Design Science Research as an Approach to Develop Conceptual Solutions for Improving Cost Management in Construction

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ABSTRACT

Despite the progress that has been made with regard to construction cost management, many drawbacks including the unpredictability of construction costs continue to raise concerns. This research study aimed to contribute to improving construction cost management by identifying the key issues which contribute to such drawbacks, and developing conceptual solutions to mitigate them. The design science approach has been selected as the overall research method. Design science approach has been augmented through an analysis to the root cause of each identified key issue, an inference of countermeasure to the each root cause (conceptual solution), and synthesis of the (practical) solutions. This research has identified failure to forecast, failure to support improvement opportunities, costs being considered as resulting from action, neglect of value consideration, poor support for inter-organizational cost management, negative influence on behaviour, and constraints created by budgeting, as key issues contributing to the current drawback of construction cost management. This study proposes the recognition of waste through flow theory, integrating costs to design, value generation theory, seeing construction as production, incentives aligned to improvement, separating the different functions of budgeting and the dynamic approach to managing costs as solutions to the identified drawbacks. The outcomes of this study contribute to developing practical solutions for constriction cost management, and also represent conceptual gains in the field.

DECLARATION

This thesis is submitted under the University of Salford regulation for the award of a PhD degree by research. Some findings during the research together with details associated with the research process itself have been published in conference proceedings prior to this submission and are detailed in page vi. The work presented was carried out under the supervision of Professor Lauri Koskela, within the School of the Built Environment, University of Salford. Unless otherwise stated in the text, I here declare that the work presented in this thesis was the result of my own work. There is no portion of the work covered in this thesis that has been submitted in support of any application for other degree or qualification at this or other institutions of higher learning.

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Mahanim Hanid
December 2013

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LIST OF ABBREVIATION

ABC	Activity-based Costing
BC	Before Christ
BER	Bureau for Economic Eesearch
CME	Construction Management and Economics
CPA	Certified Public Accounting
DSR	Design Science Research
ICT	Information and Communications Technology
IT	Information Technology
KB	Knowledge Base
LCC	Life Cycle Costing
POC	Point of Cause
QS	Quantity Surveyor
R&D	Research and Development
TQM	Total Quality Management

CHAPTER 1. INTRODUCTION

1.1 Introduction to the chapter

This chapter discusses the background of the research and the issues which led to its initiation and justifies the importance of it. Furthermore, it discusses the research aim and objectives, the research methodology and outlines the scope of the research. Lastly, this chapter presents the skeleton of the thesis by briefly explaining the content in each chapter.

1.2 Research Background

Construction industry can be generally said to be an agent in stimulating the economic activity of a country (Gruneberg, 1997). The output from construction industry can be seen as a series of investments, since the decision to build a project comes along with an expectation to receive future benefits many years ahead (Gruneberg, 1997). Furthermore, the nature of a construction project requires a large quantity and variety of resources demanding huge amounts of money to be spent.

Therefore, the decision to build is a big decision to be made so that the investor would not suffer losses in the future from the current investment. Cost is an influencing factor to be considered in making the decision, and cost management will act as a basis of information in giving guidance to the investor. The efficiency and the effectiveness with which costs are managed in construction projects will affect a good value for money and would help to determine benefits for many years ahead. The decision should be based on the exercise of cost management that covers all the activities involved throughout the project stages, i.e. from conception until maintenance phase.

Based on available definitions by Soanes and Stevenson (2008), Kirkham (2007), Seeley, (1983), Agrawal et al. (1998), Anthony (1989), Brinker (1996), Maskell (2009), Tanaka et al. (1993), Ashworth and Hogg (2007) and Kelly and Male (1993), cost management can generally be defined as a set of techniques and methods for controlling and improving company's activities and processes, its products and services to achieve cost effectiveness (cost reduction, value improvement and substitution). This is done by collecting, analyzing, evaluating and reporting the cost information in the budgeting, estimating, forecasting and monitoring of costs in order to assist in initiating and making decisions.

Since the seminal contribution by Kaplan and Johnson (1987), the literature indicates extensive discussions highlighting the need for improvements in cost management. Indeed, several researchers (Elfving et al., 2005, Flyvbjerg, 2008) call for the introduction of alternative theoretical approaches to manage cost but there does not seem to be much progress in this regard.

In the Western countries' construction industry, project management has been concerned with the unpredictability of construction costs as design seems to have become more and more complex (Pennanen et al., 2010). Construction projects create by nature one-of-a-kind prototype products and mistakes and rework are almost unavoidable. It is well known that at the beginning of a project, the physical look of a building or product as a physical object cannot be determined. These are few examples of past projects that have suffered from big differences of amount between the estimation and the final price:

- It has being reported that 88 projects analysed from one quantity surveying firm in Singapore have a difference between estimates and contract sums ranged from over-estimates of 33.7% to under-estimates of 31.30% (Cheong, 1991).
- The Scottish Parliament - the estimated price was at £270 million and it ended up with a final cost of £451 million (Clark, 2003).
- Sydney Opera House - the estimated price was at £3.5 million ($7 million) and it ended up with a final cost of 14 times more than the estimated cost (Clark, 2003).

