, describes the first engineer interviewed for the contractor. The third segment refers to the number of the interaction if there was more than one interaction for the respondent. For instance, E1a for the first interaction with engineer and E1b for the second interaction. The last segment is a page number if the raw data cover more than one page (for example from page 1 – 5 of a transcription of an interview). So, 1E1ab1-5 is the source code for page 1 to 5 of a transcription of an interview with the engineer 1 (Cavana *et al*., 2001).

4.3.1.1 Background of Case Study

The first case study interview was conducted with Mr. CH Lee (contractor) at the site office for IPPP's Building. This interview was conducted on 26th July 2011 at 9.30 a.m. and on 27th July 2011 at 10.00 a.m.

Years of Experience	: 20 years
Project duration	: 2 years
Types of Construction Contract	: Conventional

4.3.1.2 Other Issues Related to Case Study

1. The actual project completion date was supposed to be on April 2011 but it was extended with a few Extension of Time (EOT), by the client. Therefore, the new completion date was shifted to 15th September 2011.
2. According to the interviewee, in any construction project, the hardest part was starting and to finishing the project. From the interviewee's experience, the first 20% and the last 15-20% of the project work progress were the hardest part to be handled. In the beginning of the project, everyone took time to coordinate with each other and to know the exact requirements of the client. Once every project member has familiarized with the nature and culture of the project, they will know their respective scope of work. When the project has progressed towards completion (remaining of 15-20% work progress), many problems will arise. It is a challenging task to close-

out the project because towards the end, problems such as outstanding works, defects, availability of equipment, availability of a stable power supply for testing, adequateness of manpower, contactable personnel involved, quality of workmanship, leakage, coordination among different trades of work and etc. arises. This complex coordination of work towards the end of the project impedes the project handing over in a timely manner.

3. For this relevant project, the contract value was changed eight times.
4. On the second interview, the interviewee highlighted the existence of preliminary testing and commissioning which was meant for the contractor's own testing and commissioning and self-checking before joint inspection with other contractors.
5. For testing and commissioning, the structural, architectural and the system part are interrelated. For air-conditioning, it must be dust-free and for the server room, the raised floor must be prepared. Both of these elements must be completed before testing and commissioning.
6. There were three parts of testing and commissioning for this project:

a) First part : contractors own testing and commissioning;

b) Second part : witnessed test – joint inspection with Public Works Department (JKR); and

c) Final part : include final tuning and checking of all final installations (testing).

4.3.1.3 Discussion of the Case Study

In practice, it would be hard to judge the performance of a construction project because designs and plans rarely include explicit assessment about the manageability of a project. A carefully prepared pre-construction master planning and scheduling is pre-requisite for success in the later phase of construction. This construction plan would prevent the occurrence of problems that would lead to expenses of money in vain for fixing such problems (Tetsuya, 1997). Hence, as claimed by the interviewee who said that it was the hardest part to handle the project during the first 20% and the last 15-20% of the work progress is somehow reasonable as it is not easy to handle the manageability of the project merely from design and planning itself. Consequently, the manageability of commissioning for a construction project during the last 15-20% of the work progress is considered a difficult task. Adding to this predicament is the unpredictable nature of problems that might occur during commissioning.

The interviewee claimed that to close-out the project is the hardest task. This is most likely because it requires a lot of time to trouble shoot all the problems that arises during the final stage. This then causes the project manager to have less time in administrating a planned routine (Tetsuya, 1997).

4.3.1.4 Participant Observations

The researcher managed to gain access to the testing and commissioning meetings or referred to as “joint meetings” conducted by the main contractor on 1st August, 8th August and 27th August 2012 respectively. These meetings were held at the site office for this project and were attended by client, architect, main contractor and the sub-contractors. However, Department of Maintenance and Asset Management (JPPHB) did not join this meeting. The researcher participated in these meetings for an approximate observation period of nine hours in total. This field research method is advantageous in providing the researcher a platform to observe and to comprehend on the scene the actions during the joint meeting (Babbie, 2010). Besides that, participant observation enables the researcher to obtain an in-depth understanding and first-hand account of the issues being investigated. This observation also helps to provide a detail assessment of interpersonal activities. However, this observation is not without restrictions as it is difficult to gain access to this joint meeting and it is a very time consuming observation (Johnston *et al.*, 1999).

The purpose of these meetings is to have a better insight and understanding on how commissioning is being coordinated and executed towards handing over the project. It is also the aim of this researcher to identify potential problems that arise and learn the improvement methods of conducting commissioning in the Malaysian construction industry. Empirical observations of the researcher from these meetings are as follows:

- The main contractor expectation was to have 100% physical completion by 15th August 2011.
- Attendance to this testing and commissioning meeting was made compulsorily for all personnel concerned. The main contractor imposed a penalty of RM 500 for contractors, consultants, architect who failed to do so. This penalty will be later deducted from the money due to them.
- However, on 8th August 2011 when the first joint meeting was held, the power supply or referred to as “juice supply” hereof was still not yet ready. In contrast, the main contractor expected the power supply to be ready by 9th August 2011.
- In this project, cable is an item that falls under Variation Orders (V.O.). The cables laid on site was in accordance with the VO (418kW = 800 ampere) but on drawing, the changes were not reflected and it remain in its original number, 600 ampere. Due to negligence of the people involved, the cables were changed but the feeder was not changed resulting in mismatch.

- There was also an issue regarding the GSM module for ICT of this project. In order for the specialized contractor to run the external testing and commissioning, the end-user for this project had to upgrade the existing GSM module. For this contract, there was no copper cable (hard cable) to connect the building to the main GSM module located at the new chancellery building. Without the GSM module, the end-user would not be able to make external phone calls. The end-user was aware of this problem but chose to delay in making decisions and failed to inform the contractor on the remedy.
- Apart from these issues discussed during the meeting, there was also an omission of 500 sets of socket outlet, lighting point and cable. These lighting points were reduced from 4000 to 3500 points and the contractor will probably obtained only 92% of the payment after this re-measurement on site.
- It was also reported in meeting that all of the seven companies involved in testing and commissioning did not submit their respective as-built drawings and operation and maintenance manual. These as-built drawings and operation and maintenance manual were to be compiled by the main contractor before submitting to the architect.

4.3.2 Case Study 1a (IA1a1-6)

4.3.2.1 Background of Case Study

The second interview for this case study was conducted with an architect, Ar Mohd Jalani (consultant) on 24th July 2012 at his office at 2.00 p.m.

Years of experience	: 26 years
Project duration	: 2 years
Types of Contract	: Conventional

4.3.2.2 Other Issues Related to Case Study

1. The interviewee disagreed with the statement that commissioning phase being used as a catch-up phase to cover the delays occurs. It was the commitment of the contractor to make sure that commissioning was being done and it must be recorded and verified. Commissioning was not a phase that someone can take advantage of and it has to be utilized and proven.

2. According to the interviewee, the quality of the commissioning depends on the following:

i. It was the duty of the contractor to make sure everything was in order. It also depend on the contractor's company whether it was an ISO 9000 certified company wherein they will have standard operating procedures and experiences to do the work. If the contractor's company did not have in-house standard operating procedures, then usually a good client will requested this to be included such as certified ISO 9000 and comply with QLASSIC standard by Construction Industry Development Board

(CIDB) or CONQUAS in Singapore. The contractor was then required to comply with this standard.

ii. The contractor must impose QLASSIC by CIDB or CONQUAS in Singapore so that those who did not do their works will fail the quality assurance test. This will be verified by a third party who was CIDB to assess whether QLASSIC or CONQUAS was being complied and also to monitor the quality of work done. This must be imposed to ensure the quality of works but this will increase the cost of the building. The end-user has to bear the cost to pay for the quality.

iii. Consultants have to be presence at site at least once every month or once every two weeks to supervise and to see whether works were progressively being done according to construction law and in compliance with the law. In the same time, the site staffs, which were the clerk of work or resident engineers, will monitor the progress of work on site and to witness that testing has been done. They will be the one to observe that the testing was carried out by the contractor. Before handing over, the contractor has to submit the testing report verified by the site staff and confirmed by the engineers.

iv. Details of the commissioning activities will only be provided by the contractor upon the request of the architect. According to the interviewee, the client and the architect were only interested to know the outcome and not the details.

v. Commissioning was important in terms of cost as you would not say it was there but in terms of the usability of the building was important as nowadays people were talking about modern building must equipped with power supply, lift, smoke spilled systems, air-conditioning, escalators and etc.

vi. Commissioning was difficult to be dealt with as it was not visible as the inspection of the quality of work done. Therefore, it has to be observed, has to be recorded and has to have data.

3. The percentage of the project completion when testing and commissioning was carried out during the project handing over phase was about 75%. This percentage can be an indicator to predict the timely completion of a construction project because it was towards finishing level and testing such as pressure test and etc. can be carried out.

4.3.2.3 Discussions on Case Study

The quality of commissioning highly dependent on the quality of the contractor's appointed for the project. The contractor's company whether it was an ISO 9000 certified company was also important to determine the quality of commissioning. An ISO 9000 certified company will have the standard operating procedures and experiences to do the work compared with a company without those certifications.

4.3.3 Case Study Report 2 (IPM1ab1-3)

4.3.3.1 Background of Case Study

A case study interview was conducted with Mr. Ahmad Farizan (contractor) at the site office for the New Chancellery Building on 30th April 2011 at 11.00 a.m. This was a construction project to build 8 stories of new Chancellery Building for the University of Malaya.

Years of Experience : 15 years

Project duration : 2 years

Types of contract : Conventional

4.3.3.2 Other Issues Related to Case Study

1. Till to date 30th April 2011, the contractor has to pay RM 110,000.00 for Liquidated Ascertained Damages (LAD) when the interview was made. Appealed letter has been issued to the client for this matter to waive the LAD if it was possible. Indecisive client to confirm the exact types of carpet for the floor finishes for level 8th has delayed the work progress of the project. Subsequently, this has caused delay in the handing over of the building to the client. Besides that, the end-user agreed with other types of carpet whilst the Department of Development & Asset Maintenance (JPPHB) proposed to use another type of carpet. The contractor was in dilemma as the two carpets were almost similar in terms of quality and price but with different design. JPPHB demanded the contractor to use the proposed carpet as the price for it was cheaper. In fact, it was of the same price for both materials and later on JPPHB intended to remove this item from the contract. JPPHB planned to employ another sub-contractor for the installation of the carpet. The contractor was unhappy and argued about this issue. The contractor has to wait for the architect's instruction to proceed. The architect finally gave a late confirmation to the contractor to proceed with the initial type of carpet after a month of confusion and much discussion on this issue. After that, the contractor ordered the materials from a supplier in China and appointed a sub-contractor for the installation of the carpet. The work was delayed because the supplier in China requested a deposit and materials were not delivered to the site as scheduled due to payment problem. Apart from this, the main contractor was late in issuing a Letter of Award (LA) to the sub-contractor which was on March 2011 due to some unknown reasons. When this interview was carried out, the project manager claimed that the next batch of carpet will arrived on May 2011. This further delayed

the work progress and the handing over of the building to the client. Consequently, the contractor applied for Extension of Time (EOT) for the carpet under Clause J – special circumstances under the Conditions of Contract (CoC). According to the interviewee, the EOT applied for the carpet was the third in the list but it was granted 0 day for it.

2. Problems that arose during handing over to the client were:

a) There was no outstanding work and testing & commissioning was done according to the requirements of the contract. The architect who certified the Certificate of Practical Completion (CPC) was satisfied with the work done. The CoC stated that the procedures of handing over to the client depend on the form of contract being used. Before the application for CPC, the contractor had to comply with these procedures in the contract;

b) Submission of as-built drawings as specified in the contract and the number of copies to be submitted to the client such as:

- civil and structural drawings which have been approved by the civil and structural engineer;
- rainwater down pipe drawings which have been approved by the architect;
- sanitary and plumbing drawings which have been approved by the mechanical and electrical engineer; and
- submission of Operation and Maintenance Manual (OMM).

c) It is a must to synchronize the systems for testing & commissioning for all of the services.

- sending signal to control room in case of fire;
- electricity will be automatically cut-off during fire;
- sliding door will be automatically open;

- fan will be operating to suck out the smoke from the building;
- the generator will be functioning to power the lift to go to the ground floor; and
- alarms will be triggered.

All of these activities have different time slot and must be coordinated among all team members to ensure the system function accordingly. After 1 month from the date the interview was conducted, due to some unforeseen circumstances, it was realized that waterproof membrane at the plaza deck was not installed by the contractor. This mistake was detected by the client as it was stated in the Bill of Quantities (BQ). Therefore, extra time was needed, and again, the contractor claimed for EOT from the client to finish-off the uncompleted work. As a result, the contractor had to hire more workers to hack and to spray the waterproof membrane at the plaza deck.

4.3.3.3 Discussions on Case Study

One of the major problems in this project which contributed to the delay of the commencement of commissioning in this project was the conflict arose on the selection of the types of carpet to be used. This was not surprising as conflicts were intrinsic in all construction projects (Bramble & Cipollini, 1995; Zack, 1995; Fenn, Lowe & Speck; 1997; Carsman, 2000) when there was a serious difference between two or more beliefs, ideas or interests (Collins, 1995). In this case, the conflict was due to divergence in idea on the selection of the types of carpet to be used in this project. According to Ng, Rose, Mak and Chen (2002), this confrontational culture can cause loss of productivity and increased in cost. This argument was further supported by a study done by Cheung and Suen (2002) that conflicts will escalate if it is not handled properly.

Blake and Mouton (1964) suggested a conflict handling style classifications which describe integrating, obliging, compromising, dominating and avoiding. Integrating is considered to be adopted by those with high behavioural flexibility in this classification. In other words, integrating is adopted to deal with conflict as it is a resolution style dependent to their need or others need. As such, the level of conflict can be reduced or controlled. Nonetheless, conflicts arose during commissioning which indirectly indicates that there are problems. This inference was made based on Blake and Mouton’s classification on conflict handling style. Contradictorily, the purpose of commissioning to integrate all the services for building should be able to reduce conflict instead of triggering conflict. This implies that focus is needed on the problems during commissioning to determine the causes.

4.3.4 Case Study Report 2a (IC2a1-3)

4.3.4.1 Background of Case Study

A second interview was conducted for this case study with Mr. Moey (consultant) on 19th October 2011 at the site office of the New Chancellery Building at 9.00 a.m.

Years of Experience	: 10 years
Project duration	: 2 years
Types of Construction Contract	: Traditional type of contract

4.3.4.2 Other Issues Related to Case Study

1. According to the interviewee, the operation manual produced by the project manager must be verified by the client and the consultant. This manual must be approved by the client, consultant, related authorities and Bomba, an approval letter will be given by Indah Water Konsortium (IWK). This manual will then become the Operation and Maintenance Manual (OMM).
2. Before submitting this manual, each element such as electrical, sanitary fittings, sewerage, air-conditioning and lift must obtain the letter of support from authorities.

4.3.4.3 Discussions on Case Study

In this project, the interviewee did not disclose much information on issues related to commissioning but the project was delayed to be handed over to the client.

4.3.5 Case Study Report 2b (IA1a1-6)

4.3.5.1 Background of Case Study

The third case study interview was conducted with the architect, Ar Hanaz (consultant) on 9th July 2012, 2.00 p.m. at his office.

Years of Experience	: 13 years
Project duration	: 2 years
Types of Construction Contract	: Conventional

4.3.5.2 Other Issues Related to Case Study

1. According to the interviewee, the percentage of the project completion when testing and commissioning was carried out during the project handing over phase was 100%.
2. This percentage can be an indicator for the timely completion of the project because the project will be delayed if the planned commissioning cannot start according to schedule.
3. The interviewee claimed that the practitioners did anticipate these problems before they start the project. This was because they were aware of these problems and the consultant did remind them. It was also part of the tender assessment for special material.
4. Sometimes, commissioning phase was being used as a catch-up phase to cover the delays occurs. The planned duration for commissioning phase would be compressed or shorten up to complete the project on time and to make up for loss of time caused by previous delay. The planned duration for commissioning was compressed to avoid the Extension of Time (EOT).

4.3.5.3 Discussions on Case Study

In this project, the interviewee agreed that the execution of commissioning according to as planned schedule was essential to ensure that the project to be completed in a timely manner.

4.3.6 Case Study Report 3 (IE1a1-3)

4.3.6.1 Background of Case Study

A case study interview was conducted with Mr. Haji Hassan (contractor) at the site office for Laboratory of Chemistry, Faculty of Science at 26th November 2011 8.30 a.m. This was a construction of 8 stories building for Chemistry Laboratory for the Faculty of Science, University of Malaya.

Years of Experience	: 21 years
Project duration	: 2 years
Types of Construction Contract	: Conventional

4.3.6.2 Other Issues Related to Case Study

1. The instruction for changes of work for this project regardless of Architect's Instruction (A.I.) or Engineer's Instruction (E.I.) was too many due to negligence of the design for this project. Extension of Time (EOT) for 9 months was granted for this project from 10th April 2011 till 31st December 2011 due to 81 nos. of Variation Orders (V.O.) were issued. These V.O. cost around RM 6 million, in which the expected maximum amount of V.O. for a project is usually around 20% of the contract sum.
2. According to the interviewee, the total number of Variations Order (V.O.) for this project might be increased further as some of the V.O. has not been settled yet. The interviewee indirectly admitted that the delay for the project was intentionally as the quantity surveyor from Public Works Department (JKR) has slashed lots of the

initial amount that they had submitted for V.O. The interviewee claimed that the quantity surveyor had underestimated some of the works for V.O. which was done by the contractors due to measurement errors. For example: the quantity surveyor took the girth for the building from the center line but the actual girth should be taken from one side to another side due to the irregularity of the shape. This has cost the claimed amount from the contractor to be slashed from RM1.2 million to RM40, 000.00. The contractor said that they have no bargaining power as most of the works for V.O. have been completed and they have to accept the underpayment from the client.

3. Sometimes, if an item does not exist in the Bill of Quantities (BQ) for the purpose to claim for Variation Orders (V.O.), the contractor has to come out with the built-up rate for that particular item. But, the rate calculated by the contractor and the consultant will be different. Hence, this will eventually affect the amount of the Variation Orders (V.O.).

4. The interviewee said that the delay for the project was mostly due to changes of design for mechanical works. And to the date when the interview was conducted, it can be seen from the construction site that the project will most likely fail to be handed over to the client by 31st December 2011 which was only around 1 month and five days left from the completion date. Apart from this, the building commissioning has not started due to the delay of work progress and there are still many uncompleted work to be finished within this 1 month duration. Apart from this, there was a high chance that they will not be granted the second Extensions of Time (EOT) according to the interviewee.

5. The interviewee claimed the high quantity of V.O. has affected the execution of the actual contract work as much time has been spent to tackle these V.O. works.

Besides, this will also affect the contractor when applying for the second Extensions of Time (EOT) as the remaining works were part of the contract.

6. Furthermore, stop work order might be issued for this project as the amount of V.O. for this project has exceeded RM 1Million. According to the interviewee, for V.O. which amounts to RM 1Million, this new budget has to be approved by the Director of Public Works Department and for up to RM 3Million, must seek approval from the "Ketua Pengarah" and if more than RM 3Million, this new budget has to be approved by the Ministry of Work before proceeding further.

4.3.6.3 Discussions on Case Study

Some important issues pertaining to this case study such as underestimation by the quantity surveyor and underpayment from the client have caused the contractor to delay the work progress intentionally. Though these were payment problems which seemed unrelated with commissioning but this will affect the execution of commissioning when the contractor deliberately delays the work progress. The increased numbers of variation orders to be handled and the changes of design for mechanical works have delayed the planned commencement of commissioning for this project.

4.3.7 Case Study Report 3a (IE2a1-3)

4.3.7.1 Background of Case Study

A second interview for this case study was conducted with Mr. Ng Chee Kiong (contractor) at the site office for Chemistry Laboratory on 6th October 2011 at 9.30a.m.

Years of Experience	: 18 years
Project duration	: 2 years
Types of Construction Contract	: Conventional

4.3.7.2 Other Issues Related to Case Study

1. Inspection was progressively done throughout the whole project, be it for mechanical and electrical services, civil and structural works' function, and architectural installation as per shop drawings and approved materials. If the materials used were not approved, dismantling of installed works shall be done and this will consume more time. Testing and commissioning was carried out after construction, towards the end of the project before handing over to the client.
2. According to the interviewee, delays usually occur during construction and result in the construction schedule being pushed behind and this will subsequently affect the testing and commissioning date.
3. The project commenced on 31st March 2009 and was abandoned for 1 year and restarted again on 14th April 2010.
4. After the first 30% of the work was completed, the first contractor was terminated due to non-performance and the second contractor was appointed to complete the remaining work.

5. According to the project's architect, delays of testing and commissioning were mainly caused by mechanical and electrical works such as changes in end-user requirements and due to outdated information as this project was designed in year 2000 and there was a lack of updated information from the end-user.
6. Figure 4.2 shows an overview of the linear process for inspection and testing and commissioning.

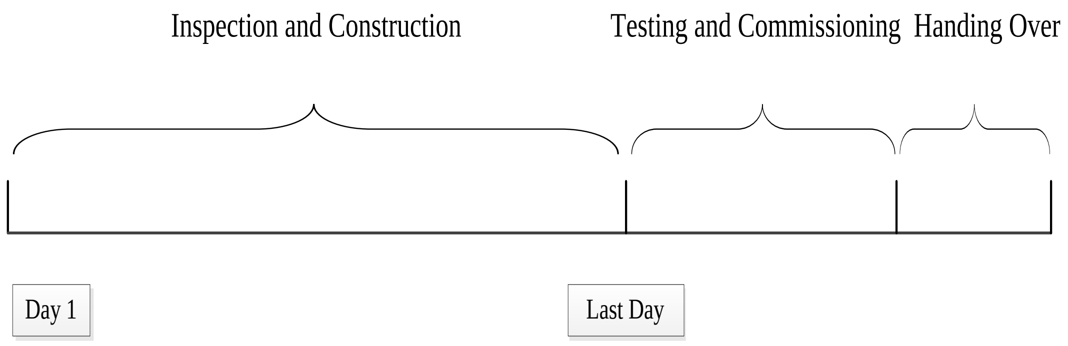


Figure 4.2: An Overview of the Linear Relationship between Inspection and Testing and Commissioning

7. Thus far, two Extension of Time (EOT) has been granted for this project (as shown in Figure 4.3). As shown in Figure 2, the first EOT was granted to extend the project by six months, from 15th April 2011 till 10th April 2011. The second EOT was granted to extend the completion date to 31st December 2011 for another 2 months and 20 days. According to the interviewee, the second EOT was granted due to delays in mechanical and electrical parts where there were many late confirmations and many changes of specifications by the end-user.

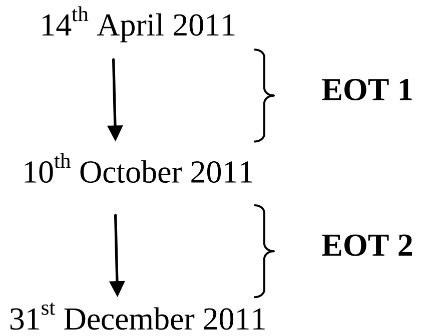


Figure 4.3: Time Flow for Extension of Time (EOT)

8. The first EOT was granted due to the undulated ground floor slabs. After detailed site investigation was carried out, it was found that the undulated ground floor slab required top up of concrete to make it balance and leveled.

4.3.7.3 Discussions on Case Study

According to the interviewee, the commencement of commissioning is highly dependent on whether there was any delay in construction phase. The interviewee differentiated inspection from testing and commissioning in construction project. According to the interviewee, inspection was progressively being done throughout the construction phase before the commencement of commissioning. The main cause of delay for testing and commissioning for this project was due to changes of requirements from the end-user for mechanical and electrical works and outdated information since the project was started in year 2000.

4.3.8 Case Study Report 4 (IE2a1-3)

4.3.8.1 Background of Case Study

A case study interview was conducted with Mr. Loh (contractor) at the site office of service block for rehabilitation, bio-medical imaging and unit cardiology, University Malaya Medical Centre (UMMC) on 30th November 2011 at 2.30 p.m. This was a construction project to construct one block of 13-storey service block and 1 basement.

Years of experience : 30 years

Project duration : 2 ½ years

Types of contract : Conventional contract

4.3.8.2 Other Issues Related to Case Study

1. Commissioning is to ensure equipments are running according to specifications and to there are adequate manpower/competent persons to operate.
2. According to the interviewee, improper management can cause bad execution of the project when the critical path method was not cleared in time.
3. LV board will be tested in factory for quality check before delivered to the site for acceptance test.
4. The person involved and equipments are important elements in testing and commissioning. The testing and commissioning has to be re-done if the person in-charge does not accept it or it was not done not in accordance with procedures.
5. The duration for testing and commissioning depends on the size of installation for that particular project. The bigger it is, the longer duration is required for testing and commissioning.
6. Unavailability of materials due to labour force will hinder or become an obstacle which will delay the commissioning progress.
7. After testing and commissioning, a checklist will be generated to check whether the equipment is functioning as per manufacturer’s requirement. These items will be tested and rectified to verify whether there are problems or whether the equipment performed as per intended design.

8. Pre-agreement will be made with the supplier. By quoting higher prices, the supplier will be able to cover up for the losses during warranty period if the project handing over was delayed.

4.3.8.3 Discussions on Case Study

According to the interviewee, it is utmost significant to clear critical path method in order to complete the project in a timely manner. Two important elements in commissioning are competent person to operate or to do testing and correct equipment for this purpose. Besides, delay in commissioning will also affect the warranty period of the installed services or equipment when handing over the building to the client.

4.3.9 Case Study Report 5 (IE1a1-3)

4.3.9.1 Background of Case Study

A case study interview was conducted with Mr. Martin Goh (contractor) at the site office on 14th April 2011at 11.00 a.m. for the construction of a new examination hall for University of Malaya. This new examination hall was built to accommodate around 40% of the students' capacity but was subsequently changed as University Malaya's management wanted to replace the current examination hall with the new examination hall.

Years of Experience : more than 40 years

Project duration : 18 months

Types of contract : Conventional

4.3.9.2 Other Issues Related to Case Study

1. According to the rules and regulation by local authority, no building is to be constructed within 66-feet from the power transmission cable. What transpired was the architect who planned the site layout for this project overlooked this regulation. The building layout was too near the cable and stop work order was issued. Consequently, the whole building layout had to be shifted to 66 feet away from the cable. Piling work had already been carried out when the stop work order was issued. Therefore, the piling work and substructure works had to be terminated and re-designed. Apart from this, soil investigation had to be carried out again due to the changes on the site layout.
2. There was delay in mechanical and electrical works due to architect's instruction to shift the design of air-conditioner conduit from the back to the side of the building for aesthetic purposes. Thus, the mechanical and electrical engineer have to re-design the layout for the wiring to accommodate this instruction, as the architect did not want any conduit to be seen.

4.3.9.3 Discussions on Case Study

In this project, similar to others projects discussed earlier, changes of design for mechanical and electrical works have caused delay in commissioning to be completed on time.

4.3.10 Case Study Report 5a (IA1a1-8)

4.3.10.1 Background of Case Study

The second interview for this case study was conducted with the architect for this project, Ar Azziady (consultant), at his office on 26th June 2012 at 6.00 p.m.

Years of Experience : 20 years

Project duration : 18 months

Types of contact : Conventional

4.3.10.2 Other Issues Related to Case Study

Aspects of commissioning from the interviewee's point of view:

1. There are two aspects of commissioning:

a) own internal commissioning; and

b) commissioning with local authorities to obtain Certificate of Practical Completion (CPC) and Certificate of Compliance and Completion (CCC) where the local authorities will inspect and issue a Certificate of Practical Completion (CPC) or Certificate of Compliance and Completion (CCC) if the project complies with the rules and regulation.

2. Commissioning has two aspects from the practical or Certificate of Practical Completion (CPC)'s and Certificate of Compliance and Completion (CCC)'s point of view. In the case for fire, sometimes, the bell, sprinkler and smoke spill are in working condition and are considered passable for Certificate of Practical Completion (CPC) but were deemed non-compliance with local authorities such as

Bomba (Fire Department). Many times, it was considered good for occupancy or Certificate of Practical Completion (CPC), but, when the authorities came and checked, the equipments failed to function properly and it is very common to encounter this problem with the Bomba (Fire Department) authorities. For this project, this problem occurred twice for smoke spills system. When the authorities came, the system was not working and failed. The most important element in commissioning is to obtain the Certificate of Compliance and Completion (CCC).

3. There are five authorities involved in commissioning:

a) Electricity – Tenaga Nasional Berhad (TNB);

b) Water – Department of Irrigation and Drainage Malaysia (JPS);

c) Lift – Department of Occupational Safety and Health (JKKP);

d) Fire – Fire and Rescue Department of Malaysia (Bomba); and

e) Sewerage – Indah Water Konsortium (IWK).

4. Actually, commissioning does not end with the acceptance of Certificate of Practical Completion (CPC). This is because during Certificate of Practical Completion (CPC), commissioning is only at a half way stage and the actual ending of commissioning spans through the Defects Liability Period (DLP) ,the operation of the building and ends after receiving the Certificate of Making Good Defects (CMGD). Usually people assume that commissioning ends at Certificate of Practical Completion (CPC) which is incorrect. The commissioning ends after receiving the Certificate of Making Good Defects (CMGD) instead of Certificate of Practical Completion (CPC). The implication of this is that the interviewee proposed the apportionment of some retention sum to be released to the nominated subcontractors (NSC) for the mechanical and electrical engineer during this period so that they will perform accordingly during the commissioning stage. Thus, during Certificate of Practical Completion (CPC), the interviewee proposed not to release the whole

moiety of the retention sum during this period and to withhold certain portion till the end of Certificate of Making Good Defects (CMGD). From the researcher's analysis, this recommendation is only applicable for private projects and it seems that the interviewee was influenced with the practical approach for private construction projects.

5. For public projects in construction, as delineated in the P.W.D. standard form of contract, it did not state the release of the moiety of performance bond to the contractor during Certificate of Practical Completion (CPC). The performance bond will only be released to the contractor upon making good of all defects or upon the issuance of Certificate of Making Good Defects (CMGD). Hence, this might be the reason for the poor commissioning in the public projects in construction. The contractor might not be motivated to perform in order to obtain Certificate of Practical Completion (CPC) because the performance bond will only be released upon Certificate of Making Good Defects (CMGD). Hence, proper commissioning was not performed to obtain Certificate of Practical Completion (CPC) and these problems were pushed forward to rectifications during Defects Liability Period (DLP). As illustrated in Figure 4.4 are the aspects of commissioning from the interviewee's view point to define commissioning in a clearer manner.

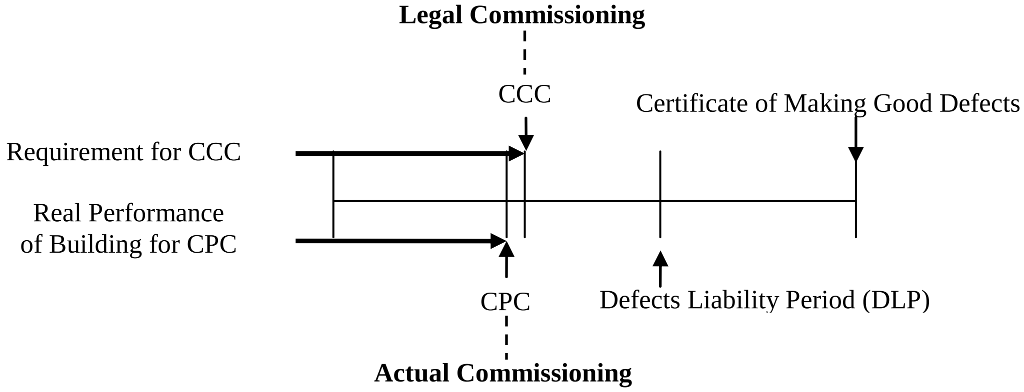


Figure 4.4: Aspects of Commissioning

4.3.10.3 Discussions on Case Study

This case study provided a new dimension on the aspects of commissioning which were actual commissioning and legal commissioning. Both of these aspects have to be fulfilled to obtain the Certificate of Practical Completion (CPC) and Certificate of Compliance and Completion (CCC). The architect also highlighted that commissioning ends during the issuance of the Certificate of Making Good Defects (CMGD) and not during the issuance of Certificate of Practical Completion (CPC).

4.3.11 Case Study Report 6 (IE1a1-3)

4.3.11.1 Background of Case Study

A case study interview was conducted with Mr. Yiaw (Mechanical & Electrical Engineer) from the contractor's side at the site office for Pediatric Ward on 15th April 2011 at 6.00 p.m. This was a construction project for the construction of a 12-storey Pediatric Ward, University Malaya Medical Centre (UMMC).

Years of Experience	: more than 10 years
Project duration	: abandoned project since 2001
Types of contract	: conventional

4.3.11.2 Other Issues Related to Case Study

1. As illustrated in Figure 4.5, the project was delayed due to the nature of the project that was an abandoned project since year 2001 and two main contractors have withdrawn due to economic crisis and other reasons. The existing contractor was the third contractor appointed to complete this project. When the main contractor was appointed in 2007, high uncertainties and long time abandonment of the construction site have led to further delay of the project. During that time, uncertainty of the site condition such as structural cracking of the substructure and the basement was flooded with water has caused difficulties for the main contractor to tender for the project.

Figure 4.5: Project Background

2. As portrayed in Figure 4.6, the appointed main contractor was paid by the client but subsequently did not pay the domestic sub-contractors which caused the work progress to be delayed. Some domestic sub-contractors were already facing financial problems and this problem was exacerbated by the non-payment from the main

contractor resulting in work progress at site to be halted. Consequently, the main contractor was terminated and the project was re-tender again.

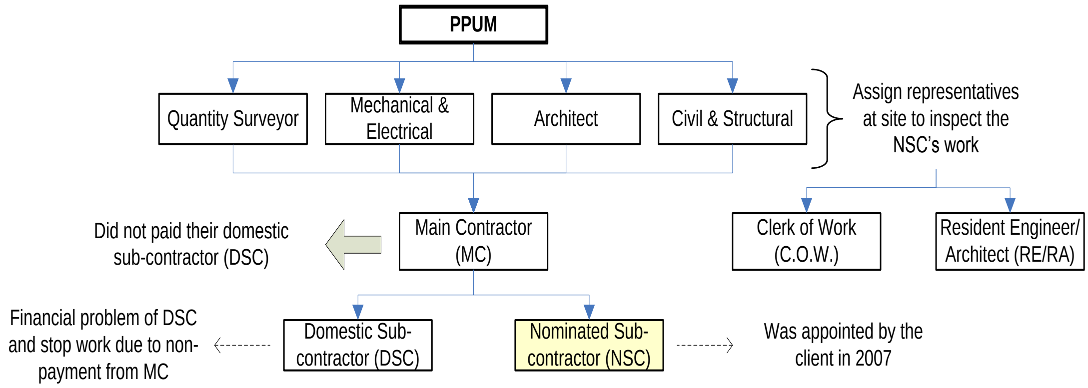


Figure 4.6: Organizational Chart for the Project

3. Liquidated Ascertained Damages (LAD) will be imposed if the contractor fails to obtain the Certificate of Practical Completion (CPC) during the post-construction stage as shown in Figure 4.7. LAD will be borne by the contractor until the approval of CPC was granted. In this project, the contractor faced problems to obtain approval of CPC from the architect.

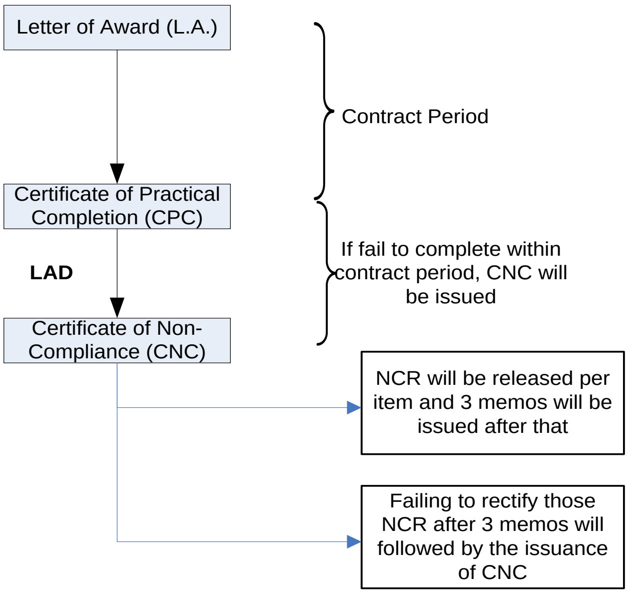


Figure 4.7: Certificate of Practical Completion

4. There are two major types of defects which are latent defects and patent defects. Latent defects such as system failure and air-conditioner not functioning properly will fall under the Defect Liability Period (DLP) after the issuance of the Certificate of Practical Completion (CPC). The duration for the DLP will be around 18 months to 2 years. However, patent defects are defective work which can be seen such as structural defect of concrete like honey comb (due to inadequate vibration when filling in the mould), bouncing (expansion of the concrete when hardening due to improper strengthening and tightening of the formwork), butterfly fall, missing part and improper installation. This kind of patents defect will consume extra time and extra cost for rework.
5. Testing and commissioning will be done after the physical work has been completed or during post-construction. Testing and commissioning were carried out in parallel with construction and the compiled testing and commissioning called “Method of Statement” will be submitted to the Superintending Officer (S.O.) before construction phase. There is a method of statement for installation and testing and commissioning respectively. Delineated inside the method of statement for testing and commissioning are the types of test such as flow test, pressure test and mega ohm for services installed.
6. There are many inspections to be carried out depending on the system performance as outlined in Figure 4.8. Most of the time, many problems will surface during testing but it is the most crucial part in commissioning. It is difficult to foresee the exact problem until actual testing has been done. Besides, before the installation of these services, a meeting among all mechanical and electrical engineers including the main contractor will be held. This meeting is utmost important for coordination of services and to come into consensus on the exact completion date. In this

meeting, engineers and main contractor will decide at which stage to cover the ceiling and at which stage to complete their work.

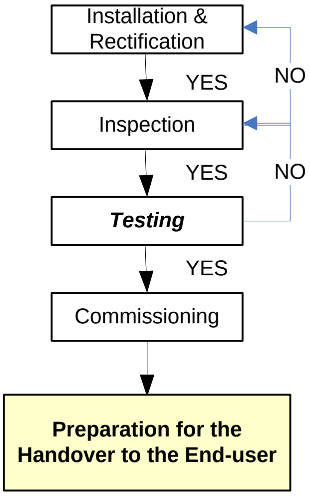


Figure 4.8: Testing and Commissioning Flow

7. In any project, communication was essential to ensure smoothness of work progress. In this scenario, the end-user has some communication breakdown with the Department of Development & Asset Maintenance (JPPHB). Thus, the main contractor was in a dilemma on whether to adhere with the end-user instruction or the JPPHB's instruction. The end-user communicated directly with the main contractor instead of communicating with the JPPHB as this department was meant to be a platform between the end-user and the contractor. The contractor was supposed to receive architect instruction or engineer instruction from JPPHB, but, in this project, these instructions were given directly by the end-user to the main contractor. The organizational chart for this project is as shown in Figure 4.9.

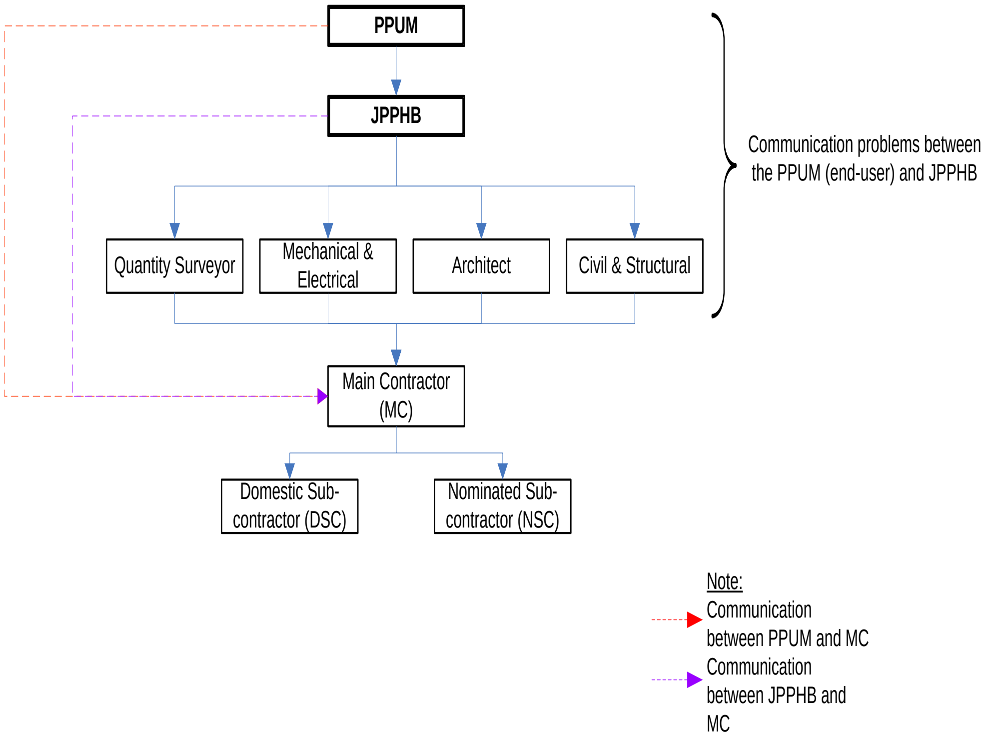


Figure 4.9: Organizational Chart for Communication Problem

4.3.11.3 Discussions on Case Study

This project itself was delayed as it has been abandoned for almost 8 years and it was revived and completed by a third contractor appointed for this project. According to the interviewee, testing and commissioning was carried out in parallel with construction. The interviewee also claimed that testing and commissioning was the most difficult and crucial part in the construction because it is very difficult to foresee the exact problem until actual testing was carried out. Therefore, coordination meeting among all mechanical and electrical engineers with the contractor must be held during commissioning. Besides that, communication among the contractors, end-user and the JPPHB department is also very important to ensure work development is progressing smoothly.

4.3.12 Case Study Report 6a (IA1a1-5)

4.3.12.1 Background of Case Study

The second interview for this case study was conducted with the architect for this project, Ar Khairul, from the contractor's side at the second floor, engineering department, University of Malaya Medical Centre (UMMC) on 11st July 2012 at 12.00 p.m.

Years of Experience	: 22 years
Project Duration	: This project started in 1999 (78 weeks project)
Types of contract	: Conventional

4.3.12.2 Other Issues Related to Case Study

1. The percentage of the project completion when testing and commissioning was carried out during the project handing over phase was about 90%.
2. This percentage not necessary can be an indicator to predict the timely completion of a construction project. For example, the likelihood for the project to be completed in a timely manner or the project was most likely to encounter delay. During this remaining 10%, major problem can occur unexpectedly and the time taken to complete this 10% of work can span almost half of the total construction time. Delay of electrical supply from Tenaga Nasional Berhad (TNB) has caused problem for this project to energize the power system for testing and commissioning.
3. Remedies can only be taken when this problem has occurred and to find solution to solve this problem.

4. There are certain things that usually pop-up towards the end of the project which they have expected. They have levy for this problem such as electrical tripping and time was needed for them to tune up. They should have allowed sufficient time for this problem which they have expected.
5. For example, the planned duration for commissioning phase would be compressed or shorten up to complete the project in a timely manner and to make up for loss of time caused by previous delay. By virtual, this is normal to catch-up for uncompleted works towards the end and to do things concurrently to expedite the work progress. By being the very end of the project, it is the nature of the project to fit everything within the deadline.
6. Coordination is the most important element in commissioning. Sometimes, there are problems during commissioning because there is no competent person to coordinate many services which work independently. If a competent person is appointed, problem which will occur can be anticipated and immediate actions can be taken to counter this problem from happening.

4.3.12.3 Discussions on Case Study

During this remaining 10%, major problem can occur unexpectedly and the time taken to complete this 10% can span almost half of the total construction time. It is normal to compress or shorten-up the planned duration for commissioning phase to complete the project in a timely manner and to make up for loss of time caused by previous delay. By being the very end of the project, it is the nature of the project to fit everything within the deadline.

4.3.13 Case Study Report 7 (IE1a1-3)

4.3.13.1 Background of Case Study

A case study interview was conducted with Mr. Yusree (contractor) from the contractor's side at the site office for the construction of a 10–storey new building for the Faculty of Built Environment, University Malaya on 31st October 2011 at 10.00 a.m.

Years of Experience	: 20 years
Project duration	: 2 years
Types of Construction Contract	: Turnkey

4.3.13.2 Other Issues Related to Case Study

1. Quality commissioning depends on the contractor's professionalism and contractors' ethics.
2. The correct engineering ethics are also important to ensure integrity and code of practice.
3. The quality of commissioning must be up to certain level before handing over to the client. Sometimes, the contractor's technicians such as the site engineer are inexperienced and the workmanship of the project constructed was also not up to certain level.
4. The issuance of the progress payment might sometimes cause the contractor to be tardy in performing their work as the progress payment has been issued.

4.3.13.3 Discussions on Case Study

In this project, it can be inferred that the professionalism and ethics of the contractor appointed is important to ensure the quality of commissioning. Experience site engineer is also important to ensure good workmanship so that commissioning can be carried out as planned.

4.3.14 Case Study Report 7a (IA1a1-8)

4.3.14.1 Background of Case Study

The second interview for this case study was conducted with the architect for this project, Ar Norain, from the consultant's side at the office on 19th July 2012 at 11.00 p.m.

Years of Experience	: 25 years
Project duration	: 2 years
Types of Construction Contract	: Turnkey

4.3.14.2 Other Issues Related to Case Study

Sub-station problems. According to the interviewee, as everything is operated by using electricity, substation is the most important element to be dealt with in commissioning. Therefore, the sub-station was needed to perform testing and commissioning.

1. Electrical supply –Tenaga Nasional Berhad(local power company), hereinafter referred as TNB approval (1 week) - recommendations (1 week) – discussion among the consultants (to do internal testing, around 1-2 weeks) - arrangement with TNB

and whether they were willing to accept the sub-station for electrical supply (around 1 week) - to give feedbacks (around 1 week) - rectifications if there are any comments from TNB and the time needed to do the rectification depends on:

a) minor comments by TNB in which the contractors can carry out the work and rectify immediately (around 1 week);
b) major recommendation and involve supplier's aspect such as generator or extra generator is needed (around 2 weeks) - arrangement for another inspection with TNB or required pictures to show compliance with given comments – after that to re-inform TNB that actions have been taken on those comments, to obtain letter of support from TNB - TNB supply electricity on permanent basis.

2. Operation of lifts (testing using permanent electricity supply from the main line) – alignment of lift (around 1 week) – arrangement with Department of Occupational Safety and Health (DOSH) (around 1 month) – testing of lift and issuance of permit to use the lift.
3. Pumping of water from suction tank of water supply – Testing the entire pump for water systems (from main supply entering suction tank - From suction tank rising to elevated level and dropping by gravity test) - and to identify leakage and rectify if there is any leakage from pipe.
4. Firefighting (depends on the size of the building).

In comparisons with construction problems, commissioning is considered less problematic but according to the interviewee, the construction must be completed beforehand, as commissioning will usually take around 2 – 3 months. Usually, it depends on Tenaga Nasional Berhad (TNB) as they can cause the duration for commissioning to lengthen from 6 months up to 1 year because during end of the year most of the officers involved are on leave and due to the lack of human resource, progress on paper work will not be progressing smoothly.

4.3.14.3 Discussions on Case Study

The architect interviewed for this case study emphasized a few main items on commissioning, such as: the importance to obtain the permanent supply of electricity from Tenaga Nasional Berhad (TNB), arrangement with Department of Occupational Safety and Health (DOSH) for inspection of lift, pumping of water from the suction tank and lastly the completion of construction. Most importantly, the interviewee stressed the significance of authority's related problem such as local power supply authority, Tenaga Nasional Berhad (TNB). On another matter, it can be deduced that commissioning problems due to water leakage is serious. This is because the pumping of water from the suction tank is one of the most important items that need to be noted during commissioning.

4.3.15 Case Study Report 8 (IE1a1-3)

4.3.15.1 Background of Case Study

A case study interview was conducted with Mr. Tan (contractor) at the site office for the construction of Stadium, University Malaya on 6th December 2011 at 10.00 a.m.

Years of experience : 30 years

Project duration : 3 years

Types of contract : Design and build (lump sum)

4.3.15.2 Other Issues Related to Case Study

1. The expected completion date for this project was April 2012.
2. This project was behind schedule for one month when the interview was conducted due to mechanical works. According to the interviewee, mechanical work for air-conditioning was a bit delay due to lots of variation orders to be cater by the contractor and these variation orders have not yet been certified and finalized to date. For the VRV systems, additional numbers of air-conditioner was added by the end-user resulted in complications in the installation works. This is because of the VRV system where the gas piping for refrigerant must be dismantled and re-installed to cater this changes and layout.

4.3.15.3 Discussions on Case Study

The problem of changes to the initial design was found in this project for mechanical works such as VRV system due to the end-user requirement. Apart from this, the issuance of lots of variation orders has also delayed mechanical works for this project.

4.3.15.4 Participant Observations

The researcher managed to attend one of the site meeting held at the construction site office on 15th November 2011. This meeting was attended by the contractor, architect, sub-contractors and some of the consultants in this project. Empirical observations during the meeting were as follows:

a) Landscape item – changes to the site plan

- Re-design has to be done and but the changes has not been submitted to the Dewan Bandaraya Kuala Lumpur, DBKL (Kuala Lumpur City Hall). These changes have to be approved by DBKL to omit "grass grip" at the parking area before the issuance of construction drawings.
- This item for grip block was removed from the landscape item and was inserted as an external work in the Bill of Quantities (BQ).

b) Variations Order (V.O.)

- There were 5 items of VO which were submitted to Public Works Department (JKR) for approval and some of these items had to be revised and resubmitted to JKR.

c) Materials

- JKR has accepted the materials for the running track but the positioning and equipment for the track are still pending for approval.
- For cold water and the ironmongeries, the sample has not been approved yet.

d) Decorative door

- Need to prepare mock up and sample for the end-user and to update their submission.
- Need to capture photos with 'blow out' for client's reference before proceeding.

In conclusion, throughout the whole meeting, the main issue concerned by all parties was the "grass grip" or "grip pave". The issue of "grip pave" and interlocking pavement was discussed intensively. Work progress on parking area had to be suspended while waiting for decision on the “grass split” area. This will be checked and confirmed by the quantity surveyor on a later date. The expected date to commence testing and commissioning for this project is April 2012.

4.3.16 Case Study Report 8a (IA1a1-18)

4.3.16.1 Background of Case Study

The second interview for this case study was conducted with the architect for this project, Ar Sufian, from the consultant’s side at the site office on 28^{h} June 2012 at 12.00 p.m.

Years of experience : 23 years

Project duration : 3 years

Types of contract : Design and build (lump sum)

4.3.16.2 Other Issues Related to Case Study

According to the interviewee, problems in this project were manageable. Basically, the project was completed on time and only encountered minor delay problems. By 29th May 2012, the project was almost completed except for some minor unfinished external works such as fencing, sign board, turfing and etc. which according the interviewee were acceptable. According to the architect, based on his own discretion, these minor unfinished works can be forgiven as long as the building was operational. Thus, as the architect for this project, the interviewee was able to verify that the building is ready to be handed over. According to the interviewee, the energizing of power for this project had a slight delay problem (around one week) but is still within the margin allowance of the main contractor. Within this margin allowance time, the contractor is allowed to crash their work programme i.e. their specific task was 10 working days but they have to complete it within 6 working days due to this problem by adding extra workforce and etc. The interviewee was asked whether it was a norm to expedite up the work during this last 5%. According to the interviewee, towards the end of the project, it is normal to rush testing and commissioning but at the same time, the uncompleted architectural works are also rushed. These two items are rushed concurrently and independently. During this period of tight schedule, workers on site are very busy because various work needs to be done independently. However, some of these elements which needed crashes have to be coordinated. For example, the concealment of ceiling which comes under architectural work cannot be installed before the installations of lightings and testing are completed. Thus, after everything above the ceiling have been installed and tested, only then can the ceiling be fixed. There are certain cases where architectural work cannot be completed unless testing and commissioning has been completed. Works, which need to be interfaced with other contractor (interfacing problems of two work scopes), will usually encounter many problems. Thus, interfacing of work scope will usually cause problems. Therefore, a little lead-time must be allowed for the completion of architectural works after testing and commissioning because lead-time will affect the overall completion date for CPC. On another matter, lead-time must be allowed in testing and commissioning for final architectural installations to close-out all items involved in architectural finishes. In the project mentioned by the interviewee, lead-time was allocated for the completion and close up of the ceiling works.

Normally, at the time of the award of the contract to the main contractor, there are certain set of documents such as insurance, performance bond, and construction work programme which are required to be submitted by the contractor. For this relevant project which was assigned to the interviewee, the construction period was 24 months.

During the initial stage of the project (after the contract has been awarded), apart from the relevant documents to be submitted, the contractor must submit the construction programme which include the detail schedule and contents from mobilization until completion of the project.. As the mentioned project was a design and build contract, part of the requirement for design and build is to hand over the project complete with Certificate of Completion and Compliance (CCC) together with the Certificate of Practical Completion (CPC). On the issue whether the occupants can move in without CCC, it depends on the agreement between the client and the main contractor because there are various types of contract. For a design and build contract, there will be a consultant appointed by the design and build contractor. For the client, they may not have the total expertise to monitor the job. Thus, they have to appoint a project manager to monitor the project on their behalf. In this particular project, the so called the management team will be the Public Works Department (PWD) which will then conduct a periodically site meeting to act on behalf of the client. For conventional contracts, the contractor obligation is to complete only up to CPC whereas CCC is normally not included in conventional contract scope. However, for a professional and ethical consultant, it still part of the consultant’s obligation to secure the CCC because without CCC by the authority, the end user is unable to occupy the building. But, the issuance of Certificate of Fitness (CF) is only valid up to April 2007. After April 2007, the submission of the building plan has been changed to CCC even for conventional project. The differences between CCC and CF are: CF is issued by the authority and CCC (so called the Form F) is issued by the principal submitting person (PSP) who is normally the architect of the project. In the project mentioned above, the PSP was the architect. When the interviewee was asked whether all defects were required to be rectified in order to obtain CCC, the interviewee answered that it is not needed as rectifications of these defects will still be carried out during Defect Liability Period

(DLP). The significance of CCC is to show the completion of scope of work as stated in the contract. If the contract does not state the need for the contractor to obtain CCC as part of the contractor's scope of work, the contractor is not obliged to rectify all the defects. Nevertheless, the defect rectification is still part of their work. This is because in order to secure CCC, the contractor must call upon the relevant authorities for inspection and to obtain a support letter from various authority departments before the application of CCC can be submitted. Before testing and commissioning are conducted, the contractor has to ensure that these items comply with the inspection by the relevant authorities. For example: one of the CCC's requirements is to secure the support letter from local fire department, Bomba, (hereinafter refers as Bomba). For Bomba, this requirement can be categorized under passive and active category. Mechanical and electrical items such as hose reel, break alarm and fire alarm are all part of the active category for mechanical and electrical scope of work. Passive category includes fire door, running distance, the air limit and the ceiling which complies with Class O requirement(related to fire).Thus, before the Bomba's inspection for firefighting services, one has to ensure that all the electrical and mechanical construction work must be completed accordingly during the testing and commissioning stage. If there is no defect detected during testing and commissioning, the mechanical and electrical consultant will verify that the construction project is ready for inspection. At the same time, the consultant can arrange for the Bomba's inspection. During the inspection, the Bomba will check for incompliance works before they issue a recommendation letter for CCC to the architect. To obtain support letters from relevant authorities, testing and commissioning should be completed systematically and by following strictly to the schedule. According to the interviewee, time is a crucial element in project construction. The interviewee was asked whether it will take extra time to complete the testing and commissioning if there were problems during manufacturer's factory test or troubleshooting. The interviewee said that this problem is bound to happen. For example: for lift services, the lift itself is from the manufacturer either from local or overseas, therefore, the procurement (place order) is done by contractor, fabrication period and the delivery, and witnessed-testing prior to delivery by contractor, consultant and sometimes client, storage at site, installations and finally testing and commissioning. One must know the period for procurement (roughly1-2 months, as it takes time to place order and confirm the order price), period of fabrication (depends on the quantity and the complexity of the items), witnessed-testing at the factory (either local or overseas) by the consultants before delivery. It is because all these testing reports are needed and testing on the mock-up system needs to be conducted. For example, the curtain wall or the actual lift. For the curtain wall mentioned earlier, it involves many testing such as wind test, lateral load test, pressure test and etc. and the curtain wall must pass all these tests. After testing is done, the ordered item will be delivered to site (but not installed). Sometimes it takes roughly 6 months for the product to be delivered if the product is ordered from overseas. Delivered materials are then stored at site before installation, followed by testing at site for commissioning to ensure it was operational. The contractor is responsible for the purchasing of these items. For mechanical and electrical maintenance services, a nominated sub-contractor (NSC) may be appointed after a period of time. When the contract is initially awarded, only the main contractor will be responsible for everything. After a certain time, a NSC may be appointed by the main contractor for the maintenance services. But the appointment of NSC must be done officially and must be made known to the client and consultant. The main contractor can select their own sub-contractors but each appointment must have the consensus from the client. The contractor can propose pre-qualified sub-contractor. On another matter, for item purchases, a tender must be called for each purchase due to the selection of price and etc. The selected NSC will be appointed with the approval of client and consultant. The appointed NSC will coordinate with the main contractor. The appointed NSC will have to do the specialize work and coordinate with the main contractor. For work related to NSCs, the main contractor will get their honorarium called profit attendance, as the main contractor has to control and coordinate various NSC.

The main contractor has to coordinate these various components to align with the overall programme. For example: before the installation of lift, the structural work of the lift has to be completed beforehand. For the installation of lift, the coordination that the main contractor must perform includes structural work and electrical work and others. During the construction work programme, Gantt chart has to be prepared in detail to show the progress stage. For instance for the work programme of lift, from the beginning of structural work until the installation of the lift and even before installation, the contractor must have estimated their lead time (with or without "float") beforehand to know the work flow for each item. The interviewee said that normally the contractor would have to allow some "float" in their work programme to cater for some uncertainties such as late delivery of material and etc. But whatever it is, the work has to be completed within a predetermined particular time frame.

During the 12th month of the project (project with a 24 months of construction period), where 12 months is calculated backward from the completion, the installation of the initial work, such as structural, wiring, housing inside the lift, guard rail inside the lift, steel cable for the lift operation must be completed. The structural work must be completed before the lift installation. Even though lift is only a small part of the project, the main contractor has to coordinate many things which include his own scope of work and also the scope of work for NSC. Subsequently, the interviewee was asked whether initial work for commissioning would contribute towards the whole project delay. The interviewee answered that it can contribute towards delay and if there were problems in the initial work, it will have a domino effects on the entire project (chain effect). The interviewee further commented that commissioning work itself could also contribute to delays. The interviewee further commented that the impact of delay in commissioning is less compared to the delay caused by construction work even though both delays are interrelated. The magnitude of delay whether it comes from the earlier stage such as structural work is rather subjective. Sometimes, structural works such as sub-structure or underground works like piling and etc. and also super structure do not exhibit any problems at the initial stage but the problems suddenly occur during commissioning stage. This is one of the commissioning delays mentioned by the interviewee.

The interviewee was asked about the magnitude of delay during commissioning. The interviewee mentioned that it can be of significance and depends on a set of problems. He added that the reasons for the ground of delays could be due to any problems and occur at any time. The interviewee mentioned that it is fine to hypothesize that commissioning problems can cause delay in the project hand over. For the project mentioned earlier, the interviewee admitted that they faced a few problems during commissioning of the project. The interviewee was asked whether the commissioning problem was due to the different typology of the building itself as it was a stadium and involves complicated components compared with office building. For the interviewee, the complication arises in this project in terms of required mechanical and electrical services as the required services are wide and broad range. According to the interviewee, the building scope of high-rise building is also included in this stadium project. But, the magnitude of scale for this stadium building is less because there is only 1 lift to be commissioned whereas for high rise building, there are 6 lifts to be commissioned and 1 fire lift. When it comes to commissioning, the procedures for commissioning are the same or more or less the same.

On the question of why certain projects have fewer problems during commissioning while other projects have more problems, the interviewee mentioned that coordination is one of the main problems. Good coordination is very crucial especially works involving mechanical and electrical items which correlates to civil and structural and architectural works. Mechanical and electrical items such as electrical components, ventilation components such as air conditioning, firefighting components, lift components, plumbing like cold water and etc. and sanitary services components are part and parcel of the building (components of the building). During construction, the contractors must install all these items. In order to install all these items, the structure and architectural components must be coordinated properly. Thus, for this purpose, the contractor must prepare a coordinated shop drawings. Lift is one of the components which have interface with electrical works such as wiring and the location of the power point. The contractor must prepare a coordinated shop drawing to show the floor plan and the location of the lift and the details of electrical works, air conditioning and ceiling. This coordinated shop drawing is needed because it shows the structures above the ceiling (architectural part) and avoid any interfacing problems by depicting the structure clearly. For instance, for a beam and dropped space of 600 mm, the architect will design the ceiling to be 1 meter below the slab so that there will be a spare of 400 mm space for mechanical and electrical items such as sprinklers and lightings and etc. to run through above the ceiling. Sometimes, these items will have to go through the structures. Due to the constraint space in the ceiling, these items have to be coordinated beforehand. Sometimes, problems arise because the contractor did not prepare proper coordination during the early stage.

The project involved by the interviewee had problems with coordination during commissioning. Coordinated shop drawing was stressed by the architect from the beginning. The interviewee's emphasis that, before the contract was awarded to the main contractor, the mechanical and electrical consultant had already pre-designed the system for air conditioning, such as using centralized system with air handling unit (AHU) room or VRV system or other systems. This means that the mechanical and electrical consultant had already designed the total system for the air conditioning and received consensus by the client before the tender and award and etc. The demerit of this system is that if the client wants to use another system or if there is any changes to rooms using air conditioning; these changes may have a big impact on the design and also the system. Usually, before the execution of these changes, the consultant will advise the client on the impact of each modification. Among the impacts due to these changes are changes in cost, changes in system specifications and impact on the installation. If delay were to happen, the contractor will have ground to claim for Extensions of Time (EOT) and if it is valid, the contractor is entitled to claim for loss and expenses if the reason of delay was due to the client. If the client insists to do any changes and is aware of the consequences, the contractor will be honored with extra time to complete the job with extra cost.

When the interviewee was asked whether commissioning causes delay, the interviewee answered that even though commissioning consists of only 5% of the last stage but there is a high probability for commissioning to cause delay in the handing over of the project. When conducting commissioning, coordination is needed between contractor, sub-contractor, and sometimes manufacturers and consultants. The consultant and the contractor must verify by themselves that the system meets all the specifications stated in the contract. Even during testing and commissioning, the parties involves (contractor, sub-contractor/specialize contractor, manufacturers) need to be certified by a competent person on behalf of the contractor. The contractor requires people with license for various scope of work such as a licensed plumber and licensed electrician from the sub-contractor and also for the verification on the entire part of the contract. Such verification acts as an internal test before the respective authorities are called.

The respective authorities will conduct proper check where there must be witnesses to verify each inspection, records of testing, standard compliance, sets of forms and documents, and verification from the mechanical and electrical consultant as the submitting person. All these documentations are very importance for the principal submitting person, PSP to submit for CCC as the documents serve as proof that all the items have been tested accordingly and comply with the specifications and requirement. On top of that, all the documents are verified by a competent person and witnessed by the consultant. For the scope of mechanical and electrical items, all these information and documents have to be gathered and later submitted to the architect. For the project mentioned, the architect is the one who handled everything and prepared the checklist for the civil and structural, mechanical and electrical, landscape etc towards the end of the project.

The checklist is prepared by the architect to determine works that have been completed, works which will be completed, schedule for testing and commissioning and schedule for the assessment by the relevant authorities. In short, the architect in this project also plays an important role as the main coordinator because the project is under design and build concept and thus, resulting in the contractor assigning the lead consultant role to the architect. Therefore, the lead consultant has to take charge of project coordination and project management in order to make the project successful.

4.3.16.3 Discussions on Case Study

Based on the discretion of the architect, CPC can be issued though there are uncompleted works on site and it is normal to rush testing and commissioning towards the end of the project. Besides that, works which need to be interfaced with other trades will cause more problems in commissioning. It is also important to allow a little lead time for the completion of architectural works after testing and commissioning because lead time will affect the overall completion date for CPC. Normally the contractor will have to allow some "float" in their work programme to cater for some uncertainties such as late delivery of material and etc. Initial work for commissioning will contribute towards the whole project delay if there were problems in the initial work, it will have a domino effects on the entire project (chain effect). Lastly, it can be hypothesized that commissioning work itself can also contribute to delays.