The above mentioned situations have prompted the researcher to further investigate the root cause of the problems in construction cost management. As revealed by the literature described by Voordijk (2009), the research in this area is very fragmented, and separate topics of research have been studied. The problem with fragmentation is that it does create the absence or the under-development of connections to the remaining subject area and also generates huge difficulties for ensuring the right topics to focus into in a research. Therefore, the real problem may not be detected because research has focused on wrong categories of problems and has produced irrelevant results as solutions.

The researcher believes that these multiple and separate topics have also led to a situation that many studies in construction cost management have isolated the problem from the whole construction process when trying to find the solution to the problems being researched. The research conducted has only focused on the area selected without connecting it to the whole construction process. There is no integration being made between these problems and the whole process of construction and therefore the relevance of the solutions recommended has not been proven. One of the example that can be referred to is research on accuracy in estimating, which has been carried out since 1982 (Ashworth and Skitmore, 1982). Thus, although in this field of research, a large number of different topics have been studied, the research hardly recognized as an excellent achievement.

Furthermore, with this kind of character, construction management and economics knowledge is claimed by Nowotny et al. (2003) to be parallel with the characteristic of Mode 2 knowledge production. With this kind of characteristic, the ultimate objective of construction management and economics knowledge production is to advance design solutions for complex and relevant field problems in the specific context of the design, production and operation of the built environment (Voordijk, 2009), instead of being an explanatory science that only develops knowledge by describing, explaining and possibly predicting (Aken, 2005). Therefore, Design Science Research is introduced in this research study as the philosophical approach because of the objective of Mode 2 knowledge production is similar to the objective of DSR.

1.3 Research Aim

The aim of this research is to develop solutions to improve construction cost management as a response to the shortcomings in the current approaches.

1.4 Research Objectives

This aim is supported by the following objectives:

1. To understand the evolution of and to identify the shortcomings (key issues) in cost management.
2. To analyse the root causes of the key issues in construction cost management.
3. To develop conceptual solutions for improved cost management.

1.5 Scope of Research

This study covers cost management within the whole process of construction, i.e. starting from inception stage until maintenance period. This selection is corresponding to the theory of production that includes transformation, flow and value and correlated with the whole process of construction from the beginning until the end (Koskela, 2000). This research focuses on conceptual rather than detail solutions. In so doing, the conceptual aspects of the studied domain are emphasized, and the big picture is dealt with rather than point-wise issues.

1.6 Research Methodology

Design science research (DSR) approach is chosen in this research for discovering and identifying opportunities and problems relevant to construction industry and for directly inventing or creating new or

improved conceptual means to address those problems. This research has chosen DSR as the philosophical approach because of the following reasons:

- Currently, much of the academic research in construction management and economics is based on the approach of descriptive knowledge (explanatory science) (Voordijk, 2009), which is theory-driven, with a core mission to develop valid knowledge by understanding the natural or social world, or more specifically - describing, explaining and possibly predicting and producing shared understanding (Aken, 2005).

- DSR, which is centred towards practical problem solving, includes prescriptive or solution-oriented knowledge where the result from scientific justification (predicting, understanding or explaining phenomena) can be used in designing solutions to complex and relevant field problems. It is rather field-problem driven and solution-oriented with a core mission to develop knowledge that can be used by professionals in the field in question to design solutions to their field problem by describing and analysing alternative courses of action in dealing with field problems.

There are many different models of DSR available and the researcher is in the opinion that the research process in those models can be summarised into three (3) major steps. There are many research techniques that have been used throughout the research process for achieving the research objectives as shown in Table 1. Figure 1 and Figure 2 also show the relationship among the research process, research techniques, research objectives and the chapters in this thesis. There are three major process involved in DSR, which are explained in the following paragraph.

1.6.1 Establishing Awareness of the Problem

The research study started with a critical literature review in order to establish an in-depth understanding of the landscape of the cost management. The current activities in construction cost management were also reviewed thoroughly to get the actual landscape of construction cost management to date in order to establish actual problems in the field. A workshop was also organized to present the literature review findings and to get the latest information regarding construction cost management from academics with different disciplinary backgrounds but focusing on construction cost management. Active discussions took place and it contributed to the developing the understanding of the current status of construction cost management.

Table 1: The relationship between research process and research techniques used in DSR

Research Process	Research Techniques	Research Objectives
Establishing awareness of the problem	1. Literature review 2. Workshop 3. Exploratory Interview 4. In-depth interview	**Research Objective 1** To understand the evolution of and to identify the shortcomings (key issues) in cost management.
Design Science Evaluation	Toyota's practical problem-solving process	**Research Objective 2** To analyse the root causes of the key issues in construction cost management. **Research Objective 3** To develop conceptual solutions for improved cost management.
Evaluation	Identifying a practical existing solution	**Research Objective 2** To analyse the root causes of the key issues in construction cost management. **Research Objective 3** To develop conceptual solutions for improved cost management.