Sometimes, structural works such as sub-structure or underground works like piling and etc. and also super structure do not exhibit any problems at the initial stage but the problems suddenly occur during commissioning stage. The complication arises in this project in terms of required mechanical and electrical services as the required services are wide and broad range. Thus, good coordination is very crucial especially works involving mechanical and electrical items which correlates to civil and structural and architectural works.

When the interviewee was asked whether commissioning causes delay, the interviewee answered that even though commissioning consists of only 5% of the last stage but there is a high probability for commissioning to cause delay in the handing over of the project.

4.4 Summary of Chapter

The pilot case study was investigated to shape and improve the concept of commissioning for future case study. Sixteen interviewees were selected for the actual case studies and some information on the background for each of these cases was presented in this chapter. The details for each of these cases will be presented in Chapter 6.

CHAPTER 5

USING EARNED VALUE ANALYSIS TO DETERMINE BUILDING COMMISSIONING PERFORMANCE

CHAPTER 5

USING EARNED VALUE ANALYSIS TO DETERMINE BUILDING COMMISSIONING PERFORMANCE

5.1 Introduction

The array of Chapter 5 is as illustrated in Figure 5.1 which begins with the introduction, definition, roles and objective of Earned Value in building commissioning. This chapter also presents components and formula in Earned Value used to measure the performance of building commissioning. This is followed with discussions on Earned Value referring to the case studies identified for this research. Lastly, limitations of using Earned Value and future recommendations are postulated.

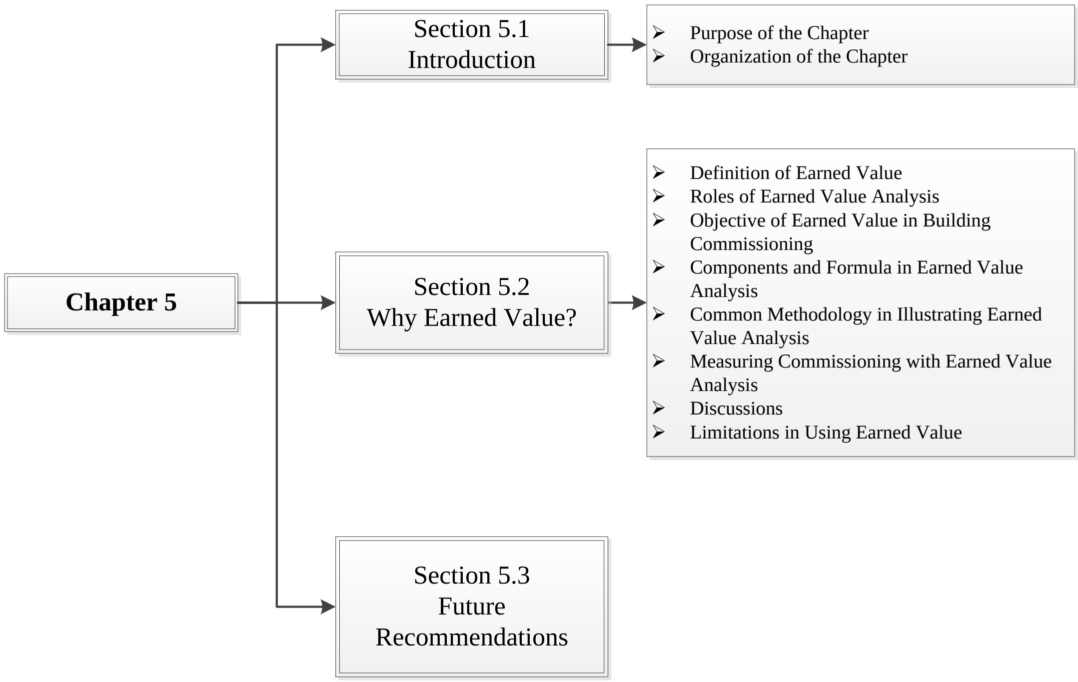


Figure 5.1: Outline of the Chapter 5

5.2 Why Earned Value?

Dating back to 1950's, the existence of problem to reconcile the measure of project progress via Gantt charts and Critical Path Analysis, people started to realize that this was not a very satisfactory way of managing projects. This method was chosen for this study because the earned value principle was easy to comprehend. Earned value comes from a basic concept that derived from accounting procedures and industrial engineering (Webb, 2003).

Earned value management was also known as "integrated cost and schedule control", because it brought together a way of measuring achievement against both time and cost goals (Webb, 2003).

5.2.1 Definition of Earned Value

Adding the value generated as time passes gives a greater insight into the project than simply comparing the planned and actual values. The worth in financial terms associated with the value generated is termed the 'earned value' (Webb, 2003). The definition of Earned Value is “A method for measuring project performance. It compares the amount of work that was planned with what was actually accomplished to determine if cost and schedule performance is as planned”. Moreover, Earned Value Analysis integrates the many important areas in project management such as project organization, scheduling, planning, budgeting; accounting, analysis, reporting and charge control (Fleming & Koppelman, 2000). Earned Value Analysis utilizes a few tools such as performance curve, work breakdown structure and a few defined formulas to depict the overall performance (Marshall, 2007).

5.2.2 Roles of Earned Value Analysis (PMI, 2013)

1) To monitor progress schedule;

2) Efficiency in time management;

3) Project completion date;

4) Budget monitoring;

5) Measuring efficiency in using resources;

6) Estimating the cost for remaining work;

7) Total project cost monitoring; and

8) Final project calculation (over budget or under budget).

As ‘Earned Value Roles’ has been clearly stated by PMI (2005), we can summarized that Earned Value Analysis has an essential role in determining the accurate measurement of physical performance against a detailed plan to allow for the accurate prediction of the final costs and schedule results for a given project. This is in agreement with Fleming and Koppelman (2000). Moreover, in any project, Earned Value Analysis has a significant role in the total management of project variables such as project scope, time, progress, cost and risks and the procurement of the main project supplies and services.

Earned Value Analysis is a forecasting tool used to predict whether the project will finish over or under the budget and a project manager will be able plan ahead as he is able to forecast the final outcome of the project based on Earned Value Analysis (Kerzner, 2009).

5.2.3 Objective of Earned Value in Building Commissioning

1. Using Earned Value Analysis to measure the importance of commissioning by clearly defining the tools used in Earned Value Analysis such as Planned Value (PV), Earned Value (EV) and Actual Value (AV);
2. Comparing the importance of each stage in a construction project using Earned Value Analysis and relating the outcome with commissioning;
3. Create a derivation for comparison based on x, y and z; and
4. Analyze and deduce a conclusion based on findings of analysis using Earned Value Analysis.

5.2.4 Components and Formulas in Earned Value Analysis (PMI, 2013)

5.2.4.1 Planned Value (PV)

According to PMI resource book, the essence of Planned Value (PV) describes how the progress of project work is supposed to be at any given point in the project schedule. It is basically a reflection of the cost that is proposed to be utilized on an activity during a specific time frame. Planned Value (PV) is the established baseline (also known as the performance measurement baseline or PMB) against the actual progress of the project that is measured. In short, Planned Value (PV) is the dollar value of the work that was scheduled for completion by this point in the project schedule (Budd & Budd, 2010). Planned Value is usually charted to show the cumulative resources used against the project schedule in an S-Curve.

5.2.4.2 Earned Value (EV)

Earned Value (EV) is the depiction of work progress at any given time frame. It is also commonly known as the Budgeted Cost of Work Performed (BCWP). It is basically a reflection of the amount of work that has actually been accomplished to date (or a given time period). In short, Earned Value (EV) is the work actually performed during the status period at its planned budget and not the actual cost (Budd & Budd, 2010).

5.2.4.3 Actual Cost (AC)

Actual Cost (AC) is also commonly known as Actual Cost of Work Performed (ACWP). It is basically a reflection of the level of resources that have been used to achieve the actual work performed to date (or a given time period). In order depict clearly the function of Earned Value, a number of methods have been used to present the Earned Value data. In short, Earned Value (EV) is the work actually performed during the status period at its planned budget and not the actual cost (Budd & Budd, 2010). Among the most common methods used to depict Earned Value Analysis is S-Curve.

5.2.4.4 Rate of Performance (RP)

It is the rate at which the project is progressing. Mathematically, it is the percentage of the work actually completed out of the total work that was scheduled to be completed till that point of time.

5.2.4.5 Cost Variance (CV)

Cost Variance calculates the difference between the actual cost incurred and the planned cost. It checks for over budget or under budget.

5.2.4.6 Cost Performance Index (CPI)

Cost Performance is used to estimate the projected or actual cost of completing the project based on the performance to date.

CPI = EV/AC

5.2.4.7 Formulas Used in Earned Value Analysis

As tabulated in Table 5.1 are formulas in Earned Value Analysis being used in the measurement of building commissioning performance to determine the importance of building commissioning on the project timely completion.

Table 5.1: Formulas in Earned Value Analysis

Term	**Formula**
Earned Value	EV = PV to date x RP
Cost Variance	CV = EV – AC
Schedule Variance	SV = EV – PV
Cost Performance Index	CPI = EV/ AC

(Source: developed from PMI, 2005)

5.2.5 Common Methodology in Illustrating Earned Value Analysis

5.2.5.1 S-Curve

S- Curve depicts the cumulative costs or other performance metrics against time. Typically, an Earned Value Management S-Curve is displayed on an X-Y axis with Time as X-axis and Performance Metrics as Y –Axis. S-Curve shape usually is flatter at the beginning and end and steeper in the middle which is typical of most projects especially in construction. The initial part of S-Curve represents a slow, starting point for the project and accelerates once work is in progress and normally decelerates at the end for typical projects (Wideman, 1994).

According to Webb (2003), S-Curve can be divided into three stages, which are:

Stage 1: Start Up

Stage 2: Peak Activity

Stage 3: Wind Down

Stage 1: Start Up

*Preliminary preparatory stage which includes planning, preparing work force as well as ordering of materials, etc.

*After the initial preparatory work has been laid, the project will move on to Stage 2.

Stage 2: Steady Stage

* Work is progressing steadily.

*Working environment has reached optimum conditions for balanced performance and repetition

*Further contractors and workers are added as project progress. Integration of every process becomes more complicated.

Stage 3: Wind Down

*There is pressure to complete the project on time.

*Testing and commissioning stage

*Project completion

As mentioned previously, S-Curve represents a slow, starting point for the project and accelerates once work is in progress and normally decelerates at the end for typical projects. But, occasionally, the S-Curve may display steep curve at the end if the project if the project is not running smoothly due to problems either in stage 1 or stage 2. This steep end has an interesting S-Curve shape and can be due to many reasons. The end of the project is usually associated with project commissioning and this is where an analysis will be done to examine the impact of project commissioning towards the whole project progress. A typical S-Curve is shown in Figure 5.2.

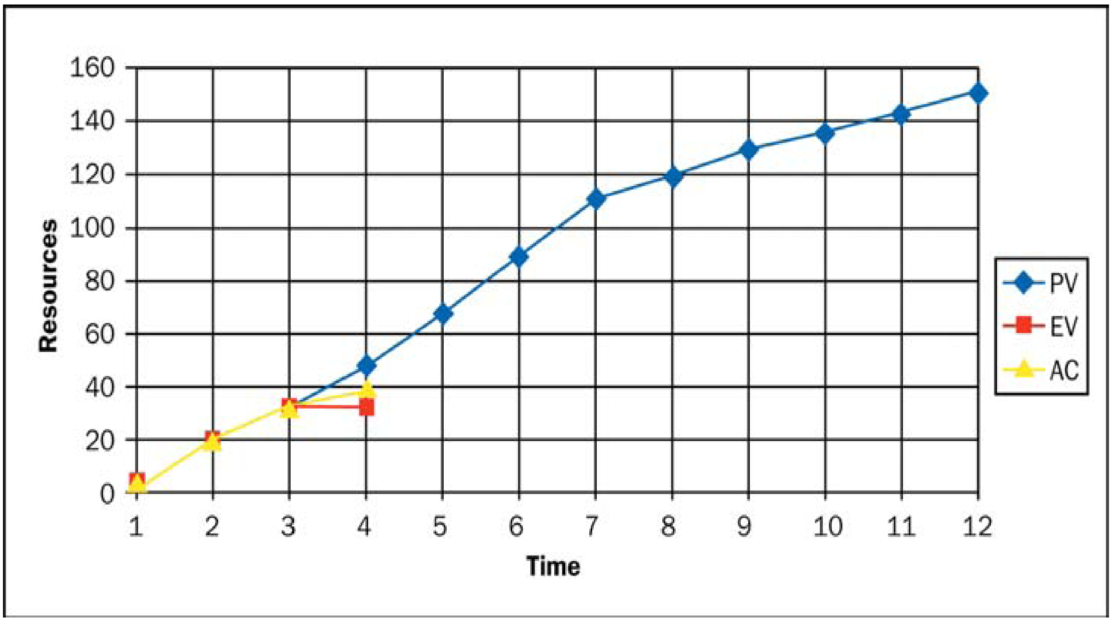


Figure 5.2: Typical S-Curve

(Source: PMI, 2005: 19)

5.2.6 Measuring Commissioning with Earned Value Analysis

As our study approach is to gauge the importance of commissioning in a construction project, the necessary data is needed to validate the importance of commissioning in construction projects. Planned Value (PV), Earned Value (EV) and Actual Value (AV) data of a few construction projects in Malaysia were collected. By using Earned Value Analysis to measure the Rate of Performance (RP) of Planned Value (PV), Earned Value (EV) and Actual Value (AV) for commissioning stage, an S-Curve was constructed to show the relevant parameters.

The data will provide solid backing that commissioning has a significant role in the entire project construction and should not be treated as a trivial part in the project construction. Failure to grasp the importance of building commissioning will increase the risk in the project safety, jeopardizing project cost and result in the inoperability of electrical and mechanical equipment.

Data from three Public Works Department's (PWD) project out of eight case studies identified for this study were collected and the values for Planned Value (PV), Earned Value (EV) and Actual Value (AV) were tabulated and the related ratios such as Rate of Performance (RP), Cost Variance (CV), Schedule Variance (SV) and Cost Performance Index (CPI) were calculated. Tables and S-Curve for Project A, Project B and C are illustrated as follows in Figure 5.3, Figure 5.4, Figure 5.5, Table 5.2, Table 5.3 and Table 5.4.

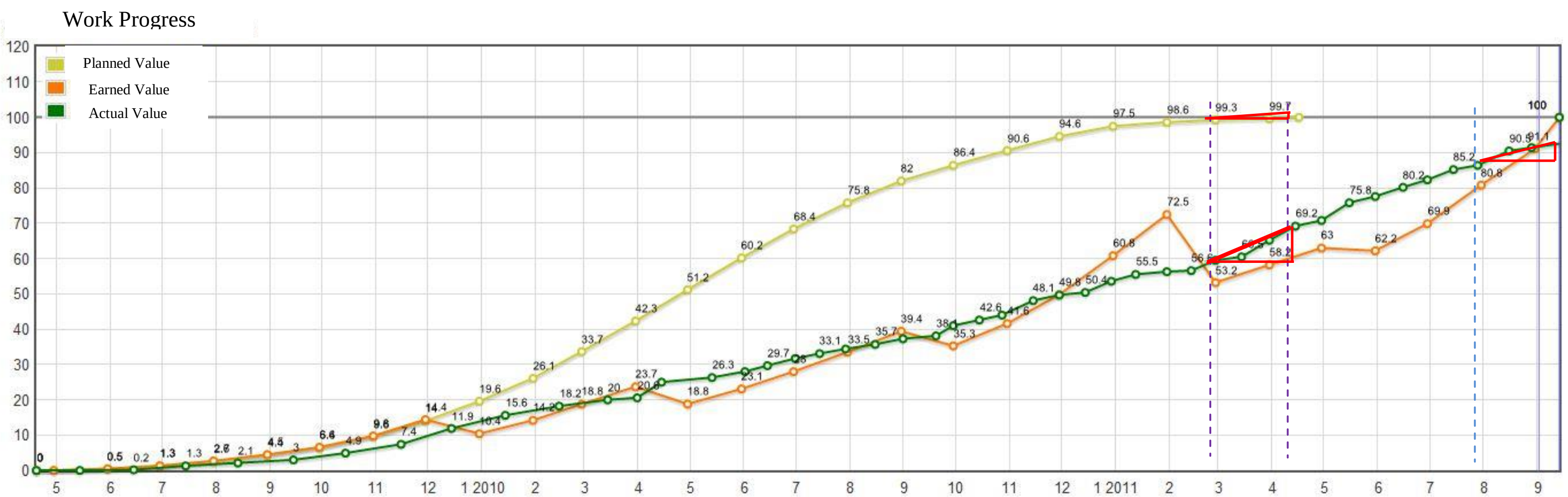
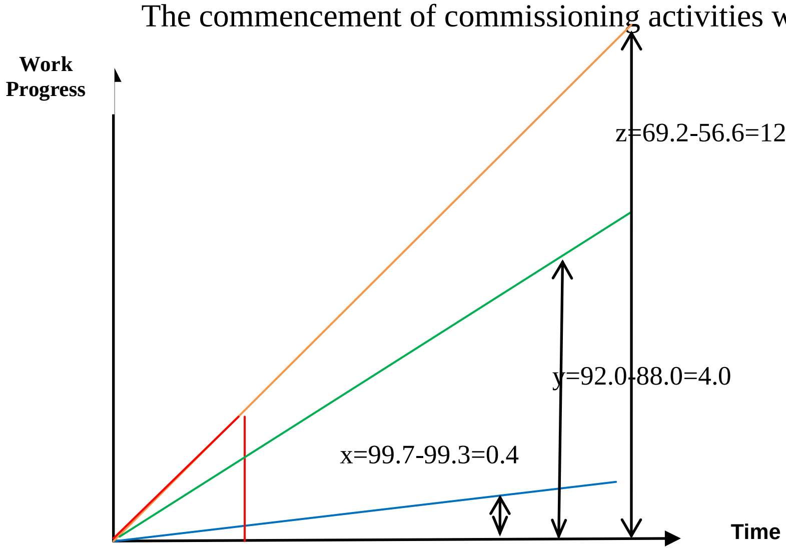


Figure 5.3: S-Curve for Project A

The commencement of commissioning activities was delayed to August 2011 from March 2011.



Legend:	
	Planned commencement of commissioning, x
	Actual commencement of commissioning activities, y
	Execution of construction activities instead of planned commissioning activities, z

z>y>x

Table 5.2: The Importance of Each Stage in Construction Project Using Earned Value Analysis for Project A

Project Stage	Year	Month	PV (%)	EV (%)	AV (%)	RP	CV	SV	CPI
Stage 1	2009	4	0	0	0	0.00	0.00	0.00	0.00
		5	0.1	0.1	0.1	1.00	0.00	0.00	1.00
		6	0.5	0.6	0.5	1.20	0.10	0.10	1.20
		7	1.3	1.3	1.3	1.00	0.00	0.00	1.00
		8	2.7	2.8	2.1	1.04	0.70	0.10	1.33
		9	4.5	4.5	2.7	1.00	1.80	0.00	1.67
		10	6.4	6.4	4.8	1.00	1.60	0.00	1.33
		11	9.6	9.6	6.9	1.00	2.70	0.00	1.39
Stage 2		12	14.4	14.4	10.3	1.00	4.10	0.00	1.40
	2010	1	19.6	10.4	12.2	0.53	-1.80	-9.20	0.85
		2	26.1	14.2	14.2	0.54	0.00	-11.90	1.00
		3	33.7	18.2	18.8	0.54	-0.60	-15.50	0.97
		4	42.3	23.7	20.8	0.56	2.90	-18.60	1.14
		5	51.2	18.8	26	0.37	-7.20	-32.40	0.72
		6	60.2	23.1	27.4	0.38	-4.30	-37.10	0.84
		7	68.4	28.6	30.6	0.42	-2.00	-39.80	0.93
		8	75.8	33.5	33.5	0.44	0.00	-42.30	1.00
		9	82	39.4	38.3	0.48	1.10	-42.60	1.03
		10	86.4	35.3	39.9	0.41	-4.60	-51.10	0.88
		11	90.6	41.6	43.6	0.46	-2.00	-49.00	0.95
		12	94.6	49.8	49.6	0.53	0.20	-44.80	1.00
	2011	1	97.5	60.8	51.9	0.62	8.90	-36.70	1.17
		2	98.6	72.5	55.9	0.74	16.60	-26.10	1.30
		3	99.3	53.2	59.7	0.54	-6.50	-46.10	0.89
		4	99.7	58.2	67.5	0.58	-9.30	-41.50	0.86
		5	100	63	69.2	0.63	-6.20	-37.00	0.91
Stage 3		6	100	62.2	75.8	0.62	-13.60	-37.80	0.82
		7	100	69.8	82.2	0.70	-12.40	-30.20	0.85
		8	100	80.8	87.2	0.81	-6.40	-19.20	0.93
		9	100	91.1	91.5	0.91	-0.40	-8.90	1.00
		10	100	100	92.3	1.00	7.70	0.00	1.08

As tabulated in Table 5.2, in stage 1, planning and preparatory work is initiated. The rate of performance, RP is above 1, implying Planned Value, PV ≈ Earned Value, EV, which means stage 1 work, is progressing accordingly. The Cost of Variance is slightly positive implying slight cost overrun, and Schedule Variance, SV is positive implying no project delay.

In Stage 2, construction work is progressing. But, the rate of performance, RP is below 1, implying Planned Value, PV < Earned Value, EV, which means work is not progressing smoothly according to plan. The Cost of Variance is ≈ 0 implying no cost overrun. Schedule Variance, SV is negative implying potential project delay in the final stage.

In Stage 3, the project was delayed due to problems in stage 2. As a result, the project final stage which was supposed to be completed in May 2011 was shifted to October 2011. In stage 3, the rate of performance, RP is below 1, implying Planned Value, PV < Earned Value, EV. The Cost of Variance is mostly negative implying no cost overrun but resources are not being used due to project delay. The Schedule Variance, SV is also negative implying project delay.

As referred to S-Curve Graph for Project A in Figure 5.3. To examine the consequences of project delay towards commissioning in Project A, the gradient for Planned commencement of commissioning, x, Actual Commencement of commissioning activities, y and execution of construction activities instead of planned commissioning activities, z were plotted.

The result is

z= 12.6 > y= 4.0 > x = 0.4

Besides that, z > y (12.6 > 4.0) or equivalent to z: y = 12.6: 4.0. This implied that the ratio of the execution of construction activities instead of planned commissioning activities to the ratio of actual commencement of commissioning activities, which are equals to z = 3.15y. It can be deduced that the rate of performance for execution of construction activities instead of commissioning activities is 3.15 multiply the rate of performance for actual commencement of commissioning activities, y. In other words, the rate of performance for execution of construction activities instead of commissioning activities is higher than the rate of performance for actual commencement of commissioning activities. Supposedly, the rate of performance for execution of construction activities should be slower towards the end when the project almost completed. This also implies that project is rushing to catch up the deadline by speeding up the rate of performance for uncompleted or unsettled construction activities.

With y > x, it means that the project is being rushed during the commissioning stage. This is due to project delay. Based on the result of y, the gradient at the final stage is also steep implying project delay in stage 2 which results in commissioning to be rushed.

Besides that, y > x (4.0 > 0.4) or equivalent to y: x = 4.0: 0.4. This implied that the ratio of the actual commencement of commissioning activities to the ratio of planned commissioning activities are equals to y = 10.0x. It can be deduced that the rate of performance for actual commissioning activities, y is 10.0 times multiply the rate of performance for planned commissioning activities, x. In other words, actual commissioning activities are rushing to catch up to complete the project when there is delay or problem during the execution of planned commissioning. When the planned commissioning activities are delayed, the performance rate for actual commissioning has to be speeded up to hand over the project to the client.

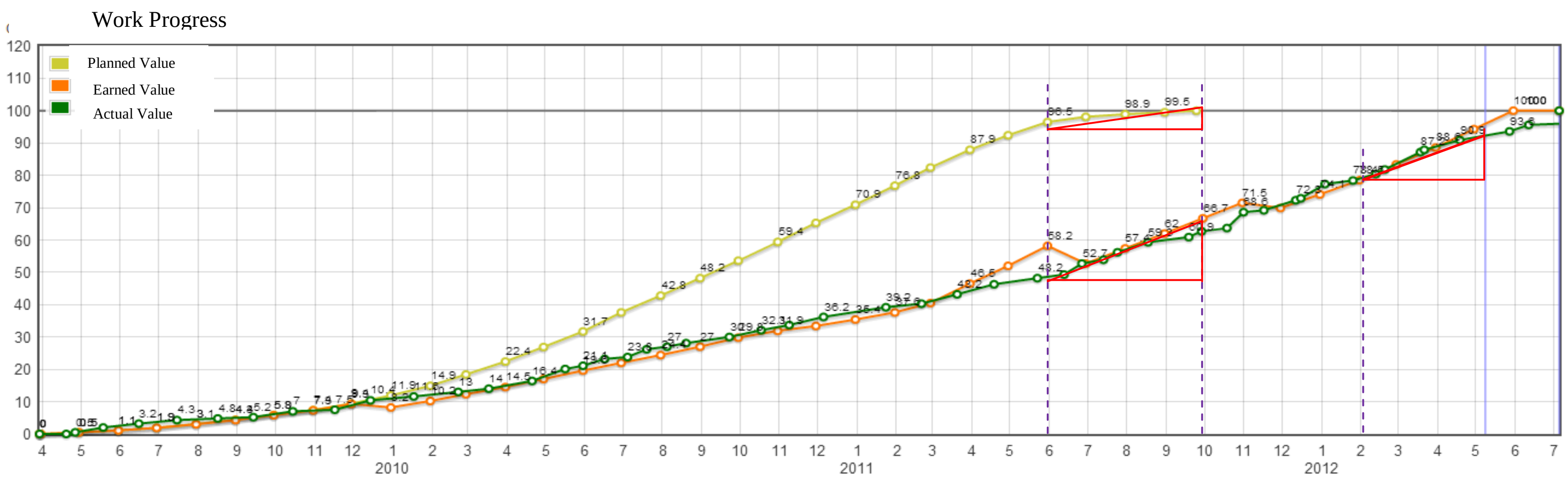
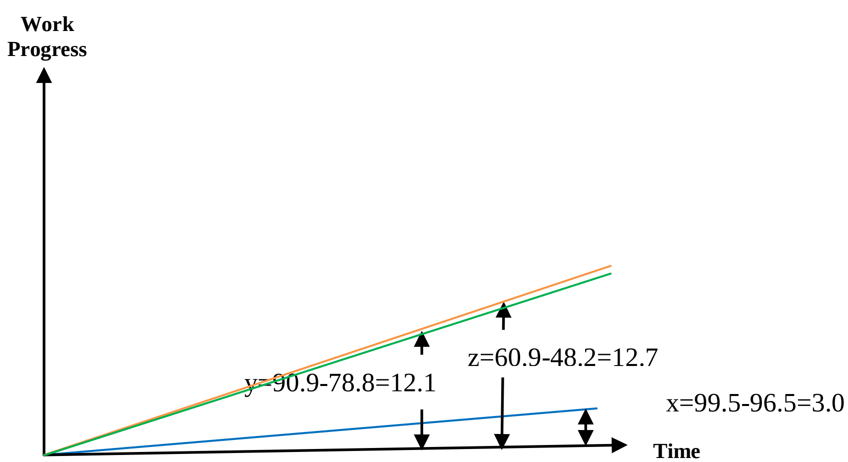


Figure 5.4: S-Curve for Project B

The commencement of commissioning activities was postponed to February 2012 from June 2011.



Legend:	
	Planned commencement of commissioning, x
	Actual commencement of commissioning activities, y
	Execution of construction activities instead of planned commissioning activities, z

z>y>x

Table 5.3: The Importance of Each Stage in Construction Project Using Earned Value Analysis for Project B

Project Stage	Year	Month	PV (%)	EV (%)	AV (%)	RP	CV	SV	CPI
Stage 1	2009	4	0	0	0	0.00	0.00	0.00	0.00
		5	0.5	0.5	0.5	1.00	0.00	0.00	1.00
		6	0.9	0.9	1.1	1.00	-0.20	0.00	0.82
		7	1.9	1.9	1.9	1.00	0.00	0.00	1.00
		8	3.1	3.1	3.5	1.00	-0.40	0.00	0.89
		9	4.3	4.3	4.4	1.00	-0.10	0.00	0.98
		10	5.8	5.8	5.8	1.00	0.00	0.00	1.00
		11	7.9	7.9	7.9	1.00	0.00	0.00	1.00
		12	9.9	9.9	9.9	1.00	0.00	0.00	1.00
	2010	1	11.9	9.2	10.3	0.77	-1.10	-2.70	0.89
Stage 2		2	14.9	10.2	10.7	0.68	-0.50	-4.70	0.95
		3	19.2	13.1	13.3	0.68	-0.20	-6.10	0.98
		4	22.4	14	14	0.63	0.00	-8.40	1.00
		5	28.7	16.4	16.5	0.57	-0.10	-12.30	0.99
		6	31.7	19.1	21.4	0.60	-2.30	-12.60	0.89
		7	38.7	21	23.6	0.54	-2.60	-17.70	0.89
		8	42.8	23.5	27	0.55	-3.50	-19.30	0.87
		9	48.2	26.5	28.2	0.55	-1.70	-21.70	0.94
		10	52.3	30.9	32.1	0.59	-1.20	-21.40	0.96
		11	59.4	31.9	34.7	0.54	-2.80	-27.50	0.92
		12	65.5	32.6	36.2	0.50	-3.60	-32.90	0.90
	2011	1	70.9	35.4	38.9	0.50	-3.50	-35.50	0.91
		2	76.8	37.6	39.7	0.49	-2.10	-39.20	0.95
		3	82.2	40	40.7	0.49	-0.70	-42.20	0.98
		4	87.9	46.5	45.5	0.53	1.00	-41.40	1.02
		5	92.3	52.2	47.6	0.57	4.60	-40.10	1.10
		6	96.5	58.2	48.2	0.60	10.00	-38.30	1.21
		7	97.7	52.7	52.7	0.54	0.00	-45.00	1.00
		8	98.9	57.4	57.4	0.58	0.00	-41.50	1.00
		9	99.5	62	60	0.62	2.00	-37.50	1.03
		10	100	66.7	60.9	0.67	5.80	-33.30	1.10
		11	100	71.5	68.6	0.72	2.90	-28.50	1.04
		12	100	70.2	70.6	0.70	-0.40	-29.80	0.99
	2012	1	100	72.8	74.1	0.73	-1.30	-27.20	0.98
		2	100	78.8	78.4	0.79	0.40	-21.20	1.01
Stage 3		3	100	82.2	82.3	0.82	-0.10	-17.80	1.00
		4	100	88.9	88.9	0.89	0.00	-11.10	1.00

Table 5.3: The Importance of Each Stage in Construction Project Using Earned Value Analysis for Project B (Cont'd)

Project Stage	Year	Month	PV (%)	EV (%)	AV (%)	RP	CV	SV	CPI
Stage 3	2012	5	100	91.3	90.9	0.91	0.40	-8.70	1.00
		6	100	100	93.6	1.00	6.40	0.00	1.07
		7	100	100	97.8	1.00	2.20	0.00	1.02
		8	100	100	100	1.00	0.00	0.00	1.00

As summarized in Table 5.3, in stage 1, planning and preparatory work is initiated. The rate of performance, RP ≈ 1, implying Planned Value, PV ≈ Earned Value, EV which means stage 1 work is progressing accordingly. The Cost of Variance is about 0 implying no cost overrun, and Schedule Variance, SV is 0 implying no project delay.

In Stage 2, construction work is progressing. But, the rate of performance, RP < 1, implying Planned Value, PV < Earned Value, EV which means work is not progressing smoothly according to plan. The Cost of Variance < 0 implying no cost overrun. But this is due to actual work progressing slowly and behind schedule, in other words there is a potential for project delay. Schedule Variance, SV is negative implying potential project delay in the final stage.

In Stage 3, the project was delayed due to problems in stage 2. As a result, stage 3 which was supposed to be completed in October 2011 was shifted to August 2012. In stage 3, the rate of performance, RP < 1, implying Planned Value, PV < Earned Value, EV. The Cost of Variance is slightly positive implying slight cost overrun. The Schedule Variance, SV is also negative implying project delay.

To examine the consequences of project delay towards commissioning in Project B, the gradient for Planned commencement of commissioning, x, Actual Commencement of commissioning activities, y and execution of construction activities instead of planned commissioning activities, z were plotted as referred to S-Curve Graph in Project B in Figure 5.4.

The result is

$z= 12.7 > y= 12.1 > x = 3.0$

With $y > x$, it means that the project is being rushed during the commissioning stage. This is due to project delay. Based on the result of y, the gradient at the final stage is also steep implying project delay in stage 2 which results in commissioning to be rushed.

Besides that, $z > y$ (12.7 > 12.1) or equivalent to $z: y = 12.7: 12.1$. This implied that the ratio of the execution of construction activities instead of planned commissioning activities is almost equivalent to actual commencement of commissioning activities, which are equals to $z = 1.05y$. It can be deduced that the rate of performance for execution of construction activities instead of commissioning activities is 1.05 multiply the rate of performance for actual commencement of commissioning activities, y. In other words, the rate of performance for execution of construction activities instead of commissioning activities and actual commencement of commissioning activities are almost the same. This also implies that project commissioning is rushing to catch up the deadline. Supposedly, the rate of performance for construction activities should be lower than commissioning activities during the project termination phase.

However, when y > x (12.1 > 3.0) or equivalent to y: x = 12.1: 3.0. This implied that the ratio for the actual commencement of commissioning activities to the ratio of the planned commissioning activities are equals to y = 4.03x. It can be deduced that the rate of performance for actual commencement of commissioning activities, y is 4.03 multiply the rate of performance for planned commissioning activities, x. In other words, actual commissioning activities are accelerated to catch up the work progress when there is delay in the execution of planned commissioning activities.

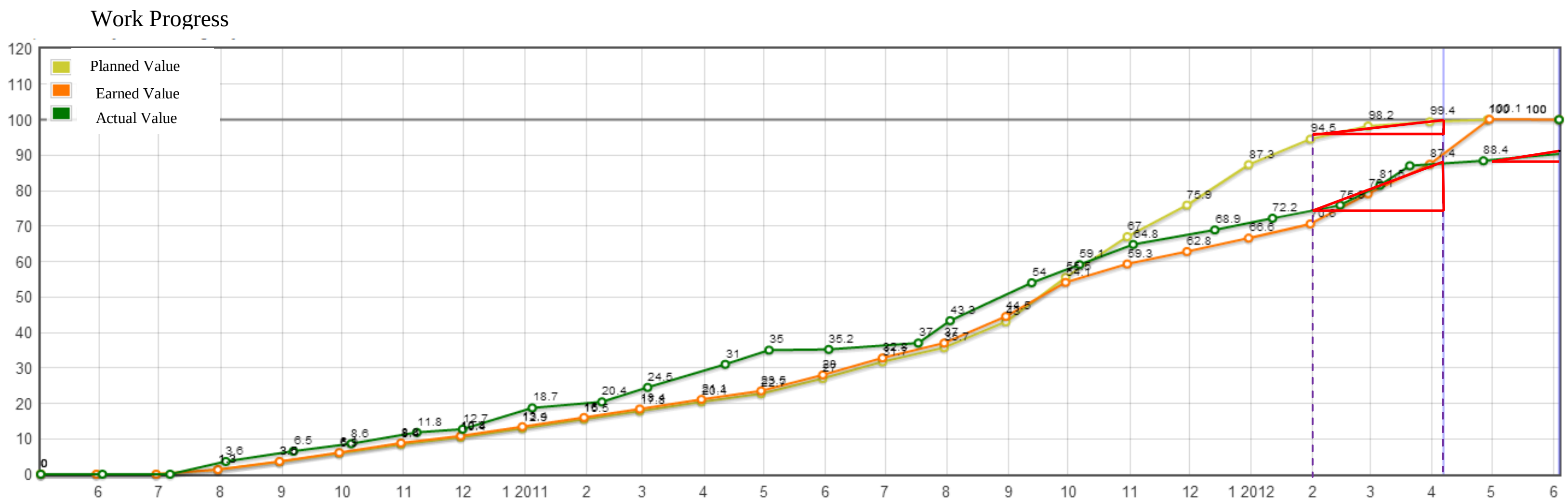
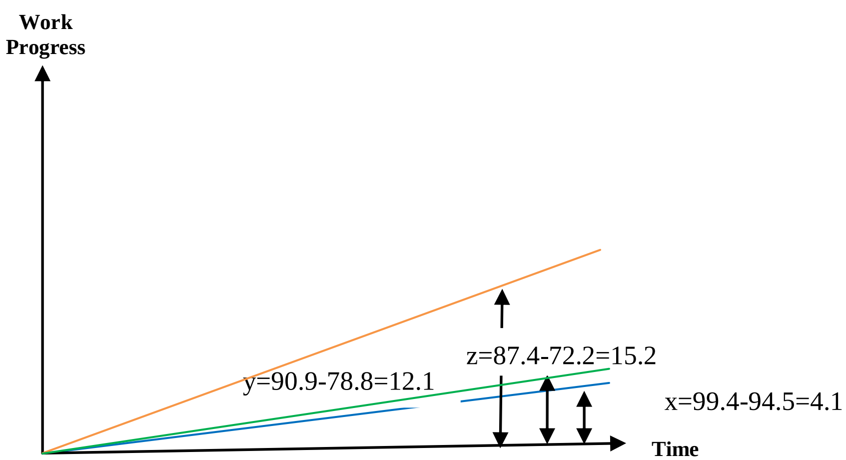


Figure 5.5: S-Curve for Project C

The commencement of commissioning activities was postponed to May 2012 from February 2012.



Legend:	
	Planned commencement of commissioning, x
	Actual commencement of commissioning activities, y
	Execution of construction activities instead of planned commissioning activities, z

z>y>x

Table 5.4: The Importance of Each Stage in Construction Project Using Earned Value Analysis for Project C

Project Stage	Year	Month	PV (%)	EV (%)	AV (%)	RP	CV	SV	CPI
Stage1	2010	5	0	0	0	0.00	0.00	0.00	0.00
		6	0.1	0.1	0.1	1.00	0.00	0.00	1.00
		7	0.3	0.3	0.5	1.00	-0.20	0.00	0.60
		8	1.3	1.3	3.6	1.00	-2.30	0.00	0.36
		9	3	2.9	6.1	0.97	-3.20	-0.10	0.48
		10	6.9	6.9	8.6	1.00	-1.70	0.00	0.80
		11	8.6	8.4	11.8	0.98	-3.40	-0.20	0.71
Stage 2		12	10.8	10.5	12.7	0.97	-2.20	-0.30	0.83
	2011	1	12.9	13	18.2	1.01	-5.20	0.10	0.71
		2	16.5	16.6	20	1.01	-3.40	0.10	0.83
		3	17.8	18.4	24.5	1.03	-6.10	0.60	0.75
		4	20.2	21.1	29.6	1.04	-8.50	0.90	0.71
		5	22.5	23.2	35	1.03	-11.80	0.70	0.66
		6	27	28	35.2	1.04	-7.20	1.00	0.80
		7	31.7	32.8	36.3	1.03	-3.50	1.10	0.90
		8	35.7	37	43.3	1.04	-6.30	1.30	0.85
		9	43	44.6	50.6	1.04	-6.00	1.60	0.88
		10	55.5	54.1	58.9	0.97	-4.80	-1.40	0.92
		11	67	59.3	64.8	0.89	-5.50	-7.70	0.92
		12	75.9	62.8	66.5	0.83	-3.70	-13.10	0.94
	2012	1	87.3	66.6	70.1	0.76	-3.50	-20.70	0.95
		2	94.5	70.6	73.3	0.75	-2.70	-23.90	0.96
		3	98.2	78.1	78.1	0.80	0.00	-20.10	1.00
Stage 3		4	99.4	87.4	87.4	0.88	0.00	-12.00	1.00
		5	100	100	88.4	1.00	11.60	0.00	1.13
		6	100	100	90.3	1.00	9.70	0.00	1.11
		7	100	100	92.2	1.00	7.80	0.00	1.08
		8	100	100	93.4	1.00	6.60	0.00	1.07
		9	100	100	97.8	1.00	2.20	0.00	1.02
		10	100	100	100	1.00	0.00	0.00	1.00

As shown in Table 5.4, in stage 1, planning and preparatory work is initiated. The rate of performance, RP≈ 1, implying Planned Value, PV ≈ Earned Value, EV which means stage 1 work is progressing accordingly. The Cost of Variance is less than 0 implying no cost overrun, and Schedule Variance, SV is 0 implying no project delay.

In Stage 2, construction work is progressing. But, the rate of performance, RP is about 1, implying Planned Value, PV ≈ Earned Value, EV which means work is progressing according to schedule. The Cost of Variance < 0 implying no cost overrun even though construction work is progressing according to schedule. Schedule Variance, SV was slightly positive initially but turned very negative at a later stage implying potential project delay.

In Stage 3, the project was not delayed as the project was rushed. This can be seen with the steep gradient in Earned Value towards project completion. As a result, the project was completed in May 2015 in accordance with schedule. Interestingly, the Cost of Variance is slightly negative towards the end of the project implying project cost has not been fully accounted or project is below planned cost. As the project was completed on time, the Schedule Variance, SV is 0 implying no project delay.

As referred to S-Curve Graph in Project C as illustrated in Figure 5.5, to examine the commissioning aspect in Project C, the gradient for Planned commencement of commissioning, x, Actual Commencement of commissioning activities, y and execution of planned commissioning activities, z were plotted.

The result is

z= 15.2 > y= 12.1 > x=4.1

With y>x, it means that the project is being rushed during the commissioning stage. Based on the result of y, the gradient at the final stage is also steep implying project delay in stage 2 which results in commissioning to be rushed.

Besides that, z > y (15.2 > 12.1) or equivalent to z: y = 15.2: 12.1. This implied that the ratio for the execution of construction activities instead of planned commissioning activities to the ratio of actual commencement of commissioning activities, which are equals to z = 1.26y. It can be deduced that the rate of performance for execution of construction activities instead of commissioning activities is 1.26 multiply the rate of performance for actual commencement of commissioning activities, y. In other words, the rate of performance for execution of construction activities instead of commissioning activities is higher than the rate of performance for actual commencement of commissioning activities. Supposedly, the rate of performance for execution of construction activities should be lower towards the end when the project almost completed. This also implies that project is rushing to catch up the deadline by speeding up the rate of performance for uncompleted or unsettled construction activities.

However, when y > x (12.1 > 4.1) or equivalent to y: x = 12.1: 4.1. This implied that the ratio for the actual commencement of commissioning activities to the ratio of planned commissioning activities are equals to y = 2.95x. It can be deduced that the rate of performance for actual commencement of commissioning activities, y is 2.95 times multiply the rate of performance for planned commissioning, x. In other words, actual commissioning activities are accelerated to catch up when there is delay during the execution of planned commissioning activities.

5.2.7 Discussions

Earned Value is a useful tool to predict the overall project progress. On top of that, with Earned Value Analysis, we are able to predict the manner in which testing and commissioning stage is to be done. Based on the results in Project A, Project B and Project C, we can conclude that the project commissioning will be rushed when there is a project delay in the middle of the project during the planned construction stage. By referring to the gradient of commissioning stage in Earned Value Analysis graph, we can see the difference in gradient for commissioning for different projects. The higher the gradient value, the faster the commissioning has to be performed to complete the project in a timely manner.

Table 5.5: Derivation of Formula for x, y and z Based on Earned Value Analysis

Project	**Derivation of Formulas**	
	Actual construction activities vs. Actual Commissioning Activities	**Actual Commissioning Activities vs. Planned Commissioning**
A	z = 3.15y	y = 10.0x
B	z = 1.05y	y = 4.03x
C	z = 1.26y	y = 2.95x

5.2.8 Limitation in Using Earned Value in Project Management

As with any analytical tools, Earned Value Analysis has limitations in accurately measuring the final outcome of any project. Basically, Earned Value Analysis is only applicable to quantifiable output such as time, budget and scope. Another limitation of this research is the use of statistical analysis. As statistical analysis helps to predict the relationship among variables used in Earned Value Analysis, the actual connection or inter-relationship can never be absolutely determined by it (Marshall, 2010).

Lastly, in any research, a larger sample size will definitely yield a better analysis. In the future, further studies over a much greater sample size can be done over a more diversify sample source.

The main components of Earned Value analysis are Planned Value (PV), Earned Value (EV), Actual Value (AV) and others and each component is quantifiable. Nevertheless, tracking actual data for Earned Value (EV) and Actual Value (AV) requires significant effort as only qualified staffs whom have the proper experience and knowledge are able to collect reliable data. Since the collected data are at best estimates of work in hand and the final results are estimated projections, the Earned Value Analysis is usually not considered the ultimate assessment of the project progress. When Earned Analysis is adopted, an essential element is the successful use of a realistically shaped baseline plan S-Curve.

Lastly, in any research, a larger sample size will definitely yield a better analysis. In the future, further studies over a much greater sample size can be done over a more diversify sample source.

5.3 Future Recommendation

As mentioned previously, Earned Value has limitation in measuring abstract output such as quality of project, happiness of client, level of satisfaction. On top of that, tracking the actual progress of the project and estimating the actual progress work takes up a lot of time and the actual date may differ from the recorded data.

In order to improve overall project, criteria such as quality and customer's satisfaction can be incorporated into the existing Earned Value Analysis. Apart from this, experience project manager can be assigned to each project to monitor the actual progress of the construction project.

CHAPTER 6

RESULTS AND DISCUSSIONS OF CASE STUDIES FINDINGS

CHAPTER 6

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6.1 Introduction

The chapter begins with the presentation of the steps involved in the process for content analysis. This is followed with the reports of cross case analysis for the case studies to made comparisons between results from the contractors' and consultants' perspectives. Comparisons were made to identify any similarities or differences among these feedbacks from different group of interviewees. Extensive discussions of these findings were reported to analyze the findings with previous empirical studies which have been done on this subject matter. Subsequently, the findings of these case studies related to building commissioning problems, significance problems and recurrence problems of commissioning are illustrated in fishbone diagrams. Subsequently, a commissioning model based on this analysis is developed to enhance building commissioning for the Malaysian institutions of higher learning.

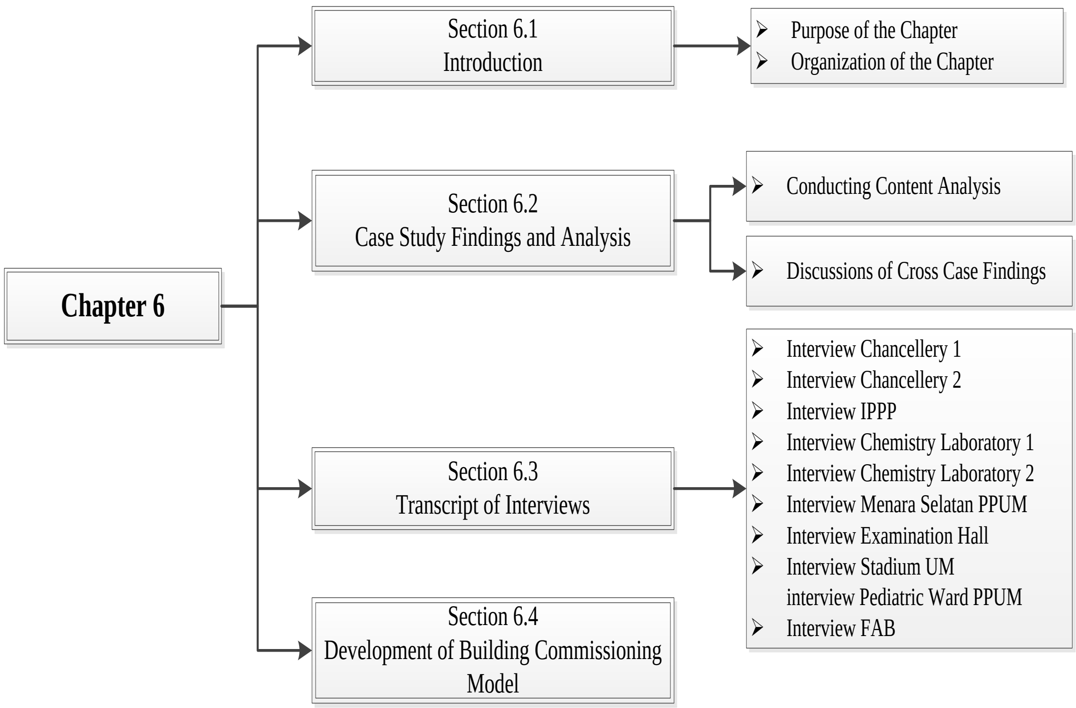

Figure 6.1: Outline of Chapter 6

6.2 Case Studies Findings and Analysis

6.2.1 Conducting Content Analysis

Content analysis is defined as a research technique for making replicable and valid inferences from texts (or other meaningful matter) to the contexts of their use (Krippendorff, 2004; p: 18).

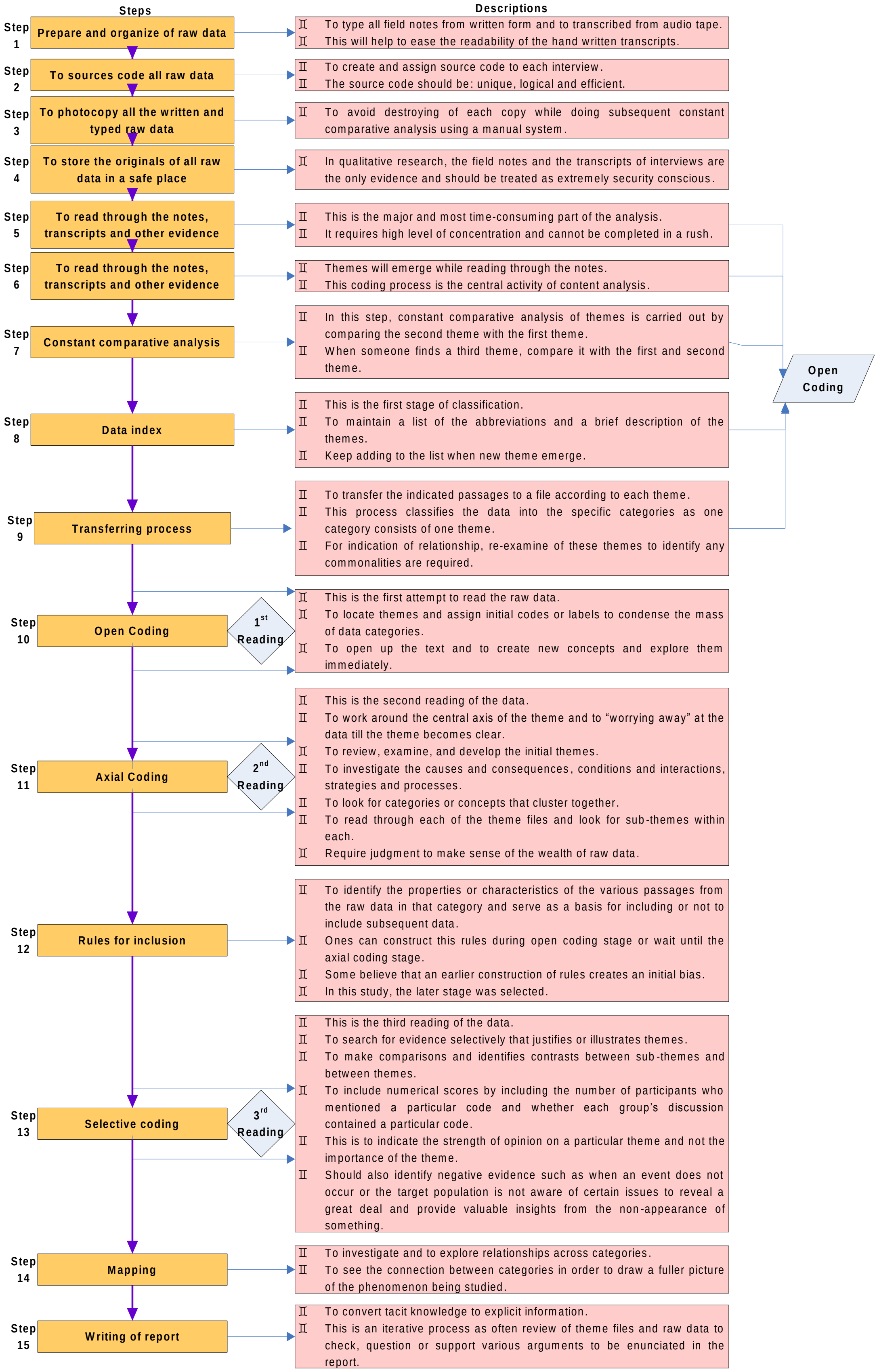

Figure 6.2: Process of Content Analysis
Developed from (Source: Cavana et al., 2001: 171-175)

Step 1: Prepare and Organize Raw Data

To prepare and organize raw data which is sourced from interviews and audio recorder from interviewees. The data is transcribed for analysis.

Step 2: Source Code All Raw Data

All raw data are source code by using alphabet and numeric symbols. The first code segment uses “I” which stands for interview followed by the second segment which describes the position of the interviewees such as “E1” for the first engineer interviewed. The third segment refers to the number of interaction if there is more than one interaction with the interviewees. For instance, E1a is used for the first interaction and E1b for the second interaction. The last segment indicates the page number of the transcript converted from the raw data. For example, p3 indicates the third page of a transcription of an interview.

Step 3: A few copy of the typed raw data is printed to ease the subsequent comparative analysis.

Step 4: The original raw data is stored in a safe place. The transcribed raw data is printed out and the softcopy is back-up in the researcher email, external hard disk and also thumb drive as this is the most precious evidence in this qualitative research.

Step 5: The notes, transcripts and other evidence procured during data collection are read thoroughly. This step is time consuming and requires high level of focus.

Step 6: Identification and Emerging of Themes

A theme coding system is a method of re-organizing the data according to conceptual themes recognized by the researcher (Minichiello *et al.*, 1990: 293). This coding process is the central activity of content analysis. For example, to analyze the perceived understanding of the interviewees on building commissioning, these themes emerged from the transcript are presented.

Step 7: Constant comparative analysis is done when the second theme emerges. When the third theme emerges, it is then compared with the first and second theme.

Step 8: Data Index

A list of abbreviations and a brief description of all themes in different sheets of paper. New additional list is added when new theme emerges. This is the first stage of classifications. These themes are underlined and as shown in Appendix A.

Step 9: Transferring process. To have a new file for each theme by using the "cut and paste" technique. This is done by cutting the coded segments from the transcripts and to paste them under an appropriate theme. This process classifies the data into specific categories and usually one category consisted of one theme. If a sentence contributes to more than one theme, this sentence will be incorporated in all the themes to which it should fall. Re-examination of these themes is needed to determine if this similarity specify a relationship.

Step 10: First arrangement and reading on the raw data. In a first attempt to compress the mass of data categories, these themes are placed and initial codes are assigned to these themes or labeled (Neuman, 1997). This step enables the researcher to open up the text to create and explore new concepts.

Step 11: Axial Coding. This is the second reading of the raw data (Neuman, 1997). To review, examine and develop the initial themes assigned during the open coding step. It is essential to search for categories or concepts that cluster together and to investigate the causes and consequences, conditions and interactions, strategies and processes. Each of these themes will be read through to identify subthemes within each category. Again, repeat the same process for these sub-themes. The most critical element in the step is the judgment of the researcher.

Step 12: Identification of the rules for inclusion (Lincoln & Guba, 1985). To identify the properties or characteristics of the various passage from the raw data in that category to serve as a basis for inclusion or exception of the subsequent data. This rule is done in this step to avoid initial bias if it is done earlier on.

Step 13: Selective coding. This step is the third reading of the data. To selectively look for evidence that illustrates or justifies themes and subsequently, to make comparison to identify contrasts between themes and sub-themes.

Step 14: Mapping. To determine the relationship between categories and have a better grasp on building commissioning in the Malaysian construction industry. To further explore the possible relationships among these themes and to focus internally to ensure these themes are distinct and have a sense of homogeneity.

Step 15: Writing of report. The last step in the analytic process and is to convert tacit knowledge into explicit information. This can be an iterative process and question or support of a variety of arguments is also enunciated in this report.

6.3 Discussions of Case Studies Results

6.3.1 Perceived Understanding of Building Commissioning from the Contractors' Perspective

From the contractors' perspectives on building commissioning in the construction industry for projects in the Malaysian institutions of higher learning, generally, four themes were generated. The first theme and foremost theme outlines the pre-requisites to be accomplished for commissioning before the commencement of commissioning. The second theme specifies the components of building commissioning. The third theme is related to actions that need to be taken or tasks to perform in order to execute building commissioning. The last theme is associated with the objectives to be attained in building commissioning.

From these findings, it can be deduced there were pre-requisites to be accomplished before the commencement of commissioning. The commencement of commissioning depends on the completion of antecedents' activities such as structural and architectural installations or completion of physical work. These installations and inspections have to be completed beforehand and to ensure there are no defects or leakages. In other words, the project must be almost completed and towards project handing over to the client with at least 90% of completion or more. Without prior completion of these antecedents' activities, it is almost impossible to carry out these commissioning activities.

Secondly, the components of commissioning are explained. These include building structural works, mechanical and electrical works, and plumbing and sanitary ware. The scope of commissioning is alleged to be more structured towards mechanical and electrical works and services.

The third theme is related to actions that need to be taken or tasks to be performed in order to execute building commissioning. Commissioning includes checking of outstanding work, final check for the whole system of mechanical and electrical, building is functioning, the equipments are running, and to other amenities are in service.

Lastly, building commissioning is perceived as a guideline to ensure that the building has been constructed in accordance with the design intent and to follow the procedures as stated in the method of statement. This is to obtain certification from the authorities. It is also the objective of commissioning to inspect the operation and functional situation- to power up or start up the available equipments, thus ensuring the equipments are in functional conditions. Commissioning also verifies that the building is performing in full functionality upon handing over. It is also aimed to ensure and verify that all the services are functioning as per specification. Building structural works have to be complied with specifications and requirements so that the building is suitable to be used by the end-user in order to handover the building with all design intent. Figure 6.3 illustrates the elements which form the understanding of building commissioning from the contractors' perspectives. This Figure is mapped from the responses and feedbacks given by the contractors involved in this research.

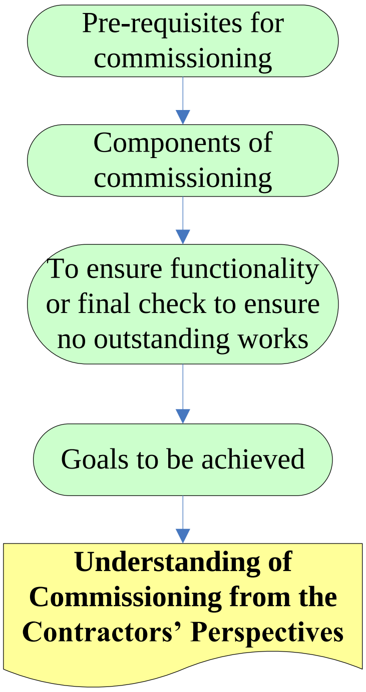

Figure 6.3: Understanding of Building Commissioning from the Contractors' Perspectives

6.3.1.1 Perceived Understanding of Building Commissioning from the Consultants' Perspectives

In comparison with the contractors' perception on building commissioning, the consultants' perspectives does not contradict with the contractor's perspective and in fact these two perceptions can be deemed as complementary to each others to provide a better understanding for building commissioning in the Malaysian construction industry for institution of higher learning. In Figure 6.4, an additional theme is derived from the consultants' perception which is the characteristics of building commissioning. It can be deduced that the consultants' seemed to emphasize more on these aspects of commissioning such as: pre-requisites and goals or objectives of building commissioning.

The first characteristic of building commissioning is perceived as an essential part of contract and is mostly related to mechanical and electrical work. It is an essential part of contract and involves mechanical and electrical work, building work, and finishes work. Commissioning is also perceived as the execution of work as stipulated in contract. Basically, building work and finishes work are not as intensive as mechanical and electrical work because they have to be really tested to deal with all the circumstances. Another interviewee perceived commissioning as a requirement to test all equipments, services and to commission the building. This interpretation is mainly confined to mechanical and electrical works.

This is followed by the second characteristics of building commissioning when it is part of construction and has to be done before the Certificate of Practical Completion (CPC) is issued. Commissioning is actually part of the construction and must be done before Certificate of Practical Completion (CPC) is issued so that building can be used as intended. For example, the building must be functioning for its purpose (usable) and commissioning is geared more towards to mechanical and electrical works.

In this regard, the pre-requisite for building commissioning in this sense depends on the types of building to be commissioned. Items for commissioning depends on the types of building, not necessarily limited to mechanical and electrical items (includes architectural items). When talking about commissioning, most of the items fall under mechanical and electrical categories with some of parts falling under civil and structural. Certain buildings also have items under architectural but this is very rare. It depends on the types of building to be handed over to the client.

For instance, in one of the interviewee's previous project, the interviewee designed a high rise office building which involved external cladding and this come under commission for architectural structure. For the finishes of the envelope of the building, the finishes can be in the form of glazing, composite panel, stone or granite finishes, or in the form of economic scale such as plaster and paint. All these finishes aspects depend on the type of building. As mentioned by the interviewee, the external gladding used for this particular building was glazing and granite. There were two types of glazing which were normal glass and special type of curtain walling. For curtain walling, special test is required for wind load and etc. The test was conducted in the specialist or manufacturer's plant where a special fabricated module for the curtain wall was constructed for the test. This test is to ensure that the specification, design and strength conform to the standard as required in the contract. The product must comply with the standard required as this is part of the requirement for the completion of the building under architectural category.

From the consultant's perspective, it can be deduced that there are three goals to be achieved in building commissioning. These goals include testing and commissioning mandatory components of building, ensuring the building is safe and fit for occupancy, and to hand over the building to the client with the building being built in accordance to customer's specification.

As mentioned earlier, building commissioning includes testing and to commissioning mandatory components of building for operation purposes. When talking about mandatory purposes, it does not merely comprise of items under architectural components, but also includes civil and structural, infrastructure, mechanical and electrical items. Besides, commissioning is an on-going process even after construction is completed as commissioning includes testing and checking on the working condition and operating function of the building. Without commissioning, the building will be unfit for occupancy. Consequently, there are so many interpretations for commissioning. One of these includes handing over the whole building to the client with the basic structure completed. Another interpretation is that the building is handed over to client with the complete equipment and trainings related to the building occupancy. Figure 6.4 illustrate the elements which forms the understanding of building commissioning from the contractors' and consultants' perspective.

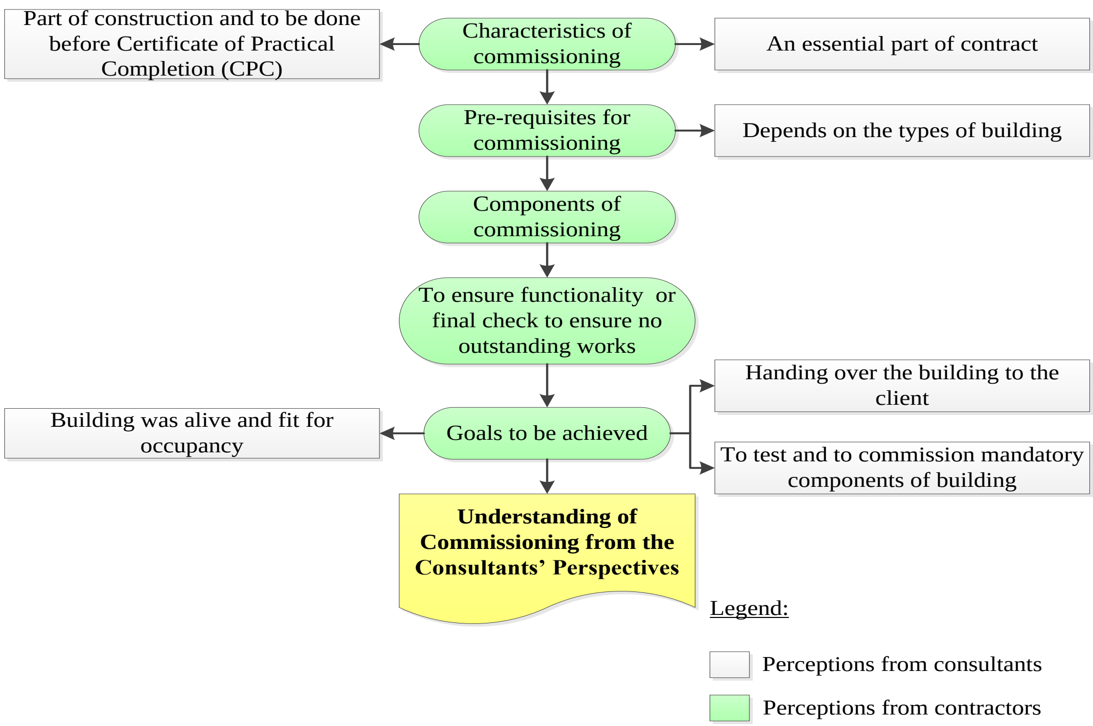

Figure 6.4: Understanding of Building Commissioning from the Consultants 'and Contractors' Perspective

6.3.2 Activities/Scopes of Commissioning from the Contractors' Perspective

The scope of commissioning is as shown in Figure 6.5. This theme relates to the mechanical and electrical supply. Before ensuring the electrical and mechanical parts, the contractor has to ensure all equipments have been installed according to manufacturer's requirements before running any test. This is to ensure that the system has been fully completed according to specifications. Testing and commissioning is to visualize any defective works such as broken glass pane or door, cracking and leakage. During testing and commissioning, the basic work comprise of:

- Visualize according to the stipulated design;
- Prepare for testing; i.e.: pressure test for plumbing; and
- Testing for functionality.

Basically, there are two major elements to be tested which are mechanical and electrical works. There were a few main parts involved other than mechanical and electrical works. The scopes of commissioning are shown in Figure 6.5 which comprised of these elements. The elements are as follows:

a) Structural – to ensure no collapse of structure and structure is durable;
b) Mechanical and electrical – all services are functioning, have been tested and are in working condition;

i) Mechanical

- Lift- Setting and tuning of lift's function to ensure proper functionality. For example, when someone presses the button for ground floor, the lift will stop at that particular floor and not the other floor;

- Air-conditioning such as temperature test and balancing for chiller and air handling unit;
- Lighting;
- Sewerage (tennis ball test will be carried out to make sure no blockage at manholes);
- Firefighting/fire protection;
- Water and water reticulation-hot and cold water;
- Plumbing and sanitary fittings; such as: functioning, no cocking at floor traps and no leakage (ping pong test will be carried out);
- Gas- centralized system and gas pipe (pressure test and flush test), medical gas for hospital; and
- Pneumatic tubes for hospital.

ii) Electrical

- Power (high and low voltage and extra low voltage such as ICT).

-continuity of wiring (continuity test and mega ohm test)

-high mass for spot light

- ICT;
- PA system; and
- Building Automation System (BAS) to monitor and control the control panel of the air-conditioner.

c) Architectural – as per design intent.

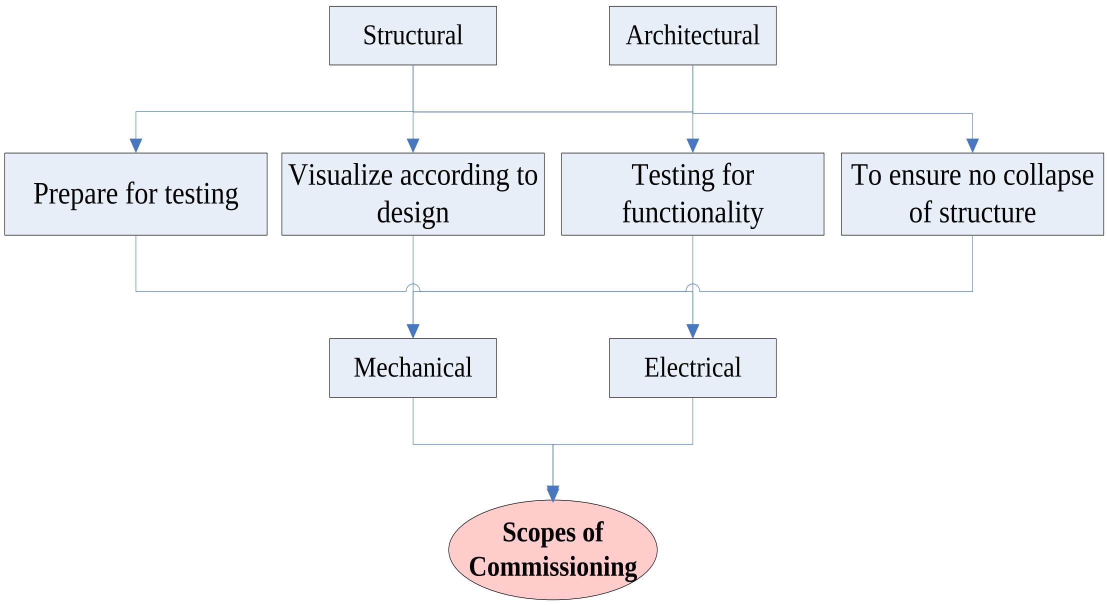

Figure 6.5: Scopes of Commissioning: Contractors' Perspective

6.3.2.1 Activities/Scopes of Commissioning from the Consultants' Perspective

a) Initial work at the beginning of the project

Before commissioning, the activities involved are initial works from the beginning of the project. Commissioning is the end part of the construction. And, before that, most of the activities have already taken place. For example, if there are 100 items in the checklist, by the time commissioning is performed, there will only be 5 items left in the checklist. Commissioning comprise of only 5% of the total work and is performed at the final stage. During commissioning, testing and some minor installation for some leftover items are done.

b) Commissioning does not necessary confined to mechanical and electrical works

Commissioning has a broad and wide meaning and does not confined to mechanical and electrical work. This was stressed by the interviewee and it is possible that commissioning could have a lot of meaning and interpretation of work scope. Normally, testing and commissioning is always related to equipment but then again the building itself, apart from the mechanical and electrical equipment can be deemed as commissioning as well. This is because without the building functioning, one cannot commission the building to the end-user. Thus, there are a few interpretations on commissioning. Commissioning comprised of the following items:

- Architecture scopes have their own items (one can deem this as commissioning); for example: if the toilet is not functioning, it would be deemed that the building has not been commissioned and one would not be able to hand over this building to the end user. Main thing of commissioning is to ensure functionality;
- Structural;
- Part of commissioning is inspection because without inspection one would not know whether it is functioning. In terms of mechanical and electrical, other than testing, it is also important to inspect whether each item is functioning properly. This was is how inspection is related to testing and commissioning.

c) To progressively check the work done

It is the duty of the mechanical and electrical engineers to check each work done progressively. This is to ensure the whole system is running accordingly, such as continuity of the circuit, water pressure test and flow test to ensure the pipe is not leaking and the toilet does not have trapped pond, all air-conditioner are in working order. For commissioning, the activities involved comprised of: firefighting, plumbing, sanitary, electrical, lift installations, ICT, PA systems, air conditioning systems, Building Automation System (BAS) and etc. According to the interviewee, it is also the scope of commissioning to obtain Certificate of Practical Completion

(CPC) and to hand over the building to the client and to obtain all supporting letters from every authorities and consultants to issue the Certificate of Practical Completion (CPC). In short, the scope of commissioning from the consultants' perspective is illustrated in Figure 6.6.

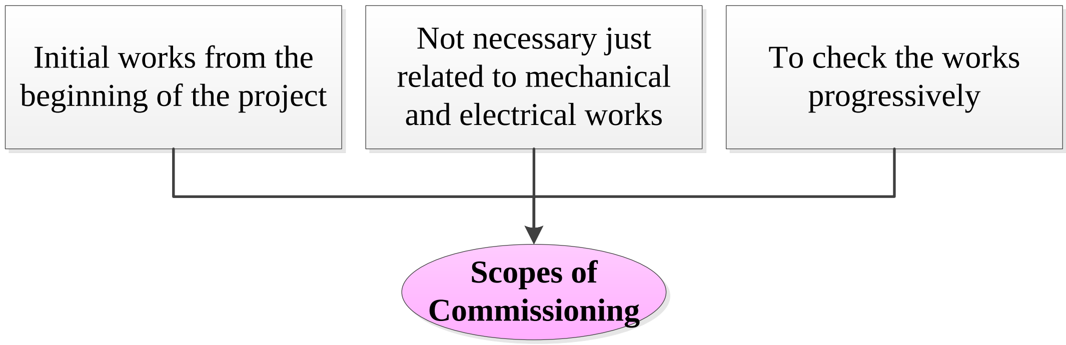

Figure 6.6: Scopes of Commissioning: Consultants' Perspective

The elements to be commissioned in this stage are:

a) Mechanical and electrical systems and services (the most important);

- Lift services;
- Air-Conditioning and Mechanical Ventilation (ACMV) systems; and
- Fire protection services (second most important) such as firemen intercom.

b) Sanitary and plumbing services;

c) Fume cupboard system;

d) Gas pipeline;

e) Extra Low Voltage (ELV);

f) ICT-PA system;

g) Energize of high tension (HT) supply from University of Malaya PPU;

h) Road access to the building and hydrant;

i) Sewerage;

j) Structural works; and

k) Architectural works such as the straightness, jointing, alignment and the finishes were not damaged.

6.3.3 Duration for Commissioning: Contractors' Perspective

The time needed for commissioning depends on:

a) Sub-contractors' work performance

Depends on the performance of the sub-contractor who had carried out the work.

b) Depends on the size of the project. Delay from previous stages or problems may affect the commissioning phase itself

The time needed for commissioning depends on the size of the project or building and has to be progressively followed. The schedule of civil, structural and architectural work normally takes about 1 month for commissioning. According to one of the interviewee, initially the duration for this commissioning was from 11st July till 11st August 2011. The interviewee claimed that due to delay from the previous stages, the duration for commissioning was condensed to 16 days for this particular project. But, when the interviewee was probed further and based on on-site observation, it was found that delays to complete the project were due to testing and commissioning itself.

Among the eight key business drivers that must be well defined in the contract for project's business deal is schedule. Schedule in this study is defined as achievability of key (intermediate and final) completion dates and consistency of its definitions.

The definition of the key milestones such as: mechanical completion, function test, cold commissioning and hot commissioning is imperative to ensure smooth project implementation. There has been a tendency to compress project schedules in order to improve the clients' project returns. This causes any project delay to pose a trade-off for the contractor and the contractor will have to spend money on acceleration or on liquidated damages for not meeting the final due dates (Branconia & Lochc, 2004). Therefore, this effect of trade-off to compresses the schedule for meeting deadline should be explicitly noticed by the contractor and client. This will cause problem in the conduct of commissioning at a later stage.

c) Varies from case by case basis and depends on the type of projects

Commissioning varies on case-by-case basis. For example, one interviewee mentioned that commissioning is done within 3 months after completion of the physical works for a building project. Apart from that, commissioning also depends on the activities to be carried out. For hospital, it will take a much longer time due to complex services when compare to conventional types of services.

d) The commencement of commissioning:

According to one of the interviewee, commencement of commissioning starts around 1 month before the project building is handed over to the client. Commissioning starts from the local power authority, Tenaga Nasional Berhad (TNB) sub-station, and depending on the quantity of the equipments to be tested, the duration may vary. This duration does not include the time taken for installation.

e) Estimated duration for commissioning:

Usually it takes around 2-3 months provided there is no system failure. If the system encounters failure, troubleshooting of problems or replacement or proposal of a new system has to be carried out to solve the problems.

Some interviewee said it takes about 1½ month. However, some claimed that for a 2 years contract, it may take around 3 – 4 months for testing and commissioning before completion. Sometimes 1 month will be allocated to allow full swing testing and another 2 months for continuous testing. Based on an overview perspective from the contractors, the duration needed and the elements encountered for the duration of commissioning work chart can be demonstrated as follows in Figure 6.7.

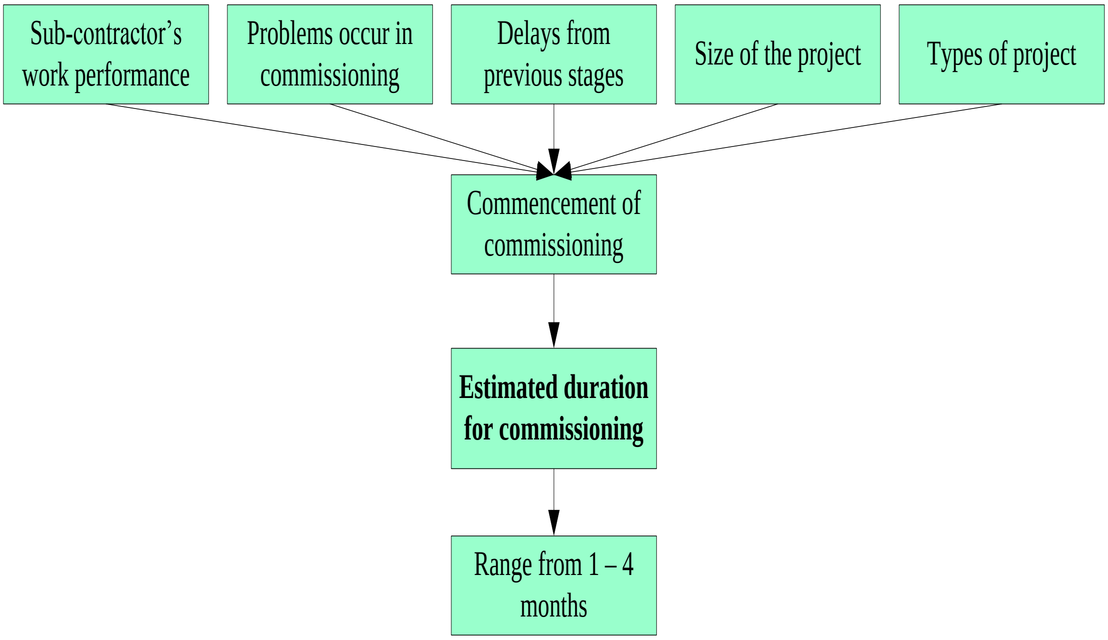

Figure 6.7: Contractors' Perspective: Durations for Commissioning

6.3.3.1 Duration for Commissioning: Consultants' Perspective

a) Sometimes duration of commissioning depends on the size of project (also depends on the number of equipments embedded within the building)

Duration of commissioning varies and depends on the size of the project. The easiest item to be compared is the equipments. The more equipment is embedded within the building, the longer time it is required to do the inspection and testing. Sometimes when testing is carried out, the equipment fails in the first test and re-testing need to be done again before re-commissioning. The size of the project and scope of the project was clearly mentioned by the interviewee to have a determinant impact on the duration needed for commissioning. From the answers given by the interviewees, it can be summarized that commissioning will take minimum 1 – 2 months and maximum 3 – 4 months if everything progresses smoothly.

b) Duration of commissioning depends on the coordination for the project

The size of the project is very subjective. If everything is in order, the size of the project does not matter. Even for a small project, if the project is not coordinated, commissioning will encounter problem. As mentioned by the interviewee, commissioning usually takes around 2 months.

c) Pending TNB's approval for electrical supply

According to the interviewee, the construction must be completed before any electrical power is provided. Duration of commissioning depends heavily on the discretion of local power company, Tenaga Nasional Berhad,(TNB) as they can cause the duration for commissioning to delay up to 6 months or even up to 1 year.

This is because during end of the year, most of the officers involved are on leave and there will be lack of people to do proper paper work to call for the tender.

d) To conduct commissioning 2 – 3 months before project handing over

Normally, testing and commissioning is conducted a lot earlier before handing over. This is to ensure that by the time the project is ready to be hand over, most of the problems will have been trouble shoot and there will only be minor glitches. Therefore, testing and commissioning is scheduled to run beforehand, around 2 – 3 months prior to handing over. These 2-3 months will be sufficient for testing and commissioning.

Therefore, to perform commissioning in an orderly manner, it is important to analyze all those determinants which can affect the execution of commissioning as shown in Figure 6.8.

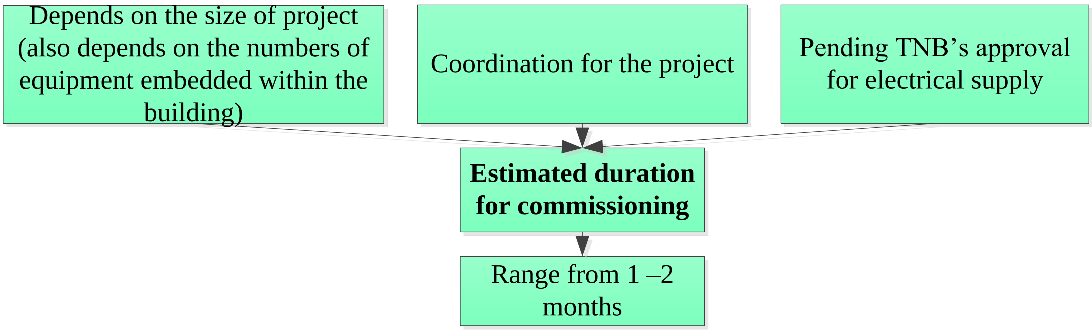

Figure 6.8: Consultants' Perspective: Durations for Commissioning

6.3.3.2 Commissioning starts at which stage of the project life-cycle?

From the contractors' and consultants' perspective, commissioning starts:

a) Progressively all through the stages/all along the way/continuous process

- Commissioning is done progressively all through the stages but it is called "testing" in these stages. It is only towards the end where the final and total commissioning is done as a final confirmation for all the systems. For example, any leakage for piping at sink will be checked progressively during construction after it is laid from riser to the first floor at reinforced concrete floor slab and wall before wall and floor finishes are installed. This will quicken the time needed for testing and commissioning at the end stage of the project. Consequently, fewer problems would occur.
- Inspections are carried out all along the way to assure quality of work and also to ensure no system failure during testing and commissioning. However, testing and commissioning is only carried out towards the end before handing over the project to the client.
- It is a continuous process. After each item has been installed, the system should be tested to verify its functionality.

b) After construction stage

Commissioning is done after everything has almost been completed. Usually commissioning is conducted after the construction stage.

Some interviewee mentioned that commissioning is done after the construction (towards the end) stage, where all fittings and piping have been installed.

c) Depends on the project schedule

Commissioning depends on the project schedule provided that the equipments have been installed and properly housed and there is available manpower to conduct commissioning.

d) Others

Commissioning starts in the early stage. For example, after submitting the form to the national sewerage company, Indah Water Konsortium (IWK) at the design stage, inspection will be done. PDC 6 & 7 inspection form will be filled and if there is no comments from the authorities, PDC 8 form shall be submitted. Training for end-user means the mechanical and electrical department from JPPHB in University of Malaya will be trained by the contractors.

From the consultants' perspective, commissioning is conducted at the following stage:

- During planning;
- Before actual completion;
- After construction;
- Normally, commissioning starts during construction, and commissioning tasks starts at the end of the project. Commissioning cannot start when various scope of work which need to be done by specific nominated sub-contractors are not completed. All works must be completed before commissioning;
- At the end of construction, when everything has been installed such as air-conditioning, commissioning is carried out. For example, if the piping is still not completed, commissioning cannot be started; and
- Towards the end of the project when work progress reaches about 90%.

6.3.4 Personnel Involved during the Building Commissioning Stage

There are two types of relationship for commissioning:

a) Internal relationship such as with client

b) External relationship such as with relevant authorities (Example: water reticulation – IWK, fire fighting – Fire and Rescue Department (Bomba), road and drainage – Kuala Lumpur City Hall (DBKL)).

In general, commissioning involves the whole team. The team can be categorized as follows:

- mechanical and electrical consultants, engineers, architect, clerk of work (from consultants, contractor and architect), authorities and manufacturers;
- main contractor, mechanical and electrical coordinator, site supervisor, technician (contractor), sub-contractors such as nominated sub-contractor;
- representatives from client (Public Works Department's Superintending Officer), representative and witness from Public Works Department (JKR), all consultants and sometimes the end-user/client.
- resident architect and resident engineers;
- project manager-to ensure project is being carried out accordingly on time and within budget; and
- Mechanical and electrical consultants who are representatives for the Superintending Officer (S.O.), client (end-user-JPPHB), and the Superintending Officer (JKR) and authorities such as Fire and Rescue Department (Bomba), National Institute of Occupational Safety and Health (NIOSH) and Department of Occupational Safety and Health (DOSH).

6.3.5 The Importance of Building Commissioning

All of the interviewees from contractors and consultants came into consensus that commissioning is very important to ensure conformance of the constructed facilities within the stipulated specifications.

6.3.5.1 Ranking from 1 (Least Significant) – 5 (Most Significant) on the Importance of Building Commissioning

The interviewees from contractors and consultants were asked to rank from 1 (least significant) – 5 (most significant) on the importance of commissioning. All of these interviewees rated 5 (the most significance) when they were asked on the importance of commissioning.

Reasons given by these interviewees differ from each other. From the contractors' perspective, as exemplified in Figure 6.9, commissioning is perceived to be significant in order to ensure functionality, to obtain Certificate of Practical Completion (CPC) and to run the building services accordingly and to comply with customer's specifications.

Commissioning is very important to detect problems and faulty workmanship and also to ensure functionality. For instance, what would happen if a building is handed over to the client without proper facilities such as air-conditioning, water and electricity? To ensure all systems are functioning and the building is safe, commissioning is thus conducted. Moreover, commissioning ensures the functionality and safety of the project. Commissioning means that the building has passed the testing requirements or has been tested as per design. Commissioning is important to ensure that the services are functioning and there is no problem during testing. Commissioning is also done to ensure the system in the building is functioning, the building is safe for occupancy and the building is architecturally aesthetic according to the design.

Secondly, commissioning is vital to obtain Certificate of Practical Completion (CPC). If commissioning is not conducted, the building cannot be handed over to the client and Certificate of Practical Completion (CPC) cannot be obtained.

Finally, commissioning is to ensure the services are functioning accordingly and complies with the specification in the contract. It is part of the contract and critical part as stated in the method of statement. Test results will be compiled and send to Public Works Department (JKR) for endorsement. Commissioning ensures that the building follows all the requirements set by local authorities and adheres to the available country laws set by the following; Bomba, Public Works Department's specification, etc.

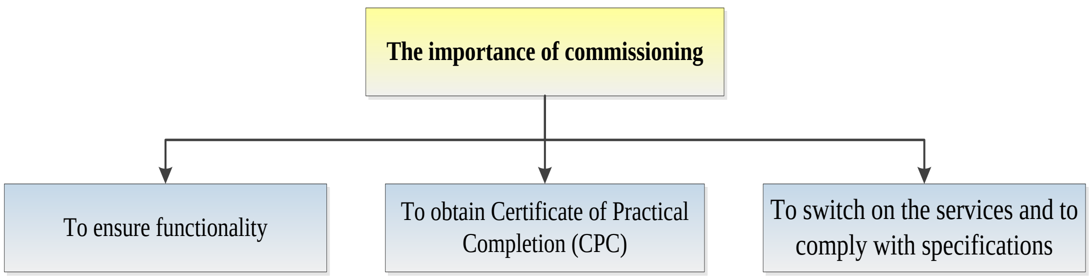

Figure 6.9: Contactors' Perspective: The Importance of Commissioning

From the consultants’ perspective, the definition of commissioning differs from the answers given by the contractors. The definition of commissioning by the consultants is as follows:

a) To ensure the building serves its intended designed purpose (fit for purpose)

Without commissioning, the building cannot be operated and the end-user cannot occupy the building if the building is not operational. The building cannot be handed over to the client without commissioning. Thus, commissioning ensures that the building serves its intended designed purpose and is functioning safely for the intended purpose. Without testing and commissioning, it is difficult to judge whether a building is safe for occupancy. It is hard to determine if the work has been satisfactorily completed as stipulated in the contract.

b) Testing the workability of all systems according to specifications and requirements to ensure functionality

Commissioning is to test all the system to ensure it is working accordingly to specifications and requirements. If the building is completed but the building services are not functioning smoothly, then the building is deemed unfit for occupancy even though the building has been completed, i.e. the lift is not functioning for a 10-storey building, or all piping has been completed but when but the water pump cannot function properly due to faulty pipe or leakage, etc. Commissioning is very important because if the building is not commissioned properly, the building cannot be used properly as per its intended design.

Installation does not guarantee the performance of the system. When commissioning is conducted, only then can the problems be revealed and these problems must be rectified before the building is handed over to the client to ensure it everything is functioning accordingly.

c) To obtain verifications from engineers to issue the Certificate of Practical Completion (CPC)

Without testing and commissioning, verification from engineers stating that the building has been tested and commissioned cannot be issued. Thus, the architect will not be able to issue the Certificate of Practical Completion (CPC) or even Certificate of Compliance and Completion (CCC).

6.3.5.2 Was Proper Inspection/Testing Done During Commissioning or is Commissioning Merely an Administrative Task to get the Certificate of Practical Completion (CPC)?

From the contractors' perspective, the majority of the interviewees emphasized that proper testing must be conducted during commissioning stage and commissioning is not merely an administrative task. Among the reasons given is that commissioning ensures functionality, quality and the building complies with all the requirements in stipulated in the contract. Testing for commissioning is monitored closely by the main contractor from the early stage of construction.

Nevertheless, there is some divergence on this matter by the interviewees. According to them, due to delay from previous phases, proper testing and commissioning might be jeopardized in the commissioning stage in order to make up for the delay incurred at the earlier stages. When the schedule is delayed, everyone is under constant pressure to deliver the project in order to avoid Liquidated and Ascertained Damages (LAD).

Interestingly, apart from this point of view, some interviewees remained neutral on this issue. For them, testing and commissioning is done partially. The building might be physically completed but testing is done in stages. Again, testing and commissioning is only for checking the functionality and safety of the installed services to ensure no failure.

The consultants' perspective differs from the perception of the contractors' interviewed in this research as half of the consultants agreed that proper inspection/testing should be done during commissioning. Commissioning is to ensure building is working properly in order to obtain Certificate of Practical Completion (CPC) and to ensure the building it functioning properly. Thus, proper inspection and testing must be carried out during commissioning and is not merely an administrative task to obtain Certificate of Practical Completion (CPC).

Nevertheless, one third of the consultants agreed that commissioning is not merely an administrative task to obtain the Certificate of Practical Completion (CPC). They mentioned that commissioning is also essential to ensure proper inspection and testing is carried out. Good administration requires good record and to ensure work progress. It is very important to have proper testing before the issuance of Certificate of Practical Completion (CPC). Proper testing and inspection coupled with good administration of work are important to ensure all defects are minimized.

A minority group of consultants claimed that commissioning is merely an administrative task to obtain Certificate of Practical Completion (CPC) because it is perceived as a formality during actual completion date. This is supported by Tseng (2005) who claimed that commissioning is distinctive from construction inspection, code compliance or merely construction administration visits by the architects. This perception needs to be eliminated to elevate the importance of commissioning in the Malaysian construction industry.

From the contractors' perspective, proper testing and inspection must be done to ensure coordination of all services at all stages, even during construction. For example: a) the under floor opening for plumber, riser, box-up and sleeve. b) for one of this case study, concrete slab for level 6 must be taken into consideration for the layout at level five.

Subsequently, the contractor wants to complete the project in a timely manner to avoid Liquidated and Ascertained Damages (LAD). The contractor takes advantage of lenient requirements in testing and commissioning. The perceived flexibility of commissioning has been manipulated by the main contractor to make up for their losses of time incurred at the earlier stages. Basically, contractors tend to be bias against commissioning in order to complete the project in time.

Nevertheless, commissioning is to check the functionality of the systems to ensure every facility such as plumbing has no leakages or damages. Proper inspection must be carried out to ensure functionality and to ensure clients' satisfaction. Commissioning is vital to ensure satisfaction for the client. The level of satisfaction from client differs from one to another such as Public Works Department (JKR), the end-user, and the Department of Development & Estate Maintenance (JPPHB) of University of Malaya. To obtain approval from the authorities concerned, proper testing in commissioning must be carried out and this test will be witnessed by the relevant authorities.

From the consultants' perspective, proper inspection must be done as there are many different departments which have their own standard formats for commissioning. For air-conditioning, there is a form to be filled up before the maintenance department (JPPHB) does any first and second round of testing and training. All of these are part of the scope in commissioning. Sometimes, at the end of the commissioning, they have to submit Operation and Maintenance Manual (OMM) as a pre-requisite for Certificate of Practical Completion (CPC). For Fire and Security Department's (Bomba) requirement, the contractor has an extra work which is to submit the "Operation Book". This book describes the technical in case of any emergency i.e.: fire. This book is kept respectively by:

- the Fire and Security Department (Bomba);
- the client's office;
- the architect; and
- the maintenance manager's office.

Therefore, proper commissioning must be done to prepare this manual. Testing and commissioning must be done correctly. Proper inspection and testing are needed to ensure all systems fully functions as required in the specifications and as stipulated in the contract. All system need to be tested to ensure the functionality and for safety purposes. Practical thing for commissioning is to ensure that the building is working and serve its intended design purpose.

Consultants agreed that proper inspection and testing and good administrative of commissioning must be carried out because commissioning must be done correctly. In short, commissioning is not a trivial work. Commissioning ensure everything is working and running smoothly, serving its intended purposes, proper documentation for the architect. The architect as the final certifier for conventional project must have the documented evidence from the consultants, nominated sub-contractor, mechanical and electrical engineer and others specialist consultants. These people serve as a witness that the building works have been correctly tested and is functioning. The respective scope of work must be tested, commissioned and verified by these professionals. Without these verifications, the architect will withhold the overall recommendations and issuance of the Certificate of Practical Completion (CPC).

Commissioning is perceived by the minority of the consultant as merely an administrative task because prior testing has been done before commissioning is conducted.

6.3.5.3 The Influence of Commissioning on the Project Handing Over: Contractors' Perspective

As depicted in Figure 6.10, commissioning is perceived to be the likely cause of delay in the project handing over. As shown in this Figure, majority of the contractors' agreed that commissioning can cause delay in handing over the building to the client. Though there are different perceptions on this matter, this is not a very significant aspect as compared to the other major reasons says.

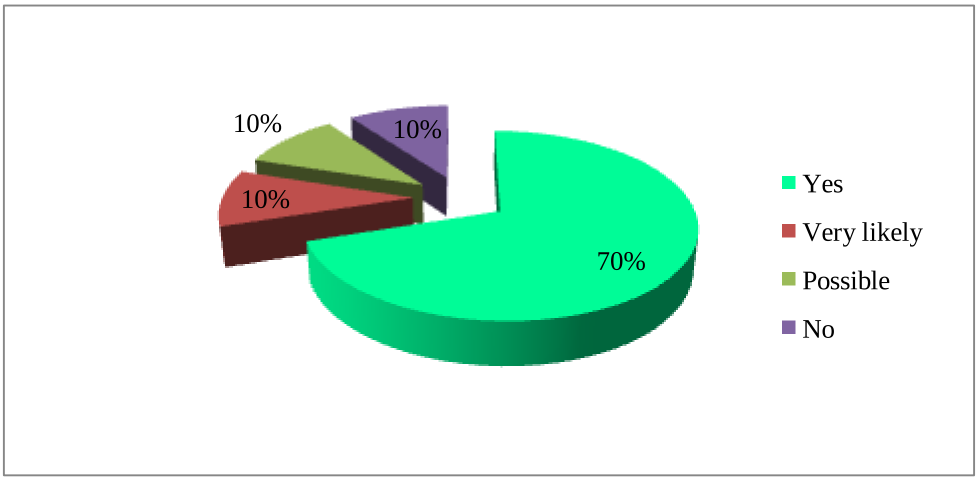

Figure 6.10: The Contractors' Perspective: The Influence of Commissioning on Project Handing Over

From the contractors' perspective, commissioning can cause delay in project handing over because when there are problems in commissioning, it can cause delay in getting Certificate of Practical Completion (CPC). Besides that, a longer time is needed for troubleshooting and to ensure functionality.

a) *Delay in getting Certificate of Practical Completion (CPC)*

Uncompleted work cannot obtain letter of support and approval from local authority which result in delay in obtaining Certificate of Practical Completion (CPC). This is because when there is delay in commissioning, it means that the building is not ready to be handed over.

b) Longer time is required for troubleshooting and etc.

When problems occur during testing and commissioning, a much longer time is needed for troubleshooting and to rectify these problems. Subsequently, the completion date will be delayed. Furthermore, Variation Orders (V.O.) and completed work has to be re-do until the problem is solved.

c) Ensuring functionality

Testing and commissioning is important to ensure functionality, safety and performance as per design intent. All equipment (services) must be tested and perform accordingly in order for a building to be considered fully commissioned. Testing and commissioning must be done at each stage of construction to ensure every stage is performing smoothly.

6.3.5.4 The Influence of Commissioning on the Project Handing Over: Consultants' Perspective

As shown in Figure 6.11, the perception from the consultant on whether commissioning can cause delay are almost similar. Half of the consultants deny that there is influence of commissioning on the project hand over but the other 33.3% agreed with this. However, another 17% of the consultants are uncertain about this because according to them, it depends on the implications on the usability of that particular problem on the usage of the building.

Some consultants claim that commissioning should not cause any delay because problems should have been solved within the commissioning period except major problems such as electrical power supply from local power authority, Tenaga Nasional Berhad, TNB. Commissioning is deemed not to cause delay in handing over the building as commissioning falls under Critical Path (CP). For example: how can someone do commissioning for lift, when the lift structure is not competed? And how can someone do commissioning for air-conditioning, if the ceiling is not completed. According to some interviewee, construction is the main cause of delay. On its own, commissioning independently does not cause delay as construction progress and commissioning are not closely interrelated.

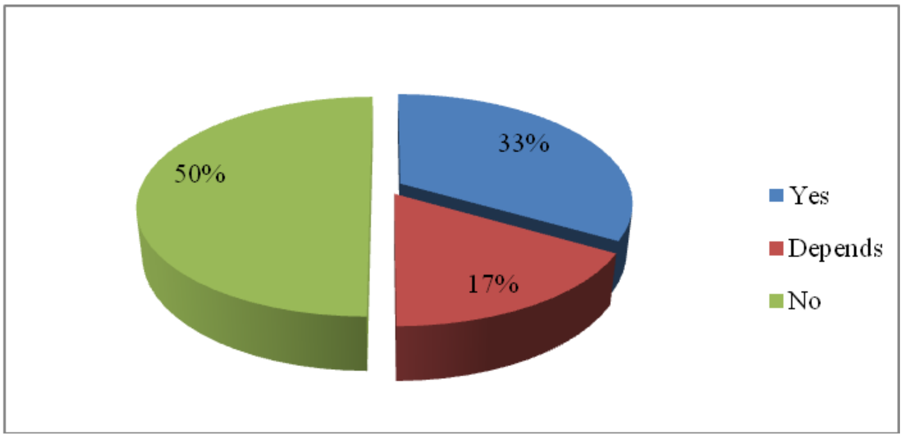

Figure 6.11: The Consultants' Perspective: The Influence of Commissioning on Project Handing Over

From the consultants' perspective who disagreed with commissioning will cause delay to hand over the project, the reasons given are as follows:

A project is critically delayed because projects are dependent upon architectural works. The mechanical and electrical engineer blames the delay on commissioning because of the incompletion in architectural works such as ceiling. But commissioning on certain items such as lift can be done independently of the whole project construction. In fact, according to one of the interviewee, some lift can be commissioned 3-4 months earlier than schedule. Items under critical path method (CPM) are dependent on each other and thus may affect the progress of each item.

Apart from this, for consultants who disagrees with this notion, the consultants mentioned that no testing and commissioning could be done to test the whole system if there is no electrical supply. Discrete system can be tested individually but full swing test is not possible. Another comment given is that project is delayed because they are critically dependent upon architectural works. The mechanical and electrical engineers will blame the delay in commissioning because of the incompletion in architectural works such as ceiling.

Another consultant disagrees with this because even though commissioning does not cause delay in handing over the building, but, in terms of building usage, commissioning does have certain impact. For example, for high-rise building or building with lots of services, the building cannot be used without being fully commissioned. The condition of services such as lift, electricity and sewerage are important and should be commissioned before the building is deemed usable. However, a building can still be used even without full commissioning if there is not many services to be commissioned. A building without many services is deemed usable as long as the electricity, lift and water are functioning accordingly.

However, for consultants who agree with commissioning have influence on project handing over, they mentioned that when testing is done at a late stage and major defects are detected, project delay is bound to occur. Another reason provided is that, in terms of usage, without proper commissioning, high-rise building or building with lots of services cannot be used.

Besides that, as scheduled in work programme, dates have been scheduled for various items to be commissioned. All project works must meet adhere to the plan so that there will be sufficient time to complete accordingly before the completion date or due date.

Some consultants did not know how to answer the question because from their point of view, no Certificate of Practical Completion (CPC) can be issued if there are major problems such as no power supply and no lift for high-rise building. Their major concern is on the safety of the building and working condition of amenities such as toilet (whether the septic tank is link to the main sewer line), sprinkler, fire hydrant equipment, hose reel, power supply.

6.3.5.5 Magnitude of Delay in Commissioning

Most of the interviewees declined to answer this question. When the interviewees were probed further, the following answers were obtained:

- Around 1 week.
- It depends (it can range from 1 week till 1 month);

- It depends on the individual problem for the project;
- It depends on the problems and the additional variation orders for that project (maximum 3-4 months); and
- There are no clear guidelines on commissioning and the definition is opened to individual interpretation.

From the consultant's perspective, there was a case where commissioning caused 1 year delay in a school project due to local power authority, Tenaga Nasional Berhad, TNB's comments. When TNB came for inspection, many comments were given and the contractor had to repair many things. Initially, these repaired items were not included when the submission was approved but due to the changes of officer, these items were later included. During submission, officer A was handling the project but as the project was completed two years later, the officer has changed and was handled by a new officer B. Thus, new things were imposed by local power authority as new equipment had to be used.

6.3.5.6 Please Rank the Seriousness of Delay in Commissioning from 1 (Least Serious) – 5 (Most Serious)

As depicted in Figure 6.12, it is illustrated that delay in commissioning is regarded as the most serious causes of delay by most of the interviewees participating in this study. The rest of the interviewees rated this as very serious, moderately serious and slightly serious.

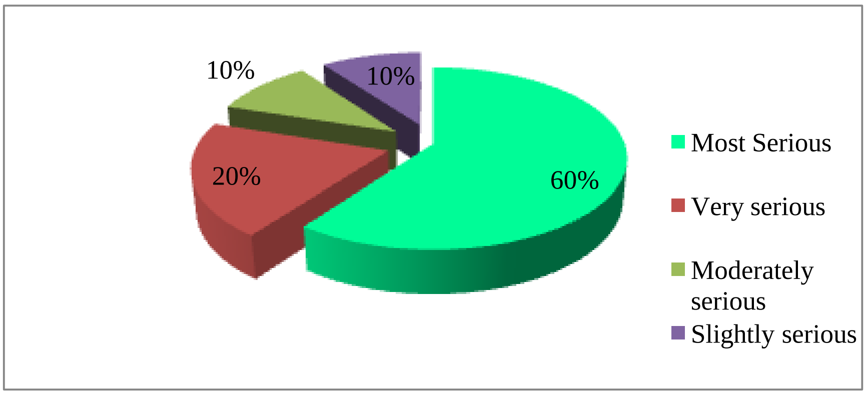

Figure 6.12: The Seriousness of Delay in Commissioning

6.3.5.7 Effects of Problems in Commissioning

From the contractors' perspective, delay in commissioning implies that the contractor will have problems in handing over of the building to the client on time and the end-user would not be able to occupy the building according to schedule. One of the most significant impacts is that the main contractor will have to pay for Liquidated Ascertained Damages (LAD) to the client. Late handing over of the building to the client will also impose cost impact to the contractor. Late in handing over and LAD are the 2 main reasons for delay in commissioning. This fact was highly emphasized by the consultants. When the completion date was extended, the contractor had to bear the overhead costs. Besides, the warranty period from the supplier will be shorten and became the contractor has to bear the extended warranty period as shown in Figure 6.13.

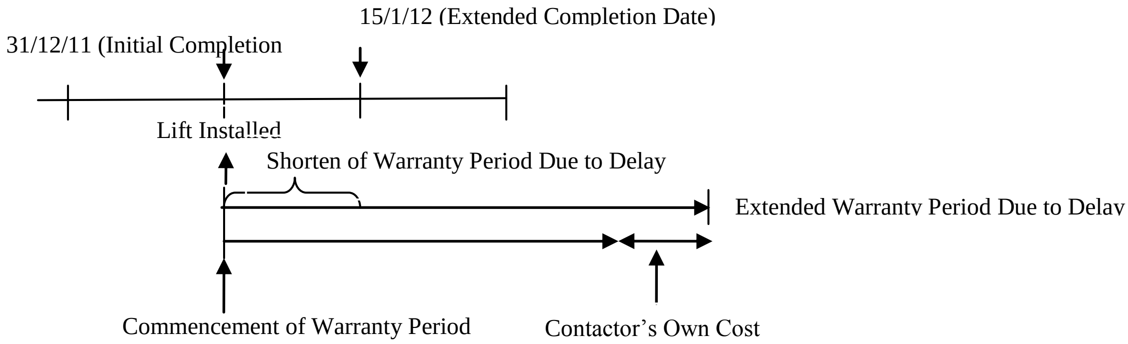

Figure 6.13: Impact of Delay in Handing Over on the Warranty Period for Installed Services

Sometimes, the interviewee will apply for Extension of Time (EOT) when there is delay in commissioning. The contractor might be awarded with Certificate of Practical Completion (CPC) but it does not mean that everything is in perfectly order. The CPC might be issued based on certain condition. For instance: Defects may exist but the contractor should remedy these defects at a later stage. Sometimes, it depends on the level of acceptance of the client as some clients might find that leakage is a trivial defect for them. Apart from this, outstanding work might be pushed forward to be rectified during Defect Liability Period (DLP).

From the consultants' perspective, commissioning causes delay in obtaining Certificate of Practical Completion (CPC). One has to redo and to rectify these commissioning problems if is any delay during commissioning. Commissioning will also affect the revenue of the client if that building is to be rented out to tenants. Besides that, commissioning will also affect the overall completion of the project in terms of rental and usage. For residential or commercial project which is bound with others types of agreement such as condominium, the developer is bound by the agreement with the buyers like Sales and Purchase Agreement (S&P), if the developer fails to hand over to the buyer on the agreed date. The developer will have to pay penalty to the buyers. Thus, project completion is very crucial.

6.3.5.8 The Influence of Commissioning Problems on Project Timely Completion

When there are outstanding works and problems in testing and commissioning, the commissioning will be delayed. It also means that the building is not ready to be handed over to the end user. This will delay the handing over of the project to the client. This will also cause delay in obtaining the Certificate of Practical Completion (CPC) and affect the work programme. Consequently, Liquidated Ascertained Damages (LAD) will be imposed to the contractor.

As a result, the building cannot be handed over to the client if it is not functioning accordingly. Delay is also cause by:

a) Cannot hand over;

b) Cannot call for inspection from authorities; and

(a) and (b) will cause no issuance of Certificate of Practical Completion (CPC).

Lastly, if the client does not accept these conditions, it will affect the project completion. After the CPC, there are still some works to be done such as:

- documentations of paperwork; and
- system functionality check.

From the consultants' perspective, commissioning will affect the project in terms of usability of the building. In design and build project, Certificate of Compliance and Completion (CCC) is part of the project scope. Upon receiving CCC, only can the contractor proceed to obtain CPC.

6.3.6 Discussions on the Perceived Understanding of Building Commissioning from the Contractors' and Consultants' Perspectives

Randers (1980) characterizes the conceptualization process as the "stage that establishes the focus of the study – the general perspective and the time horizon. The critical decisions are made on what part of reality to study and how to describe it". Therefore, the conceptualization model focuses on building commissioning which encompass the perception and the duration needed for building commissioning. Perception is regarded by Bruner (1957) as an inferential process, in which the perceiver plays a maximal and maximally idiosyncratic role in interpreting, categorizing, or transforming the stimulus input. According to Bruner (1957), perception involves an act of categorization. The nature of the inference from cue to identity in perception is, in no sense different from other kinds of categorical inferences based on defining attributes (Bruner, 1957: 123f.). Richardson and Pugh (1981), (Roberts, Andersen, Deal, Garet, & Shaffer, 1983), and Sterman (2000) accentuate that any modeling effort should be guided by a clear purpose and a set of questions. The purpose of the conceptualization model is to have a model capable of explaining the dynamic nature of building commissioning and its various characteristics. Therefore, to have a better perception on building commissioning for the institutions of higher learning in Malaysia, a conceptualization model of building commissioning classifications needs to be constructed.

On the other hand, Brunswik (1956) mentioned that perception must simultaneously integrate many different avenues of approach, or cues. The various rivalries and compromises that characterize the dynamics of check and balance in perception must be seen as chiefly responsible for the relative infrequency of precision. This is due to the machinelike precision of the reasoning processes. On the other hand, the organic multiplicity of factors entering the process constitutes an effective safeguard against drastic error (Brunswik, 1956: 91f.). Various similarities and differences on the perceptions of commissioning are drawn from the interviews' results. These similarities and differences are characterized and integrated to provide a check and balance for the conceptual model of building commissioning classifications. Brunswik (1956) mentioned that perception must concurrently integrate many different possibilities of approach.

From all these definitions as tabulated in Table 2.2 (Page 47), it has been found that the common words used for the definitions of commissioning are: quality assurance, process, document, building systems, design, install, testing, functional, and operational. From these definitions, it can be proposed that, building commissioning can be defined as a quality assurance process to verify and document the building systems where the buildings are designed, installed, tested and function to meet the operational needs of the building's owner and the end-user. Commissioning has traditionally being viewed as a task performed after system assembly and before hand-over as a final check and acceptance test (Xiao & Wang, 2009). Therefore, a new definition model of building commissioning for construction projects is being proposed to suit the context in the Malaysian construction industry; especially for projects in the public institutions of higher learning in Malaysia. For the suggested commissioning definition, it is almost impossible to verify the definition model since most of the people interviewee does not share a common understanding about the definition in question.

Although the interviewer can strive to have the meaning being made in the interview as much a function of the participant's reconstruction and reflection as possible, the interviewer must nevertheless recognize that the meaning is, to some degree, a function of the participant's interaction with the interviewer. Only by recognizing that interaction and affirming its possibilities can interviewers use their skills to minimize the distortion that can occur because of their role in the interview (Siedman, 2006).

The purpose of building commissioning to ensure all building facility systems function in accordance with all the design intent and documentation is aligned with the general systems theory. This theory highlights that systems are compose of interdependent components in some relationships. Therefore, the conceptual model in Figure 3.5 which combines empirical world, case studies, and theories is vital to generate Figure 6.14.

Transformation theory is also plays an important role in the systematic combining as commissioning is actually a process by which inputs are changed into outputs. The output in this context is referred to handing over of the building to the client.

Therefore, the commissioning process in which resources, assets, and competencies of an organization are put together to produce a desired output must be dwelled in carefully to identify the potential problems which might affect the output. These commissioning problems can then be viewed as the constraints that need to be improved. When the constraint is minimized, variations will be reduced and the quality of the throughputs will improve.

These theories of transformation and general systems are interrelated to explain the rational choice theory. This is because when the planned commissioning is delayed, the contractor has to expedite the work progress and to take advantage of the commissioning period to avoid the penalty of Liquidated Ascertained Damages (LAD).

From Figure 3.5 (Page 113) on systematic combining, we can see that it has strong relationship with Figure 6.14 (page 263) on the conceptual model of building commissioning. As systematic combining is a process where theoretical framework, empirical fieldwork, and case analysis evolve simultaneously to construct a conceptual framework of commissioning, we can relate it to conceptual model of building commissioning which essentially identify the concept of building commissioning which is defined as a quality assurance process to verify and document the building systems where the buildings are designed, installed, tested and function to meet the operational needs of the building's owner and the end-user. As both Figure 3.5 and Figure 6.14 aims to complement, deepen and harmonize the general concept of building commissioning, there is an essential need to always improve the existing commissioning framework by always linking the theoretical aspects and matching it with the current demand based on empirical analysis. In short, Figure 6.14, conceptual model of building commissioning is a form of derivation of Figure 3.5 based on existing commissioning theory with empirical analysis and feedback from experienced contractors and consultants.

What is needed for the building commissioning in the Malaysian construction industry is a simple and understandable model capable of explaining the dynamic nature of building commissioning and its various characteristics. For an organization, pivoting the definition of goals or objectives provides an obvious but crucial component on what constitutes an organization. The coordination of number of activities of individual towards some objective or goal has been designated as a distinctive feature of organizations (Parsons, 1956). The same proposition goes for the definition of goal or objective of what constitute building commissioning. Figure 6.14, is a conceptual model of building commissioning. The model comprise of a conceptual classifications which is used to explain the nature of building commissioning. The classification includes eight groups of characteristics, which are:

1. CHARACTERISTICS affecting the coverage and activities of building commissioning;
2. PRE-REQUISITES or initial works to be done before actual building commissioning;
3. COMPONENTS of building commissioning;
4. Ensuring FUNCTIONALITY or final check to ensure no outstanding works;
5. DURATION for commissioning for construction projects;

6. ACTIVITIES/ELEMENTS of the building commissioning process to express the level of detail of the information and understanding to be gained;
7. PERSONNEL involved in the building commissioning; and
8. GOALS to be attained in building commissioning in which building commissioning completes each of these activities or elements and proceeds to the next detailed stage before project ‘hand over’.

An important finding is that these eight characteristics together form a basis to better explain and understand the nature of building commissioning for public institutions of higher learning in the Malaysian construction industry. This model also aims to provide a more holistic view and better insight into building commissioning.

<table>
<tr><th colspan="4">CONCEPTUAL MODEL OF BUILDING COMMISSIONING</th></tr>
<tr><td>The characteristics of commissioning…</td><td>Pre-requisites for commissioning …..</td><td>Components of commissioning …..</td><td>To ensure functionality or final check to ensure no outstanding works …..</td></tr>
<tr><td>1. CHARACTERISTICS
an essential part of contract
part of construction
the execution of works as stipulated in contract
to be done before Certificate of Practical completion (CPC)</td><td>2. PRE-REQUISITES
a) Completion of physical works such as architectural and structural installations must be completed beforehand;
b) Completion of installations and inspections for necessary items; and
c) Work progress is at least 90% or more.</td><td>3. COMPONENTS
a) architectural and building structural works; and
b) mechanical and electrical works.</td><td>4. FUNCTIONALITY
a) Everything is functioning,
b) Project is running – equipment running, and
c) Services are available.</td></tr>
<tr><th colspan="4">5. DURATION</th></tr>
<tr><td colspan="4">-Depends on sub-contractors' work performance
-Depends on the size of the project and can be affected by delay from previous stages and commissioning phase itself
-Varies from case to case and depends on the type of project
-Depends on the number of equipment embedded within the building to be tested (scope of commissioning)
-Depends on the coordination of the project
-Pending local power authority, TNB's approval for electricity supply
-Estimated duration for commissioning: 1 – 4 months
-Commencement of commissioning: 2 – 3 months before project handing over</td></tr>
<tr><th colspan="4">6. ACTIVITIES</th></tr>
<tr><td colspan="4">During testing and commissioning, it is required to:
• Visualize according to design;
• Prepare for testing; i.e.: pressure test for plumbing; and
• Testing for functionality.
a)Structural – to ensure no collapse of structure and no structure flaws;
b)Mechanical and electrical – all services are functioning, have been tested and are in working condition;
i) Mechanical
• Lift- Proper setting has been calibrated so that lift is functioning properly, i.e.: when someone pressed the button for ground floor, the lift will stop at that particular floor and not on other floor;
• Air-conditioning such as temperature test and balancing for chiller and air handling unit;
• Lighting;
• Sewerage (tennis ball test will be carried out to make sure no blockage at manholes);
• Firefighting/fire protection;
• Water and water reticulation-hot and cold water;</td></tr>
</table>

- Sanitary and plumbing services; such as: functioning, no cocking at floor traps and no leakage (ping pong test will be carried out);
- Gas- centralized system and gas pipe (pressure test and flush test), medical gas for hospital; and
- Pneumatic tubes for hospital.

ii) Electrical

- Power (high and low voltage and extra low voltage such as ICT);
- g) Energize of high tension (HT) supply from University of Malaya PPU

-continuity of wiring (continuity test and mega ohm test)

-high mass for spot light

- ICT;
- PA system; and
- Building Automation System (BAS) to monitor and control the control panel of the air-conditioner.

c) Architectural – as per design intent; the straightness, jointing, alignment and the finishes are not damaged.

7. PERSONNEL INVOLVED

There are two types of relationships concerning commissioning:

a. Internal: Client

b. External: Authorities (such as: water reticulation – IWK, firefighting – Bomba, road and drainage – DBKL).

In general, the whole team which are involve in the project commissioning such as:

- mechanical and electrical consultants, engineers, architect, clerk of work (from consultants, contractor and architect), authorities and manufacturers;
- main contractor, mechanical and electrical coordinator, site supervisor, technician (contractor), sub-contractors such as nominated sub-contractor;
- representative from client (Public Works Department's Superintending Officer), representative and witness from Public Works Department (JKR), all consultants and sometimes the end-user/client.
- resident architect and resident engineers;
- project manager-to ensure project is being carried out accordingly on time and within budget; and
- Mechanical and electrical consultants who are also representative for the Superintending Officer (S.O.), client (end-user-JPPHB), and the Superintending Officer (JKR) and authorities such as Bomba, NIOSH and JKKP (Jawatankuasa Kesihatan dan Keselamatan Pekerja).

8. GOALS OF COMMISSIONING

a) to ensure the designated building has been constructed in accordance with the design intent and to proper procedures has been followed as stated in contract;
b) to obtain certification from the relevant authorities;
c) it is also the objective of commissioning to ensure the operation and functional system-i.e.: to power up or start up an equipment and ensure its functional conditions;
d) to verify that everything is fully functioning upon project handing over;
e) to ensure and verify that all the services are functioning as per specification; and
f) building structural works are in compliance with specifications and requirements in order to ensure the building is suitable to be used by end-user and all the intended design are fulfilled upon handover of the building.

Figure 6.14: Conceptual Model of Building Commissioning

From the contractors' perspective, sometimes, Certificate of Practical Completion (CPC) is issued though there are outstanding works. This is because the project was delayed and Certificate of Practical Completion was issued with the conditions that those outstanding or uncompleted works are to be finished or to be completed during Defects Liability Period (DLP). This is also called 'partial handing over' in which part of the building has been completed but some works remain.

There are some interviewees who claimed that commissioning takes a relatively short time to perform as most of the project has been completed before commencement of commissioning. Commissioning is usually done before project hand over and the percentage of project completion is about 95% before commissioning is done. There are two main parts of building commissioning. They are of:

a) Equipment; and
b) Testing and commissioning – 5 – 10% of the cost for mechanical and electrical.

However, from a consultants' perspective, the scenario for execution of commissioning has drawn an equal strong point of view when the interviewees were asked whether commissioning was progressively done throughout the project or it is carried out after construction, towards the end of the project. According to consultants, commissioning is progressively done throughout the project – and it is basically a progressive and continuous monitoring process. For instance, throughout the construction process, coating of structural work has to be done progressively. It is impossible to do checking of the inner structural work once the structural parts are coated or covered. Thus, continuous monitoring has to be done in each stage and not at the end of the project. Another suitable example where progressive monitoring is important is on the frame of the building. It is impossible to test and verify the strength of the building frame (commissioning work) once building is completed. Thus, it is important to check for defects during commissioning in each progressive stage and the project can only progress to the next stage after necessary requirements have been verified in each stages. If progressive checking and validation is not done accordingly in each stage, the final outcome may differ from the original specifications. It will be too late to rectify any problems such as leakages, structural problems and others once the building is near completion. The keywords for commissioning according to consultants are progressive checking and monitoring.

According to one of the interviewee, he claims that commissioning is progressively being carried out throughout the whole project, but not inclusive of thorough testing which will be done towards the end. Commissioning is usually carried out after construction, towards the end of the project before handing over to the client. Another interviewee further commented that commissioning is progressively being done throughout the project. It will be conducted hand in hand with construction and is carried out after each completion of construction stage. Commissioning is done towards the end of the project as some items only can be tested towards the end. Whether commissioning is progressively carried out throughout the whole project or after construction is important as everything is interrelated. Commissioning definition varies as there are certain assessments which can only be tested towards the end of the project.

On the contrary, another group of interviewees perceived that commissioning is carried out after construction which is towards the end of the project for the client but did mentioned that there are certain checks which have to be carried out progressively. For example: testing of all pipes in the ceiling before being concealed, certain things and services beneath the ceiling must be done before being concealed unless the suspended ceiling is removable. If the ceiling is not removable, prior testing before the ceiling is concealed is required. This is to ensure any services beneath the concealed area are functioning perfectly before the ceiling is concealed. Testing of services beneath the suspended ceiling area can be exempted provided that the ceiling board is removable and verification testing can be conducted towards the end of the project.

According to the interviewee, it is said that commissioning is carried out during construction, towards the end of the project. Commissioning has also being carried out after construction, towards the end of the project. It is done towards the end of the construction but before Certificate of Practical Completion (CPC) and continues till the end of Defects Liability Period (DLP).

6.3.6.1 Discussions for the Figure of Definition

Commissioning is not an additional phase of a project and it is not an isolated testing event. Commissioning is not TAB (testing, adjusting, and balancing). Commissioning is not equipment start-up test and it is very likely to engross TAB, equipment start-up, and testing of various types. But, these are just a part of the larger whole of the commissioning process as it occurs throughout all phases of a project (Grondzik, 2009).

Based on the definition of commissioning by Grondzik (2009) and the explanation of commissioning from the contractor's perspective, we found that there is a slight discrepancy between theoretical and practical interpretation. As such, it will be best to delve into the differences of all interpretations. Note that the main objective of this discussion is not to pin point the right or wrong interpretation but rather to bridge the differences of theoretical approach and practical approach.

According to Grondzik (2009), commissioning involves TAB (testing, adjusting and balancing), equipment start-up, and testing of various types which are part of the larger whole of the commissioning process as it occurs throughout all phases of a project.

Whereas, from to the contractor's perspective, commissioning is usually done before the 'handing over stage' where the percentage of completion is 95%. From the consultant's perspective, commissioning may be defined as progressive checking and monitoring activity. As we can see, each respective interpretation of commissioning is slightly different. The main difference between the interpretation of a contractor and a consultant is the commencement time of commissioning. For a contractor, commissioning is done at the end of the project whereas for a consultant, commissioning starts from the very beginning of the project and progresses until completion. On top of that, based on the definition of Grondzik (2009) who opines the same interpretation concept of commissioning as the consultant, we feel that this interpretation has strong merits. The contractor may view that commissioning only starts at the end of a project because each contractor has different task and are not in-charge of the total integration. But for a consultant, he or she has to manage the whole project integration and must be able to control the whole process flow of the entire project. Thus, it is essential for a consultant to grasp the basic understanding of commissioning from the very beginning of a project. Based on the fundamental concept of commissioning, we are leaning slightly towards the interpretation of the consultant as the basis of commissioning. Even though there are different types of interpretation for commissioning, the common goal is to complete the project in time and fulfill all the specifications as stated in the requirement.

6.3.6.2 Validation of the Model

Normally, the term ‘model’ refers generally to computer simulation models, but many of the points are applicable to mathematical and theoretical models as well. According to Rykiel (1996), validation is not a vital activity for assessing research models, but is significant for building model reliability in the user community. Goodall (1972) associated validation with testing to determine the degree of conformity between a model and the real system, and proposed that the suitable questions to ask of a model is how good its predictions are, not whether it should be accepted or rejected in the sense of hypothesis testing. Although he stated that validation is never complete, he did not suggest any validation standards. Therefore, in this study, face validity is conducted. Five knowledgeable people in the industry with more than ten years of working experience in the industry were asked if the model and its behavior are reasonable. The five people were contractors and consultants in the construction industry. This test suggests that the model logic and input-output relationships appear reasonable 'on the face of it' given the model's purpose. Some models have high face validity by virtue of their longevity and wide spread use (Sargent, 1984). The test is conducted by asking these people on the accuracy, user friendly, flexibility, compatibility and cost consuming of the conceptualization model of building commissioning classification. Majority of the interviewee agreed with the model in meeting the purpose of the research.

6.3.7 Commissioning Problems from the Contractors' Perspective

From the contractors' perspective, commissioning problems and the frequency for the occurrence of these problems were demonstrated in Figure 6.15 and Figure 6.16 respectively. Frequency of construction and commissioning problems as shown in Figure 6.16 is derived from Figure 6.15 to show the magnitude for the occurrence of construction and commissioning problems. Figure 6.16 is essential to complement Figure 6.15 to present the magnitude for the occurrence of these problems. Results obtained from the semi-structured interviews conducted with the contractors involved in relevant projects are compiled and presented as follows.

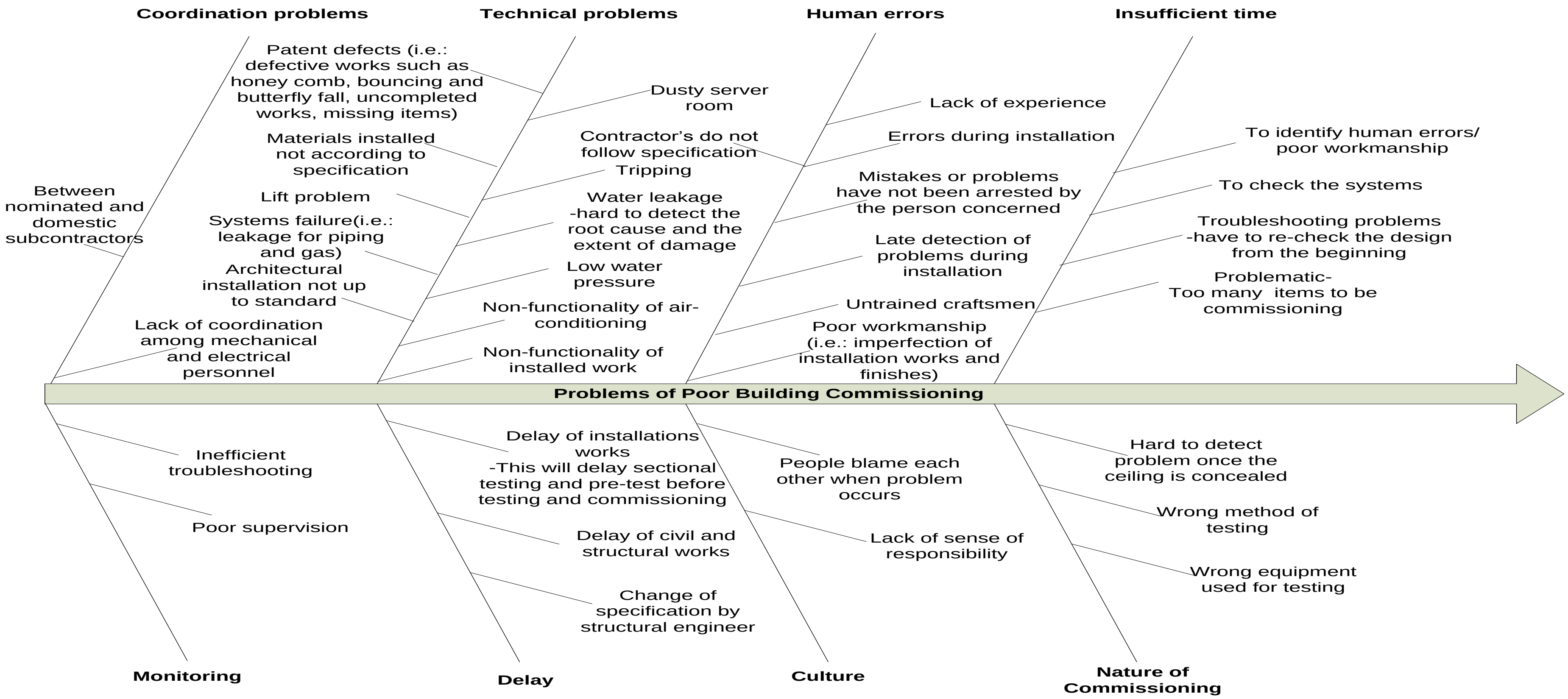

Figure 6.15: Fishbone Diagram of Commissioning Problems for Construction Projects in a Public Institution of Higher Learning in Malaysia: Contractors' Perspective

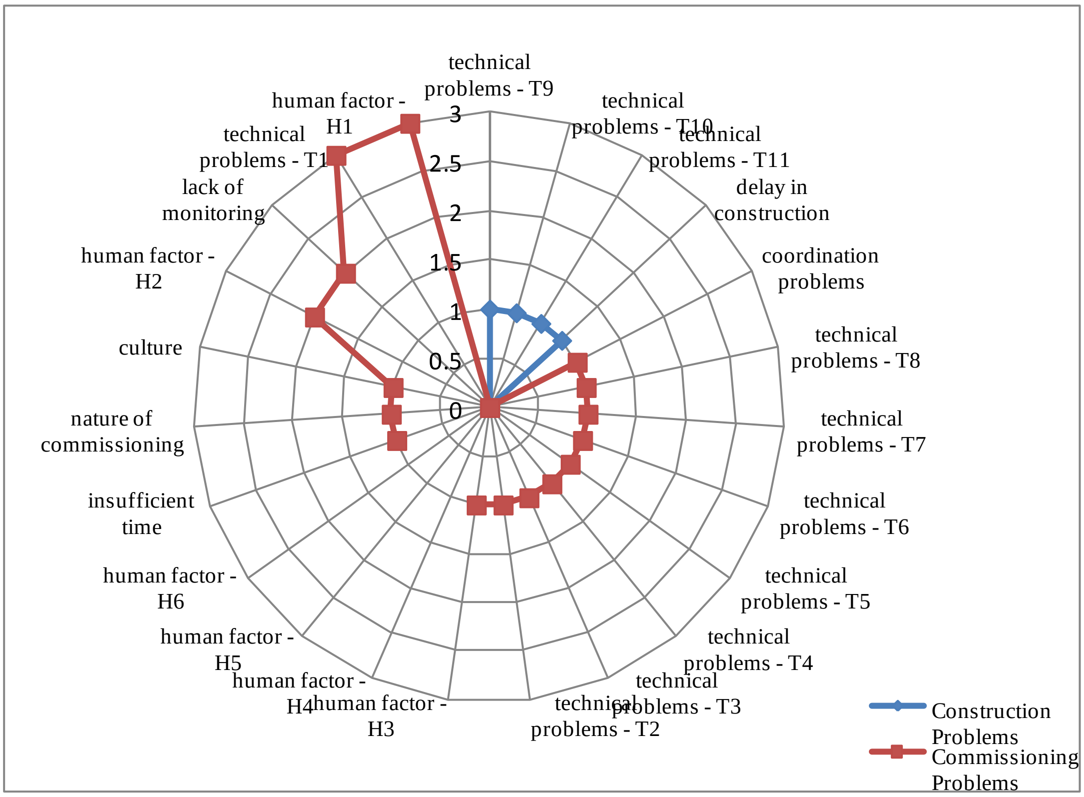

Figure 6.16: Frequency of Problems in Construction and Commissioning: Contractors' Perspective

Footnote	**Description**
Technical problem T1	Water leakage
Technical problem T2	Lift problem
Technical problem T3	Systems failure
Technical problem T4	Dusty sever room
Technical problem T5	Tripping
Technical problem T6	Low water pressure
Technical problem T7	Non-functionality of air-conditioning
Technical problem T8	Non-functionality of installed work
Technical problem T9	Architectural installations not up to specifications
Technical problem T10	Materials installed not according to specifications
Technical problem T11	Patent defects
Human factor H1	Poor workmanship
Human factor H2	Errors during installations
Human factor H3	Contractor does not follow specifications
Human factor H4	Mistakes or problems have not been arrested by the person concerned
Human factor H5	Untrained craftsmen
Human factor H6	Lack of experience

a) Coordination problem

i) Between mechanical and electrical engineer and the plumber

According to the interviewee, thus far there were not many problems during commissioning. There were some problems of coordination between nominated sub-contractors and the domestic sub-contractor. However, this problem was considered manageable by the project manager. Problems that arise: coordination problem between mechanical and electrical engineer and the plumber.

ii) Architectural work

Problem of coordination between architecture works internally and externally.

b) All elements are possible problem causes in commissioning

Generally, all elements in commissioning can cause problems. For instance, low water pressure, water leakage, tripping, non-functionality of air-conditioning and dusty server room and etc.

c) Outstanding works

Sometimes, the Certificate of Practical Completion (CPC) is issued though there are outstanding works. This is because the project was delayed and Certificate of Practical Completion (CPC) was issued with the conditions that those outstanding or uncompleted works are finished or will be settled during Defects Liability Period (DLP). This is also called partial handing over in which partial of the building has been completed but not the whole building.

i) Patent defects such as:

- Uncompleted work such as damaged tiles on the lift floor that need to be changed;
- Defects or missing items that can be seen;
- No proper installation for finishes or anything that can be seen easily;
- Defective works such as honey comb, bouncing and butterfly fall.

d) Overlook the importance of commissioning

It only takes a short duration to perform commissioning as everything has been completed before the commencement of commissioning.

e) Unforeseen problem

i) Installed items not functioning.

- Poor installation

Before testing and commissioning, all the installations must be completed and pre-test at each section.

- Testing of the services is quite problematic as there are many items to be tested; and
- Wrong method of testing and wrong equipment.

Sectional testing

↓

Pre-test

↓

Testing and commissioning

ii) Water leakage problem while conducting pressure test – hard to detect problem and the extent of damage to architectural works i.e.: ceiling and lights; and materials;

iii) Lift problems, such as the lift movement is not smooth.

f) Delay of civil and structural works

System failures such as leakage for piping, gas and architectural installation are not up to standard. For structural part, the defective works for civil and structural part would be rectified during construction. Any errors for civil and structural work will be rectified along the way.

g) Change of specification by the structural engineer. For example; to increase the size of the columns and to increase the floor level.

- Contractor did not follow specification.

6.3.7.1 Causes for Identified Commissioning Problems from the Contractors' Perspective

a) Monitoring

The main contractor monitors the testing and commissioning from the beginning of construction stage. Therefore, there are only some hiccups during commissioning. But, these are misstep are to be managed and to be rectified immediately. Besides, troubleshooting by sub-contractor is usually very efficient.

- Lack of supervision

b) Workmanship

Poor workmanships of contractor and sub-contractors. Sometimes, there are imperfections of work in installation due to human errors. Errors during installation occur as most of these works are done manually.

a) To increase the size of the column; and

b) To increase floor levels.

c) Sometimes people blame each other when problem occurs

This is because during installation of all construction items, mistakes or problems have not been arrested by the person in-charged in a timely manner. Besides that, poor supervision, untrained craftsmen and lack of sense of responsibility could be the reasons for this problem.

d) Lack of experience and lack of knowledge

Materials installed do not follow specifications, for example the thickness of piping is incorrect and different types of glue are used for joints and bents.

e) Coordination

Lack of coordination among personnel involves in mechanical and electrical works.

- Once ceiling is concealed, it is very difficult to detect any problems above ceiling.

<u>Corrective measure:</u>

- To check back on the design-start from the beginning
- To check the system
- To identify human error-workmanship and how to monitor the work progress.

6.3.8 Commissioning Problems from the Consultants' Perspective

From the consultant's perspective, commissioning problems and the frequency for the occurrence of these problems are demonstrated in Figure 6.17 and 6.18 respectively.

a) Change of intended purpose for the building

- According to the interviewee, change of intended purpose for a building causes many problems. For example, the change of priority for the intended purpose of a building may cause the capacity of the air-conditioning to reach its maximum and beyond. Thus, the air-conditioning is unable to support the cooling system of the building when it is 100% occupied as the original system was not designed to meet a higher capacity system which was due to new changes of specification in the building. Thus, everything needs to be re-calibrated and redesign and this process cost extra money and time.

b) Discrepancy between the client's perspective and the consultant's perspective

Sometimes, from the consultant's point of view, a building may meet the performance requirement stipulated in the contract but from the occupants' point of view, it might not fulfill their requirement.

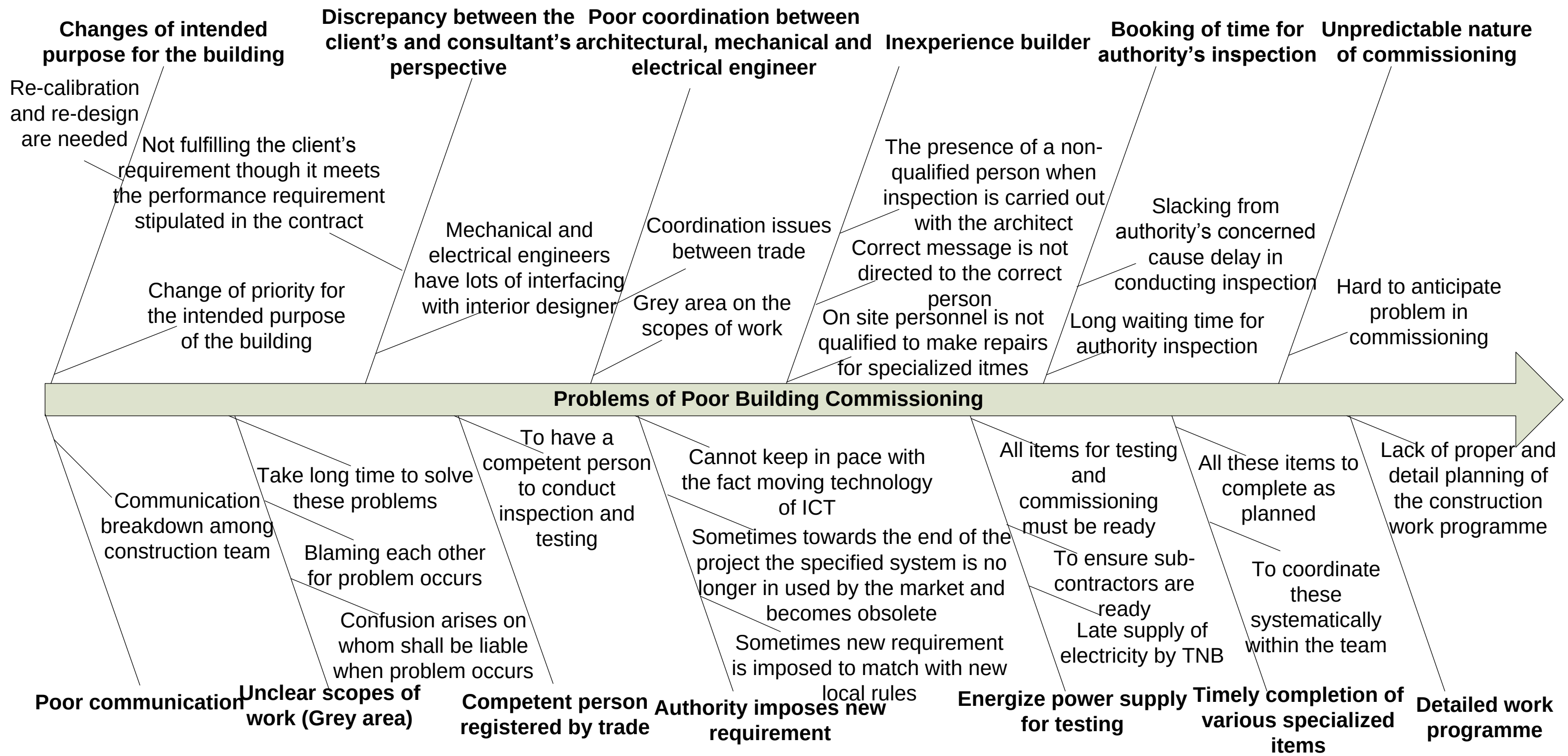

Figure 6.17: Fishbone Diagram of Commissioning Problems for Construction Projects in a Public Institution of Higher Learning in Malaysia: Consultants' Perspective

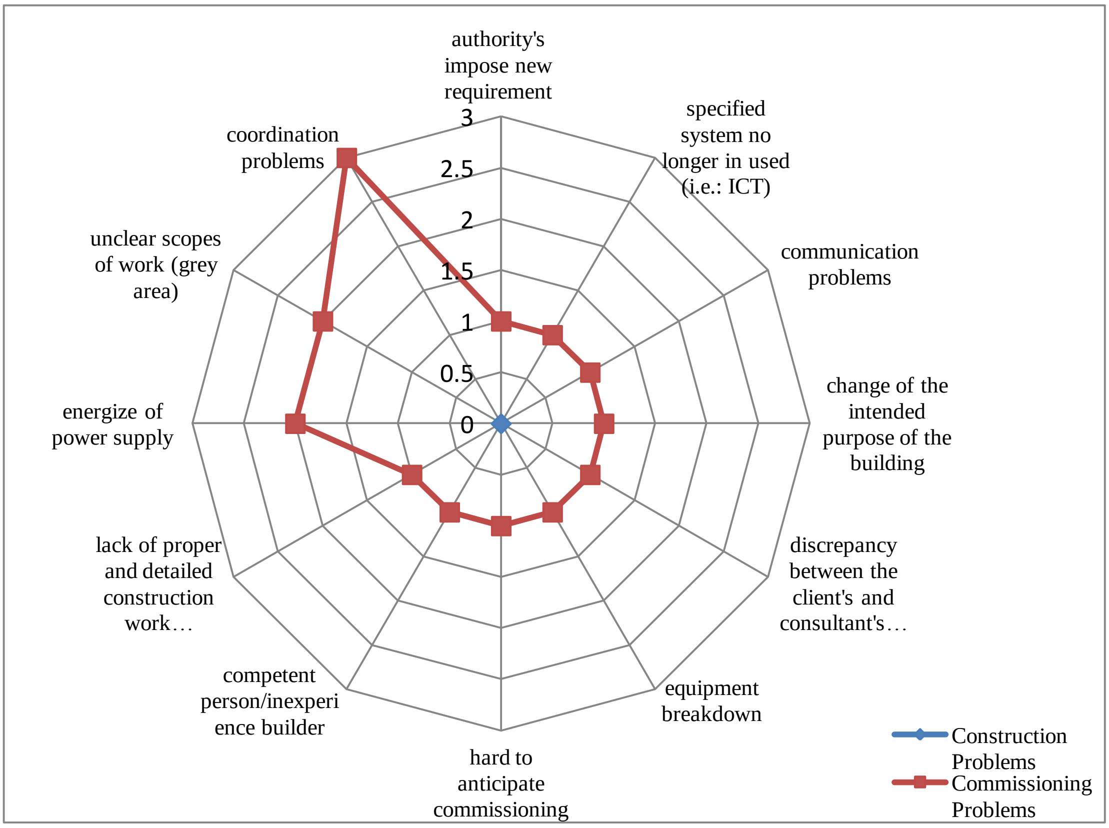

Figure 6.18: Frequency of Problems in Construction and Commissioning: Consultants' Perspective

c) Poor coordination

- Poor coordination between architecture, and mechanical and electrical engineer. As a result, things are not done properly.
- Mechanical and electrical engineers have lots of interfacing with the interior designer as well. But poor coordination among these professionals happens a lot in the construction industry.
- The main problem for this particular project is the coordination issue between trades such as: architecture and mechanical and electrical engineer; between mechanical and electrical engineer and interior designer; mechanical and electrical engineer and structural engineer.

- Coordination among different trade-when a comment is made during discussion, there could be a grey area where one's scope of work overlaps the other person's scope of work.

d) Inexperience builder

- Inexperience builders (construction team on site, it could be the main contractor and the sub-contractors) – sometimes, a non-qualified person is present when inspection is conducted with the architect and the correct message was not directed to the correct person.
- Depends on the quality of the main contractor to follow the designers' specifications.

Suggestion: The presence of the right person according to trade is important to improve this problem. When inspection is conducted, any comments have to be specifically informed to the person in-charged. Sometimes when this comment is passed to the main contractor, the main contractor might deliver a different message to the sub-contractors. Therefore, miscommunication will result in many mismatched in requirements during construction. (For the particular project mentioned by the interviewee, three site coordinators were changed).

Not only can minor unforeseen breakdowns be costly, on-site personnel typically are not qualified to make repairs for specialized items such as reprogramming for Building Management Systems (BMS). Deferred maintenance sometimes includes repairs for specialized items. Therefore, more money, time, and coordination, are required to bring in a specialized repair person (Wilkinson, 2011).

e) Poor communication

- Communication breakdown among construction team.

f) Unclear scope of work (grey area)

- Problems due to unclear scope of work (grey area) – for example fire fighting. When doing some plumbing for firefighting works, during the hanging of piping, the main contractor might have tampered with those items when doing they did their ceiling work. But the fire fighting contractor's claimed that somebody else damaged their work. There is confusion and they blamed each other for the problems that occurred and it may take a long time to solve these problems. There is always an unclear scope of work in construction activities.
- There is delay in restarting the converters for Bulgarian copper smelter. The client claimed that the delay to restart the copper converter was the fault of the contractor. But, the contractor managed to prove that the client had poorly coordinated activities between its engineering department (which was in-charged for the revamp contract) and its operations department (which had to prepare the converter for repair and the utility supplies for the restart). The conflict was only resolved when top management interfered and decided to drop all claims in this case and transfer potential penalties to future time targets which were indeed achieved (Branconia & Lochc, 2004).
- Architecture works depends on the job scope, but plumbing is basically under the main contractor's scope of work. On the other hand, plumbing work in the building could be by some others party. Thus, there could be delays in construction.

g) Competent person registered by trade

- To have a competent person registered by trade to do testing and etc.

Technical experts knowledgeable in the specific technological areas associated with the project are an integral part of the contractors' development team. The main purpose of having such a team is to gain in-depth knowledge of the final outcome. This will then allow for maintenance and even improvement of the final outcome by the end-user's organization without any external help (Dvir, 2005).

h) Authority imposes new requirement

- Sometimes local authority or government body imposes new thing to match with new local rules. For example, Telekom's requirement for ICT. In a contract, local authorities have specified certain things, for instance, if a project is prolonged and the required system is no longer in the market, it will be difficult to continue with the local authority requirements as the ongoing project has already been tendered. Obviously, the delay is due to contractor's problem. Consequently, towards the end of the project the specified system is no longer in used by the market and becomes obsolete. As ICT is a fast moving technology and can cause many problems, the local authority still imposes new requirement to the contractor and what was specified during tender is no longer applicable.

i) Energize power supply for testing

- When doing testing and commissioning, things under scope of work such as lift might be ready and other items may be ready but if the electrical work is not energized, every item cannot be tested. Therefore, it is crucial to energize the power supply according to schedule. If not, items for mechanical and electrical such as firefighting cannot be tested. Local power company, TNB is crucial item in project commissioning. Once it power supply is energized, testing and commissioning date needs to be fixed. When preparing the checklist, the key factor for the architect is to energize power to execute testing and commissioning independently. All other items for testing and commissioning must be ready before the date to energize the power supply. During the energizing of power supply; all these items of testing and commissioning for mechanical and electrical components must be ready before the day of test.

- Sometimes, the sub-contractor will blame the electrical contractor for the absence of the energizing of power that delayed the testing and commissioning. The sub-contractor will blame the other party (no power) for the delay in executing their respective testing but actually, they themselves are also not prepared for the testing. The sub-contractors themselves sometimes are also delay. Hence, it is important to ensure that these sub-contractors are ready before the test date.
- For all these items to be tested, the most crucial part is the electrical work. It is important to ensure that all these NSCs are ready for testing and commissioning before certain deadline, if not, it will be of little use even if the energizing of power is ready. Therefore, there will be idling time for the electrical contractor if not every party involved is coordinated properly. It is crucial to make sure any item or trades, which need electrical supply to do testing, and commissioning to complete their respective work are ready before certain deadline set by the architect.
- Late supply of electricity by TNB can cause delay in commissioning;

j) Booking of time for authority's inspection

- Long waiting time for the authority inspection is another problem according to the interviewee. Schedule of the authority to come for inspection is another problem for projects wherein the planned date for inspection with authority does not match with the authority's schedule. Slacking from testing authorities will result in delay. This problem has caused many delays to building projects as the authority's is not pro-active in project commissioning.
- Timely inspection date with various authorities' technical department is very important to secure the letter of support.

k) Timely completion of various specialized items for testing and commissioning

- Timely completion of the various specialized items to complete in accordance with the scheduled time. If these items can be completed accordingly, timely and as planned, it will not cause any problem.
- To coordinate systematically for testing within the team i.e.: consultant and contractor.

l) Detailed work programme for testing and commissioning

- All these items have to be meticulously discussed in the construction work programme.
- Lack of proper and detail planning of the construction work programme by the main contractor will cause project delay. Sometimes, the main contractor just does not plan properly only allocates 2 months for testing and commissioning without any details. For example, for a 24 months project, during the first month, the main contractor will provide a very detail programme of the initial stage. The

estimated duration for testing and commissioning will be 2 months which is reasonable as this is the standard period for testing and commissioning as they have already allocated a safe period in the construction programme for testing and commissioning. But during the middle of the construction when mechanical and electrical items and etc. were installed, the main contractor must furnish the architect with a very detail construction programme which incorporates all components for testing and commissioning.

m) The unpredictable nature of commissioning

- Difficult to anticipate the problem in commissioning until testing and commissioning was carried out.

n) Equipment breakdown

- Generator set for essential power supply (to be used as battery back-up in case of electricity break down) has malfunctioned and needed to be sent back to the manufacturer in overseas for repair and to change all the hose.

6.3.8.1 Causes for Identified Commissioning Problems from the Consultants' Perspective

a) Change of requirement by the client

- Different priority by the University of Malaya to make this building a main building instead of a support building.

b) Nature of commissioning

- Sometimes when a building is ready for commissioning, the owner might suddenly have a change of plans or change of specification for a designated building. For example, due to the changes in design of a building, the air-conditioning system might not be working. This may be due to the fact that someone has to reload back the ducting due to a beam in which they did not coordinate and communicate due to this re-design. As the beam has blocked the routing and results in a longer routing and less efficient air-conditioning, this causes the air-conditioning to function ineffectively.

c) Communication problems

- Communication problems – if proper channels were set up earlier, this problem should not happen.

d) Planning of construction programme

- Planning of the programme is very important.
- The normal concerned are actually coordination and timely completion of a project. And if this fails, testing and commissioning for that part will be delayed. Internal testing and commissioning must be done before calling for authority's inspection.

e) Delayed due to some others problem

- This problem can be caused by delayed due to site problem, contractor's problem, contractor's financial problem and materials no longer in production and etc.

f) Authority's related problems

- For this project, CCC was part of the item in contract, therefore, getting the letter of support from all authorities during the contract period is very crucial.
- External factor which is beyond control such as: authority's inspection and support letter.

g) Coordination by the main contractor

- Coordination by main contractor to coordinate all the nominated sub-contractors;
- The appointment of competent person to coordinate testing and commissioning.

h) Payment issue from the main contractor to the sub-contractor

- Late and non-payment from main contractor to nominated sub-contractors. Sometimes it is due to payment problem which causes problems in commissioning, such as: the main contractor is paid by the client but did not pay the nominated sub-contractors, i.e.: the nominated sub-contractors have done 60% of work but only get paid for 40% of the work done.

6.3.9 Discussions of Commissioning Problems

Table 6.1 illustrates some of the similarities and divergences from the view points of the contractors and consultants on problems during commissioning.

Table 6.1: Comparisons of Commissioning Problems from the Contractors' and Consultants' Perspective

<table>
<tr><th>No.</th><th>Contractors' Perspective</th><th>Consultants' Perspective</th></tr>
<tr><td rowspan="2">1.</td><td>• Change of the specification by the structural engineer</td><td>• Change of intended purpose for the building
• Client's requirement was subjective and differs from project to project</td></tr>
<tr><td colspan="2">These changes initiated by the client or the end-user were uncontrollable but it also implies that there might be lack of the client's involvement in the project before the actual commissioning. According to a commissioning coordinator (Kirsila et al. 2007), the client should be integrated into the project before the actual commissioning. This will enable the client to take part, learn and comment on the activities carried out during commissioning and be prepared to receive the delivery of the project. With this initiative to become a customer-centric contractor instead of purely conducting commissioning might aid in avoid these changes from the client.</td></tr>
<tr><td rowspan="2">2.</td><td>• Poor coordination</td><td>• Poor coordination
• Poor communication</td></tr>
<tr><td colspan="2">Commissioning is to be considered as a partial step toward integrated practice. In an integrated practice, disciplinary boundaries and walls around project phases are supposed to be broken down. In commissioning, all participants are working seamlessly toward a common goal, without the communication gaps and uncertainties that can arise from the conventional design-bid-build approach (Elvin, 2007). However, coordination problems among construction team has further emphasized that there is a deficiency in the execution of commissioning in Malaysian institutions of higher learning.

Communication is the key to success on any multi-phase project spanning several months to several years. The commissioning process, and more particularly, the commissioning team, should act as an effective project integrator during the transition to fully integrated practices (Grondzik, 2009).

In the Malaysia context, usually the commissioning team is represented by the construction team involves in the construction project. However, there is an absent of a special team to integrate the different individual elements of commissioning. Therefore, poor coordination and communication among the construction team must be addressed by an experienced by coordinator or consultant.</td></tr>
<tr><td rowspan="2">3.</td><td>• Unforeseen problem</td><td>• Unpredictable nature of commissioning</td></tr>
<tr><td colspan="2">All elements are possible to cause problems in commissioning.</td></tr>
<tr><td rowspan="2">4.</td><td>• Overlook the importance of commissioning
• Incompleteness of outstanding works</td><td>• Unclear scope of work (grey area)</td></tr>
<tr><td colspan="2">Building commissioning is not a replacement for the conventional building acquisition process. Instead, it acts as a supplementary to that process.</td></tr>
</table>

Table 6.1: Comparisons of Commissioning Problems from the Contractors' and Consultants' Perspective (Cont'd)

<table>
<tr><th>No.</th><th>Contractors' Perspective</th><th>Consultants' Perspective</th></tr>
<tr><td>4.</td><td colspan="2">Consequently, commissioning should not be expected to correct project problems through last minute interference at the end of construction (Grondzik, 2009). This has further highlighted the importance and clearly emphasizes and made known of the scopes for building commissioning.

Patent defects such as no proper installations for finishes and anything that is visible are among the primary commissioning tasks for non-mechanical features. According to Stum (2001), it is an essential part to go beyond the conventional by commissioning non-mechanical features to ensure that the product/material/services/equipment are installed properly. This circumstance place further emphasis on the quality assurance endeavor at the specification phase rather than after installation (Stum, 2001).</td></tr>
<tr><td rowspan="2">5.</td><td>• Delay of civil and structural works</td><td>• Timely completion of various specialized items for testing and commissioning</td></tr>
<tr><td colspan="2">This is not surprising as commissioning is described as the problem solving process of the project rather than the start-up of the equipment or the handing over to the client (Kirsila et al., 2007). Therefore, delay in completing civil and structural works has been reported as one of the commissioning problem. Although defective works for civil and structural works can be rectified during construction. However, errors which failed to be rectified along the way before the deadline for commissioning will cause problems in commissioning later on. This claim is supported by consultant's who also claimed that timely completion of various specialized items for testing and commissioning will not cause commissioning problem.
Besides that, during the developing process for a project, the substance from one project phase will move towards the next phase. Thus, most of its sub-processes move ahead in the same direction and this implies to all phases in the project life-cycle (Kirsila et al., 2007). Upstream problems which remained unresolved such as delay in the completion of civil and structural works will definitely affect the downstream activity. Apparently, this downstream activity means the commissioning for the project to hand over the building.</td></tr>
<tr><td rowspan="2">6.</td><td>-</td><td>• Inexperience builder
• Competent person registered by trade</td></tr>
<tr><td colspan="2">Many firms have used inexperienced staff and untrained engineers as commissioning engineers due to the severe shortage of competent commissioning expertise (Tseng, 2005).</td></tr>
<tr><td>7.</td><td>-</td><td>Authority imposes new requirement- Booking of time for authority's inspection</td></tr>
<tr><td>8.</td><td>-</td><td>Energize of power supply for testing</td></tr>
<tr><td>9.</td><td>-</td><td>Unavailability of detailed work programme for testing and commissioning</td></tr>
<tr><td>10.</td><td>-</td><td>Equipment breakdown</td></tr>
</table>

6.3.10 Commissioning Problem which has the Most Significant Impact: Contractors' Perspective

Figure 6.19 and 6.20 illustrates significance commissioning problems and the frequency of these significance commissioning problems. Figure 6.19 was derived when the interviewees were asked on the significance commissioning problems. Subsequently, Figure 6.20 was derived from Figure 6.19 to present the magnitude for these problems. These Figures complement each other to present a better insight on the significance commissioning problems for these case studies. Some of these answers as illustrated in Figure 6.19 are similar with Figure 6.15 and some of it is different answers. Comments given by the interviewees are as follows:

- More towards technical side such as: to re-check the setting, valve and line for lift, fire fighting and air-conditioning;
- Wet systems such as fire protection systems and sanitary and plumbing, air-conditioning mechanical ventilation (ACMV);
- Element related with water supply-water leakage due to improper jointing of cable or pipe;

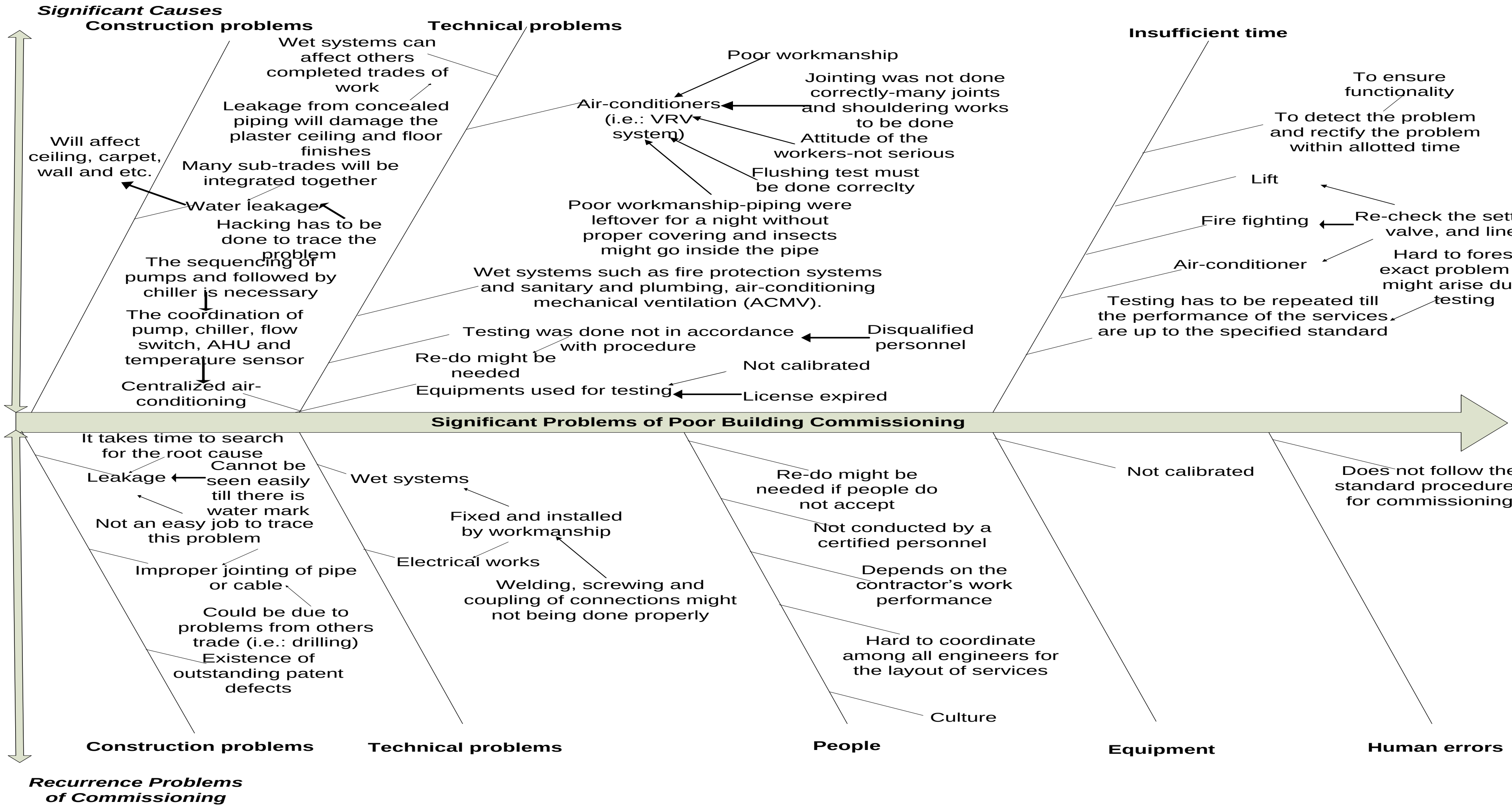

Figure 6.19: Fishbone Diagram showing the Significance and Common Commissioning Problems for Construction Projects in an Public Institution of Higher Learning in Malaysia: Contractors' Perspective

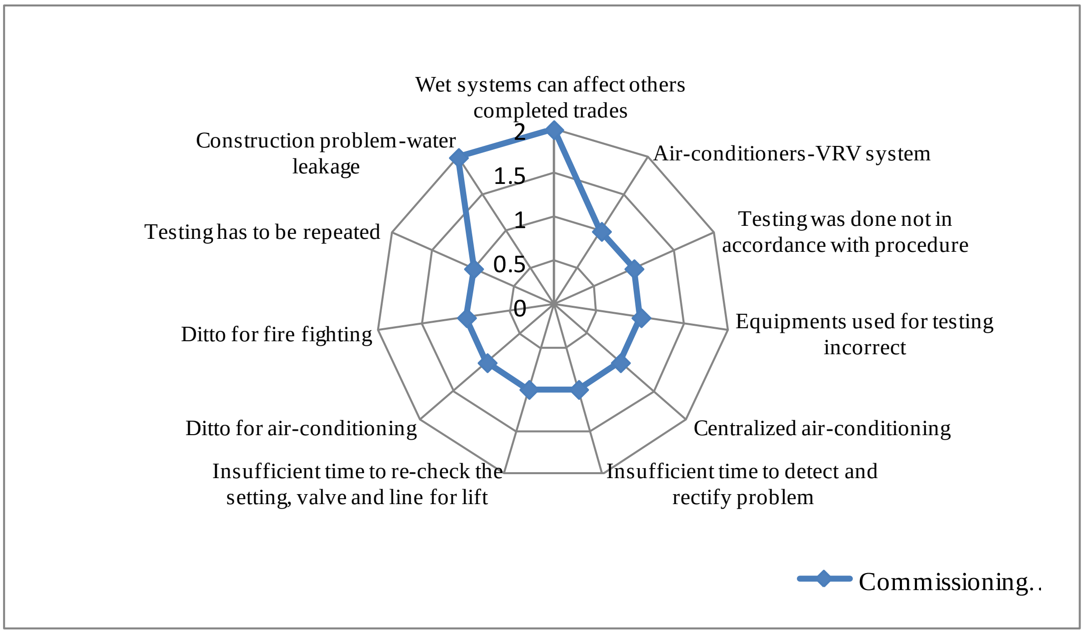

Figure 6.20: Frequency of Significance Problems in Commissioning (Technical Slant Related Problems): Contractors' Perspective

- The testing not done according to procedures. Unqualified personnel without license performing testing. The equipment for testing is not calibrated or the license has expired;
- Centralized air-conditioning;
- Every item can caused major delay;
- Air-conditioner such as VRV systems which involves lots of shouldering and joints;
- Testing part of the services takes a very long time and is done to iterate till the testing of the services is up to the specified standard and no problem occurs before proceeding to commissioning; and
- When there is a failure, the most important thing is to detect the problem/rectify the problem within the allocated period of time.

6.3.10.1 Causes for Commissioning Problem which has the Most Significant Impact: Contractors' Perspective

a) Many sub-trades will be integrated together and are interrelated

Wet systems can affect other completed trades of work as well. For example, leakage of concealed piping can damage the plaster ceilings and affect the entire work progress. If the floor finishes is carpet, the consequence of leakage will be much worse. When there is leakage, hacking has to be done to trace the problem and this will affect the wall, carpet, ceiling, and many other trades.

b) Test done by an incompetent person

Commissioning is not done according to requirement where an unqualified person without proper qualification and experience performs the test.

c) Coordination of work

The coordination of pumps, chiller, AHU, flow switch and temperature sensor are important. The sequencing of pumps is followed by chiller. The commissioning steps in planning are necessary.

d) Unpredictability problems during testing and commissioning

Every item tested in commissioning has a possibility to cause delay. It is tough to single out any particular item which causes delay during commissioning. It is also difficult to foresee the exact problems that might arise during testing.

e) Poor workmanship

- Joint is done incorrectly
- Flushing test not done correctly

- pipes are left overnight and insects has infiltrate the inner pipe

- for VRV systems, the inner pipe must be clean before testing can commence.

All of these items are important to ensure functionality is performing to specifications.

6.3.10.2 Commissioning Problem which has the Most Significant Impact: Consultants' Perspective

The interviewees gave diverse answers to this question. Each of them has different perception on the most significant problem for commissioning. According to the interviewee, these problems vary and the commissioning problems depend on the particular project. For example: for hospital', the most common problem is the air-conditioning system because the air-conditioning system is quite unique as they normal filter system cannot be used to filter germs. On the other hand, for office building, usually the main problem is the installation of the lift especially for high rise building. Air-conditioning problems has not only occurred in high rise building but also in low rise building. Air conditioning problem is one of the main problems found in commissioning.

From the perspective of architect, building finishes is cited as one of the significant problems of commissioning. This is because:

- Sample of materials (submitted sample does not understand the standard and this problem is dragged for a long time);
- Lead time to order; and
- Constructed and rejected items (defects).

Therefore, planning of the construction programme during initial stage is noteworthy to counter this problem.

It is the duty of the mechanical and electrical engineers to make sure everything is in working order. Without electrical power supply, no testing can be conducted. Therefore, electrical works are among the most significant problems in commissioning to be dealt with. Testing for others things are not possible without electric power supply. Although temporary supply can be used for testing, for full commissioning, a total system checks where all the electrical items such as all the air-conditioning and all the lifts are tested simultaneously. For temporary supply, the power capacity is limited and thus, proper commissioning cannot be performed. For local power authority, Tenaga Nasional Berhad (TNB), a few problems arises during the commissioning stage. For example, sometimes, TNB takes about 6 months to call for tender for the laying of the cables. Therefore, according to the interviewee, TNB has a very big role to play during commissioning as TNB deals with the electric power supply for the contractor. Without electric power supply, it is impossible to conduct many tests such as running the water pump, firefighting tests and others.

Another major problem caused by the inconsistent power supply by TNB is electrical works problem. Electrical problems from TNB affect commissioning of power supply. This is because to complete the TNB power supply chain, cabling and etc. has to be done and the TNB building must be handed over to TNB before the installation of switch gear. There is a lack of coordination by TNB personnel in terms of timing and others when TNB building is commissioned. This will impact the overall project completion date as failure to deliver the TNB building to TNB will cause disruption in power supply. Since TNB personnel are not pro-active in conducting their task , this will affect the whole commissioning schedule and the energizing of power for testing and commissioning as power will not ready.

Problems such as leakage and workmanship fall under the category of defects. But, it depends on the severity of the defects. If leakages are detected, these leakages have to be rectified immediately as the impact of leakages will affect testing and commissioning and will subsequently deteriorates the efficiency of the whole system.

In general, it is almost impossible to determine the most significant problems of commissioning as these problems differ from each project. Nevertheless, coordination is very important during commissioning. If there is a lack of coordination, problems may arise and causes repetitive work and thus increase the cost and delay the entire schedule. For example, for ceiling, if electrical installations are not completed before ceiling is covered up, many problems will occur at a later stage. Consequently, interface trades problem can also affect the work progress. Some lead time is recommended during commissioning for final architectural works in order to remedy any outstanding work.

6.3.11 Common Problems of Commissioning and Its Causes: Contractors' Perspective

As illustrated in Figure 6.21 is the frequency for common problems in commissioning that tend to recur from project to project. This Figure is distinctive from Figure 6.16, 6.18 and 6.20. The interviewees were asked to comment on what were the problems that repeatedly found in these projects. Some interviewees responded that there is no recurrence of commissioning problems for different projects. Some of them claimed that different problems will appear in different types of project and it is difficult to specify any exact problems. Furthermore, the recurrence of this problem varies and depends on the performance of the contractor. However, some interviewees mentioned that same problems do occur in different projects (mode of problem are more or less the same).

Generally, some people claimed that the recurrence of problem is due to water leakage. Problems of wet systems and electrical works are prone to recur from project to project such as leakage, and improper connection of cable or pipe.

Most of the time, the same problem occurs because contractors did not follow the specified or required standard procedures. Every trades and elements supplement and complements each other to make it a total functional system. All these trades and elements run in tandem with each other. For instance, for VRV systems, the inner pipe must be clean before testing can commenced. Frequency of these recurrence problems in commissioning is presented in Figure 6.21 to emphasize the occurrence of this problem in construction project.

From the contractors' perspective, there are two main elements in commissioning, which are: people and equipment. These services or systems are fixed and installed by human. Therefore, during the works of welding, screwing and coupling of the connection, some work might not have been done properly. Sometimes, testing is not conducted by certified personnel and the equipment was not calibrated properly resulting in malfunction of equipment. Some installation problems may also be caused by the attitude of the workers who are not serious in their work.

Besides, different contractor has different type of performance standard. It is very hard to coordinate all the engineers involve in the layout installation of services. Lack of coordination can caused many problems and further exacerbates the delay progress of the project.

Every commissioned item can be a contributor to delay. Thus, to catch or trace the problem is not easy. For examples, for leakages, many other trades might cause leakage such as drilling from other trades. It takes time to search for the root cause and leakage cannot be seen easily until there is water mark spot detected.

These problems may be due to the culture of the industry. Testing and commissioning is actually part of the requirement/specification of construction projects according to law and regulations. If it is not done according to procedures, re-do and rectifications might be needed if the customer does not accept the end product.

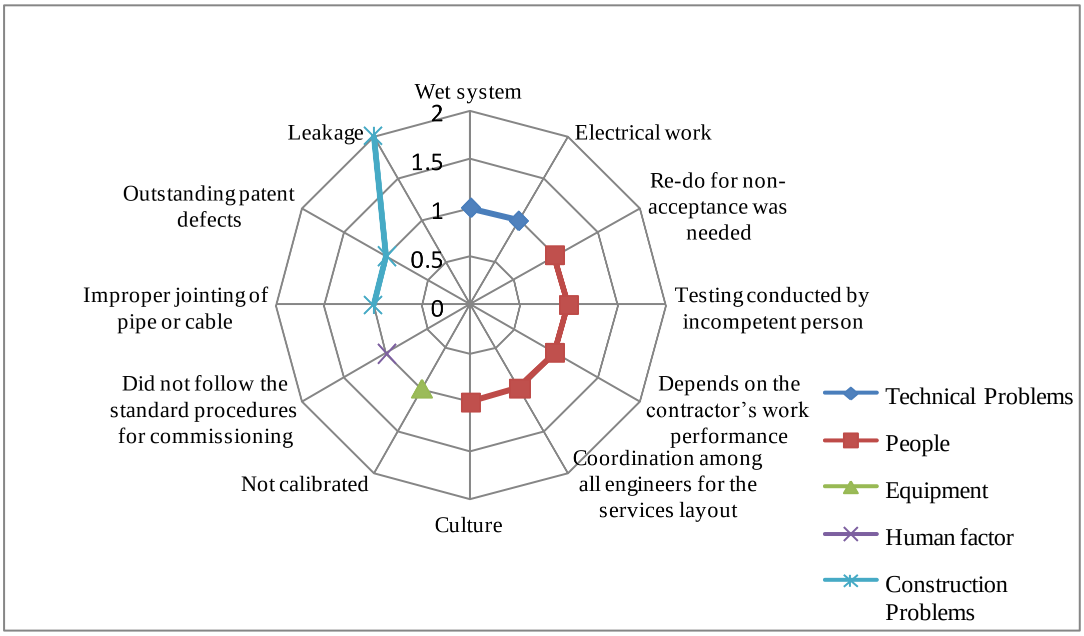

Figure 6.21: Frequency of Common Problems in Commissioning: Contractors' Perspective

6.3.11.1Common Problems of Commissioning and Its Causes: Consultants' Perspective

From the consultants' perspective: Problems that recur from projects to projects and its underlying causes are summarized in Table 6.2.

Table 6.2: Summary of Recurrence Problems in Commissioning and Its Causes

No.	**Recurrence problems**	**Causes**
1	Every project is unique and depends on the building typology. For a hotel, the main commissioning issue would be plumbing; and for office building, the common problems are air-conditioning, lighting and lift problem.	To focus on the same type of building typology to identify the common problem.
2	The problems are almost the identical.	Differ from project to project.
3	Local power authority (TNB)'s problem.	It is because it takes time for TNB to call for tender and everything depends on the discretion of TNB's tender board.
4	The same problems occur for different projects.	The procedures are more or less the same.
5	Varies between projects.	The main contractor must have a very good mechanical and electrical coordinator to coordinate and to monitor the progress of the project.

6.3.12 Interrelationship of Commissioning Problems with Other Phases in the Project Life-Cycle

Table 6.3 is the summary of the interrelationships between the problems of construction and commissioning from the contractors' and consultants' perspective. Construction problems are one of the major inhibitor for the execution of commissioning. Interference from client, late completion of civil and structural works, variation orders, half-baked systems and lack of supervision are among the construction problems that has a big influence in commissioning. Figure 6.20 further demonstrates this statement on the influence of construction on the execution of commissioning.

Figure 6.22: Effect of Construction on Commissioning

a) Interference from client

Interference from client such as additional requirement from client and changes of room layout for services, delay in decision making and others have caused the project progress to be delayed.

b) Completion of civil and structural works

Without completion of structural and architectural works, it is almost impossible to run testing and commissioning. For testing and commissioning, power supply is needed to test the equipment. If the civil and structural works have not completed, the mechanical and electrical work cannot be tested. Delays in civil and structural works will also affect the architectural installation and mechanical and electrical works as well. Problems in mechanical and electrical works will delay some civil work progress such as the completion of brick wall and ceiling finishes.

c) Variation Orders

Additional and the increased number of Variation Orders (V.O.) will affect the actual progress of work. Re-testing might be required due to additional variation orders such as change of layout from the end-user.

d) The system itself is half-baked and not ready for commissioning

Some of the system cannot be partially commissioned and must be tested in full swing mode (not fit for commissioning). The following are some of these problems:

- Lift not running; and
- No letter of support from authority.

e) Lack of supervision – Contractors overlook some critical problems and affect this will have an adverse effect at the whole system at a later stage. As a result, all these construction problems will delay the handing over of the building to the client.

Table 6.3: Interrelationship of Commissioning Problems with Other Phases in the Project Life-Cycle

Interviewee	Is commissioning caused by delay in previous phase in construction?	Which stage?	Why?	Problems identified from previous phase
E1	Yes.	Construction stage.	-	Delayed in decision making on the floor finishes for level 8th and etc. has caused the progress to be delayed.
E1a	Interrelated.	-	Delay in construction will affect the schedule in commissioning.	Some of the system cannot be partially commissioned and must be in full swing mode (not fit for commissioning) • Lift not running; and • No letter of support from authority.
		Commissioning phase.	-	-
A1	Yes.	Construction.	-	-
		Commissioning phase.	Could be due to mechanical and electrical works, faulty equipment in the air-conditioning.	
E2	Yes.	Structural and architectural works.	This is because the installations of structural and architectural works have to be completed before testing and commissioning can be executed. Structural, architectural and commissioning are interrelated with each other.	Without completion of structural and architectural works, it is almost impossible to run the testing and commissioning with the absent of power supply. For testing and commissioning, power supply is needed to test the equipment for this purpose.
		Commissioning phase.	Possible. Besides, troubleshooting in this phase could cause delay in project handing over though the contractors will speed up the durations required for testing and commissioning to cover up the delay	-

Table 6.3: Interrelationship of Commissioning Problems with Other Phases in the Project Life-Cycle (Cont'd)

Interviewee	Is commissioning caused by delay in previous phase in construction?	Which stage?	Why?	Problems identified from previous phase
E2			from previous phases; but, the project will be delayed. This is necessarily to counter the loss of time caused by delay in previous phases.	
A2	Yes.	Construction.	It depends on the work performance of the main contractors and the appointment of the right sub-contractors to do the work correctly from the beginning. This will be tested and observed by the clerk of work and verified by the engineers. Pre-selection of the sub-contractor is important to appoint the correct person to do the work.	-
		Commissioning phase.	It has to be from day one based on the reputation of the sub-contractors and past experience. It is not solely based on the cost.	-
E3	Yes.	Construction.	-	Additional and the increased number of Variation Orders (V.O.) will affect the actual progress of the work. Re-testing might be required due to additional variation orders such as change of layout from the end-user.
		Commissioning phase.	Possible but rarely from commissioning itself.	-
E3a	Yes.	Mostly due to delay occurred from construction phase. Delay during construction such as civil and structural works and architectural	-	Delays in civil and structural works will affect the architectural installation and mechanical and electrical works as well.

Table 6.3: Interrelationship of Commissioning Problems with Other Phases in the Project Life-Cycle (Cont'd)

Interviewee	**Is commissioning caused by delay in previous phase in construction?**	**Which stage?**	**Why?**	**Problems identified from previous phase**
E3a		works.		
		Commissioning phase.	Problem in testing and commissioning are mostly caused by delays in construction.	
E4	Yes.	Construction.	-	Will affect the project hand over period.
		Commissioning phase.	Yes.	
E5	Possible.	From civil and structural work in construction phase.	-	If the civil and structural works are not completed, then the mechanical and electrical works cannot begin.
		Commissioning phase.	Sometimes the problem is from testing and commissioning itself like cabling problem.	
E6	Yes.	Construction stage.	Variation orders are the first stage to be handled. In this project, there were too many variation orders and it was too sudden to be handled and tackled by the project team.	Re-testing might be required due to additional variation orders such as change of layout from the end-user.
		Commissioning phase.	Yes. If it did not follow the specifications and procedures.	
A6	Yes.	Construction stage.	The completion for specific mechanical and electrical items cannot be completed due to incompleteness of pre-requisite works such as structural and architectural works. Delays occur in pre-requisites works will affect the commissioning of the project.	For lift, during initial stage, the architect has designed the size for the lift core but during construction stage, problem occurred on the foundation using piling. When piling was done for the lift core, the piles have sank and disappeared (there was something wrong with the soil during piling). This problem has to be solved even during

Table 6.3: Interrelationship of Commissioning Problems with Other Phases in the Project Life-Cycle (Cont'd)

Interviewee	**Is commissioning caused by delay in previous phase in construction?**	**Which stage?**	**Why?**	**Problems identified from previous phase**
A6				structural work before installation of lift. Problems at the initial stage due to problem of piling can also cause delay. If this problem is not resolved. it will have a domino effect on commissioning. If the structural works and the housing of lift are not prepared accordingly, the NSC will not install the lift. This will have a direct effect on the lift as this is the pre-requisites for installation of lift and testing of lift.
	Yes.	Commissioning phase.	-	-
E7	Yes.	-	-	Problems in mechanical and electrical works will delay the work progress of brick wall and finishes for ceiling.
A7	Yes.	Construction.	Delay in getting the required equipment during construction. Commissioning is done towards the end of the project; if the problems occur towards the end then it will affect the overall schedule.	-
		Commissioning	If the problem occurs very close to the execution of commissioning but not too early before commissioning. If the problems occur 1 month before commissioning then the contractor is still	

Table 6.3: Interrelationship of Commissioning Problems with Other Phases in the Project Life-Cycle (Cont'd)

Interviewee	**Is commissioning caused by delay in previous phase in construction?**	**Which stage?**	**Why?**	**Problems identified from previous phase**
A7			able to solve the problem before the commencement of commissioning.	•
E8	Yes.	Delay for commissioning can occur at any stages.	The overall work progress itself were delayed. Thus, the commissioning work started late because of the delay occurred previously.	• The system itself is not ready; • Some of the system cannot be partially commissioned and must be tested in full swing (not fit for commissioning); • Interference from the client such as additional requirement from client and changes of room layout for services; • Lack of supervision-overlook some problems and affect the whole system.
	Yes.	Commissioning phase.	-	-
A8	Yes.	Construction stage.	In terms of delay in handing over or delay in owner using the building? If the contractor has completed all the work or his scopes of work (has fulfilled the contract) then he should hand over because he has already completed all his scope of work. If the delay is due to TNB's problem, then the client will have to suffer from the delay.	Construction must be completed beforehand before commissioning. At the end of the day, the building has to be completed. For example for lift installation, the building has to be ready prior the installation of floor except for certain parts (for whatever services and spaces). Items installed under hidden compartment must be completed before concealment for ceiling. The building has to be completed for

Table 6.3: Interrelationship of Commissioning Problems with Other Phases in the Project Life-Cycle (Cont'd)

Interviewee	**Is commissioning caused by delay in previous phase in construction?**	**Which stage?**	**Why?**	**Problems identified from previous phase**
A8				testing.
		Commissioning phase.	For instance, the contractor has to fulfill his work according to the contract but pending full commissioning due to TNB's delay. This will not affect the handing over to the client (the contractor's has to hand over) unless the contractor's has not completed his work according to the contract. For example, for sewerage, the contractor has done the work but IWK asked for contribution, as long as payment is not received for desludge of manhole to the IWK's main sewer. Therefore, IWK will not issue the letter of support. Therefore, it will not affect the hand over because the contractor has done their work. The owner still cannot use the building because letter of support from IWK has not been received.	-

6.3.13 Recommendations to Mitigate Commissioning Problems

Without testing the systems, it is difficult to determine the functionality of it. According to the interviewees, it is difficult to control Variation Orders and they have to trace the problem back to its source. Consequently, it is not easy to mitigate problems in commissioning. In mitigation of this problem, professionalism and the contractors' ethics must be of top priority to have a quality building.

From the consultants' perspective, by that time any problem is found, a much longer time will have to be spent to rectify the problem to meet the schedule. Therefore, planning for commissioning before the start of the project must be done accurately during planning of the work programme.

6.3.14 Anticipation of Commissioning Problems before the Commencement of Project

Most of the interviewees from consultants and contractors claimed that it is very difficult to anticipate problems in commissioning. Among the reasons given by the interviewees are as follows:

- Difficult to predict potential problems. For example, the issuance of Variation Orders is not part of the work programme;
- Contractors always underestimate the complexity services installation;
- Along the way, there are many unforeseen things and this is unavoidable. For example, vandalism;
- Difficult to anticipate problems for an abandoned project. In the beginning, the newly appointed contractor is unaware of the exact condition of the project till further site investigation is carried out.
- Problems can only be found towards the end of investigation.

Surprisingly, anticipation of problems beforehand is considered to be an almost impossible task by the interviewees. The reason given is covered in the Project Quality Plan (PQP).

CONCLUSIONS AND RECOMMENDATIONS

CHAPTER 7

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 Introduction

It is utmost essential for contractors and consultants to know the common activities for commissioning that need to be planned beforehand even during construction stage. In summary, this study is related to building commissioning for construction projects for the public institution of higher learning in Malaysia. The aim of this research is to delve into the problems during commissioning stage and the interrelationships of these problems with problems arise in other phases in the project life-cycle. This chapter summarizes the overall research findings, assesses the contribution of the study, depicts the limitations of the study and recommends avenues for future research.

7.2 Conclusions of Main Findings

The main findings drawn from the research are discussed and summarized to achieve the research objectives delineated in Chapter 1.

7.2.1 Objective 1

The first objective of this research is “to redefine the scope and understanding of building commissioning from the contractors’ and consultants’ perspective” is achieved by semi-structured interviews. The conceptual model of building commissioning enhances the existing defined understanding of building commissioning. This conceptual model provides a more holistic and in-depth perceptions on building commissioning for construction projects for the public institution of higher learning Malaysia.

Conceptually, the definition of building commissioning is most comprehensive where it capable to combine these characters into the conceptual model. There are eight groups of characters, such as: characteristics, pre-requisites, components, ensure functionality, durations, activities or elements, personnel involved and the goals to be attained in building commissioning have formed the basis for this model.

Besides that, the contractors’ and consultants’ view point on commissioning are also compared and contrasted with the existence definition of commissioning. These view points from contractors and consultants are slightly differed among each other’s but it does present some ideas on the current practice of commissioning for construction projects in the public institutions of higher learning Malaysia. Therefore, this objective is vital to generate a comprehensive and precise understanding of commissioning in the context of the Malaysian construction industry. With these perceptions in mind, this will definitely assist to improve the conduct of commissioning later on.

7.2.2 Objective 2

The second objective, "To identify problems during commissioning and the relationships of these problems with other phases of the project life-cycle" is accomplished by conducting semi-structured interviews through case studies from a public institution of higher learning in Malaysia. Comparisons of these interviews findings among contractors and consultants have revealed that problems during commissioning are due to: poor coordination and poor communication, change of the requirement by the client or change of the intended purpose for the building or change of the specification by the engineer, occurrence of unforeseen problems, unpredictable nature of commissioning, unclear scope of works, delays of civil and structural works, timely completion of various specialized items for testing and commissioning. The consultants interviewed further added on a few factors such as: inexperience builder, lack of competent person registered by trade, new requirement imposed by the authority, time needed to make appointment with authorities for inspection, energize of power supply for testing, unavailability of detailed work programme and equipment breakdown.

In order to achieve this objective, problems during commissioning are identified. This is followed with the identification of significance commissioning problems and common commissioning problems that tend to recur from project to project. These problems which have been identified in this study are pivotal to indicate problems that need to be attended or mitigated in a timely manner. Apart from this, problems during commissioning are mostly interrelated with problems during construction stage.

7.2.3 Objective 3

The third objective, “to determine the underlying causes for these commissioning problems” is attained from data collected through semi-structured interviews. It is the interest of the researcher to know the causes for the occurrence of these problems during commissioning. Some of these problems are significance in affecting the handing over of the project and tend to recur from project to project. Without knowing the underlying causes of these problems, it is hard to anticipate the occurrence of these problems in future projects.

7.2.4 Objective 4

The last objective of this research, “to measure the importance of building commissioning and its effect on project completion by using Earned Value Analysis”. From the S-Curve plotted for Project A, Project B and Project C, it can be concluded that the project commissioning will be rushed when there is a delay in the middle of the project during the planned commissioning stage. By referring to the gradient of commissioning stage in Earned Value Analysis graph, we can see the difference in gradient for commissioning for different projects. The higher the gradient value, the faster the commissioning has to be performed to complete the project in a timely manner. Therefore, it can be deduced that commissioning is utmost important in influencing the project completion and project performance.

7.3 Contributions of the Study

Building commissioning is utmost essential to ensure conformance of the constructed faculties with the design intend. It is also a quality assurance process to verify and document that building systems function as designed and meet the operational needs of the building owner. However, people tend to overlook the significance of commissioning as it is conducted towards the end of the project. Consequently, it is extremely important to determine the perceived understanding of building commissioning from the contractors' and consultants' perspective to be used by the practitioners in the construction industry.

Merriam (2001) suggests that insights gleaned from case studies can directly influence policy, procedures, and future research. The outcome of this study provides a conceptual model of building commissioning which outline the key characteristics of building commissioning. This conceptual model is expected to help practitioners to have a better insight on building commissioning. Subsequently, this comprehensive model of commissioning also serves to clarify the practitioners' thought and enhance their knowledge on commissioning. With this model, it is hoped to assist the practitioners to be better prepare and plan their resources and manpower more efficiently and effectively to overcome any unforeseen problems towards the end of the project.

The conceptual model of building commissioning also helps the practitioners and planners to understand the impact of commissioning problems might have on the project timely completion. Furthermore, this model serves as a basis for further research in this area. This model will also help the researchers who are seeking solutions for construction delay in relation to the project life-cycle.

The research findings on three levels of problems such as commissioning problems, significant commissioning problems and recurrent problems of commissioning provide a better opportunity for the practitioners to understand the impact of building commissioning can have on the project timely completion. This awareness is hoped to attract attentions of all concerned parties on the importance and ramifications of building commissioning.

On a practical note, this study is expected to improve the performance of construction projects by having a better-planned construction work programme as a guide to be taken into consideration in future projects to improve the building commissioning performance. Besides that, there are no studies which have been done in this area for building commissioning in Malaysia.

A proposed work programme of building commissioning as illustrated in Figure 7.1 is generated to inform the construction practitioners on the common activities of commissioning that needed to be planned even during construction stage. With this work programme in mind, it is expected to improve the conduct of commissioning for future projects in the public institutions of higher learning in Malaysia.

7.4 Limitations of Study

The research has accomplished its aims to develop a conceptual model to improve building commissioning in construction projects for a public institution of higher learning in Malaysia. However, these limitations of this study are worth mentioning as described as follows.

This research is confined to the public institutions of higher learning in Malaysia. According to Woodside and Wilson (2003), for a given study, focusing on the research issues, and/or empirical enquiry on the individual is the central issue of case study research. Skinner (1966: 21)….states that instead of studying a thousand rats for one hour each, or a hundred rats for ten hours each, the investigator is likely to study one rat for a thousand hours. Thus, to study one rat, this study focuses on a case from the public institution of higher learning in Malaysia. Consequently, the results obtained may not be representative of the population of the Malaysian construction industry. However, according to Easton (2010), generalization of any kind is not possible unless there is some invariance in the world. Moreover, the interviewees participated in this study are experienced practitioners in the Malaysian construction industry with at least more than ten years of working experience.

Besides that, the construct of this study is to develop a conceptual model to improve building commissioning excluding the quantifiable magnitude of the improvement of project performance. The magnitude of this improvement is not in the scope of this study due to time constraint.

Apart from this, the outcome of this study does not take into consideration the influence of project information such as: types of procurement method and contract sum of the project. According to Walker (1994) who found that procurement methods do not influence the time performance of projects. This is most similar to this study to determine the influence of building commissioning on the project timely completion. In a research conducted by Love in 2002, at the 95% confidence level, no significant difference in the total cost of rework was experienced in project using different procurement methods. This study also suggests that rework can adversely influence project performance. Therefore, it can be concluded that rework costs do not significantly vary among procurement methods employed. As a result, this study presumes the same for the performance of building commissioning that it do not significantly different between different types of procurement methods.

7.5 Recommendations for Future Research

The limitations outlined above indicate several aspects where there is potential for future improvement in the industry. Hence, based on the findings and limitations of the research, a number of recommendations are proposed to provide direction for future research.

As indicated in the previous section, the research context was limited to building commissioning in the public institution of higher learning. Generalizations beyond this sample cannot be made. Thus, it is plausible that there may be significant differences in the findings if data were collected from the private institution of higher learning in Malaysia.

As an extension of this study, additional quantitative evidence is needed to determine the relationships between commissioning problems and the project performance and project timely completion. A quantitative study in future would be a way to assess more accurately the influence of building commissioning on the project performance and to complete the project in a timely manner.

For further studies, it would be interested to look deeper into these identified commissioning problems which comprises of three levels of problems and to come out with a ranking of those problems. A questionnaire survey can be administered to achieve this objective. Besides that, future study can be focused on certain types of procurement method to evaluate whether there are any similarities or differences found amongst different procurement method on building commissioning.

Moreover, the common activities of building commissioning that need to be taken into consideration even during construction stage shall be inspected by the relevant building authorities. This measure is vital to confirm the final outcome is in compliance with the specified requirements or specifications i.e.: Green Building Index (GBI). Consequently, in the future, it is useful to study if inspections by the authorities and construction team can or should be outsourced to an independent third party.

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APPENDICES

APPENDIX A: List of Publications

The following papers have been produced in the course of the research undertaken of this thesis for the Doctor of Philosophy (PhD). The papers are included in the Publication section.

Journal and Conference Papers

i. Kho Mei Ye, and Hamzah Abdul-Rahman. (2011). Attentiveness of Building Commissioning in the Malaysian Construction Industry, *World Academy of Science, Engineering and Technology*, 80, 255-259.
ii. Hamzah Abdul-Rahman, Wang, C., and Kho, M.Y. (2011). Potentials for Sustainable Improvement in Building Energy Efficiency: Case Studies in Tropical Zone, *International Journal of Physical Sciences*, 6(2), 325-339.

Submitted Paper for Review

i. Hamzah Abdul-Rahman, Samiaah M Al-Tmeemy, Zakaria Harun, Mei Ye Kho. (2012). The Relationship Between Cost of Control Activities and the Quality Failures, *International Journal of Project Management.*

APPENDIX B: Case Study Interview Questions

No.	Questions Asked		
	Level 1	**Level 2**	**Level 3**
1	What is your understanding of building commissioning?	What are the activities involved?	Usually how long it takes?
2	Do you think commissioning stage is important to ensure conformance of the constructed facilities and building with specifications?	Please **rank** from **1** (least significant) – **5** (most significant) on the importance of building commissioning.	Why?
3	How is testing and commissioning being conducted in the Malaysian construction industry? a) Progressively being done all through the project, **OR** It is carried out after construction, towards the end of the project to the client but except for certain thing which was carried out progressively. b) Please give reasons for your selection in 3 (a). c) Please specify other reasons if the above statement in 8 (a) does not reflect your answer.	What are the problems in commissioning?	What are the causes for these problems in commissioning?

No.	Questions Asked (Cont'd)		
	Level 1	**Level 2**	**Level 3**
4	What are the elements to be commissioned in this stage? a)______________ b)______________ c)______________ d)______________ e)______________	a) Which aspect has the most significant delay? b) From these aspects, which element recurs from project to project? (common problem)	Why? Why?
5	Is delay in commissioning derived from previous phases in the project life-cycle? Or the problem merely from commissioning phases itself?	If **Yes**, which stage of the project life-cycle? How to mitigate this problem?	What are the problems in this phase that will cause subsequent delay in commissioning phase?
6	Who are the personnel involved in the commissioning stage?	Commissioning started in which stage of the project life-cycle?	
7	Are proper inspection/testing being done during commissioning or commissioning is merely an administrative task to get the Certificate of Practical Completion?	Why?	
8	Will commissioning causing delay in handing over of the building to the client?	Why?	
9	What are the effects/impacts of delay in	How will it affect the project	Do people consider this problem

No.	Questions Asked (Cont'd)		
	Level 1	**Level 2**	**Level 3**
9	commissioning? e.g.: rental and usage of the building.	completion?	before they start the project?
10	What is the magnitude of delay in commissioning? How many days of delay in commissioning?	Please **rank** the seriousness of delay in commissioning from **1** (least serious) – **5** (most serious).	

Years of experience :

Completion date :

Position :