Exploratory interviews and in-depth interviews were also conducted to look at a range of similar and contrasting opinions from different people with a different interest. This is to strengthen the precision, the validity and the stability of the findings. Exploratory interviews were first conducted before in-depth interviews and the objective was to critically review the initial list of predetermined key issues in construction cost management, to clarify any problem that had not been clearly defined and identify any other key issues which could be investigated and addresses when developing the solution. Next, in-depth interviews were conducted for looking into the perspectives or opinions from another different group of professionals which is practising traditional cost management on the key issues of cost management in construction industry.

1.6.2 Design Science Evaluation

This is the stage where the development of conceptual solutions took place. To develop the conceptual solutions, the root cause from those seven key issues needs to be identified. The problem solving process used in the Toyota Production System and the 5-Why Analysis was used to achieve this. The dominant idea is that when starting from the problem situation, there needs to be a multi-level analysis towards the root cause of the problem, and then the countermeasure should be focused on eliminating this root cause rather than any superficial cause. To proceed from explanation of a problem to the countermeasure, it is suggested that this is roughly similar to an abductive inference, which is leading to a hypothetical solution at the conceptual level. Thus, the target of this research has been found.

1.6.3 The Evaluation of Conceptual Solutions

At this stage, the conceptual solution is evaluated. In normal DSR, one would build a solution through synthesis and try it out in practice. However, in this research study, it is sufficient to point out existing practical (that is they are clearly working in practice) solutions that are compatible with the conceptual solution. The conceptual solution is evaluated through them.

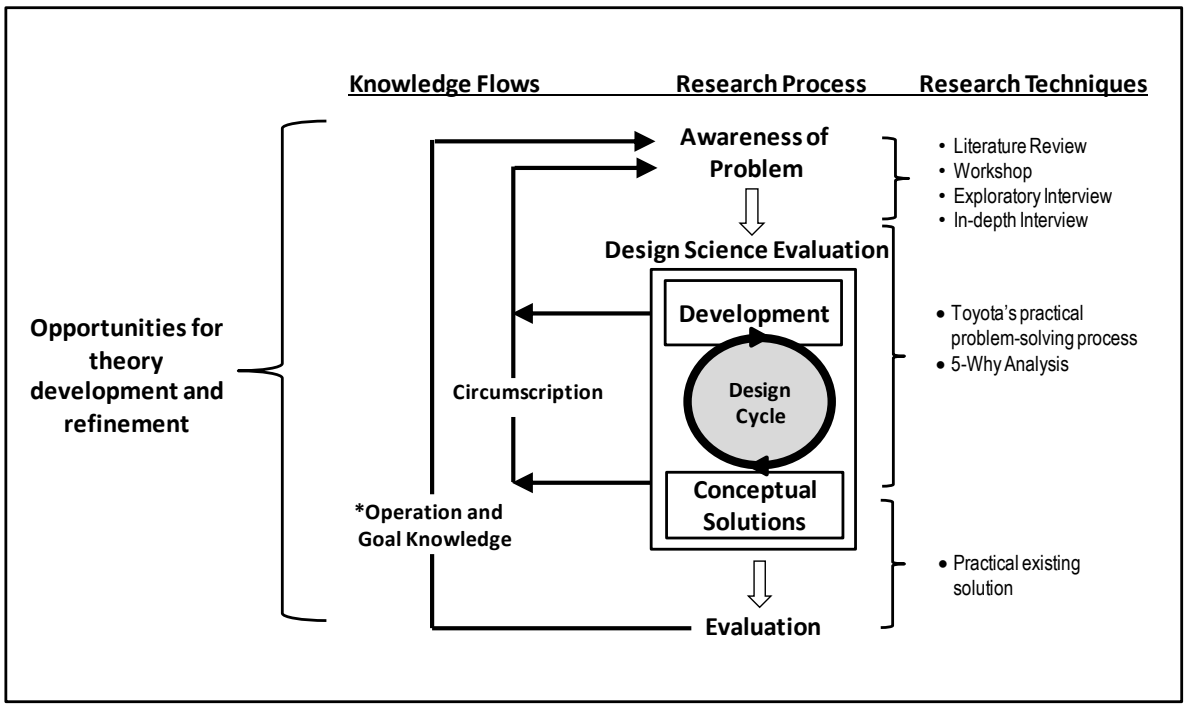


Figure 1: The relationship between research process and research techniques

1.7 Structure of this Thesis

The chapters of this thesis are arranged based on the research process in this research study. It can be is summarised as in Figure 2 and Figure 3. The summary of the chapters following this Chapter 1 is presented as follows:

Chapter 2 - Research Strategy

This chapter describes Design Science Research (DSR) which is the research paradigm used for this study. It also examines different research process in DSR for choosing the suitable one in order to discover the key problems to the research area and to establish its link to the theoretical explanation. A detailed explanation on the improved research process that is tailored to this study is presented.

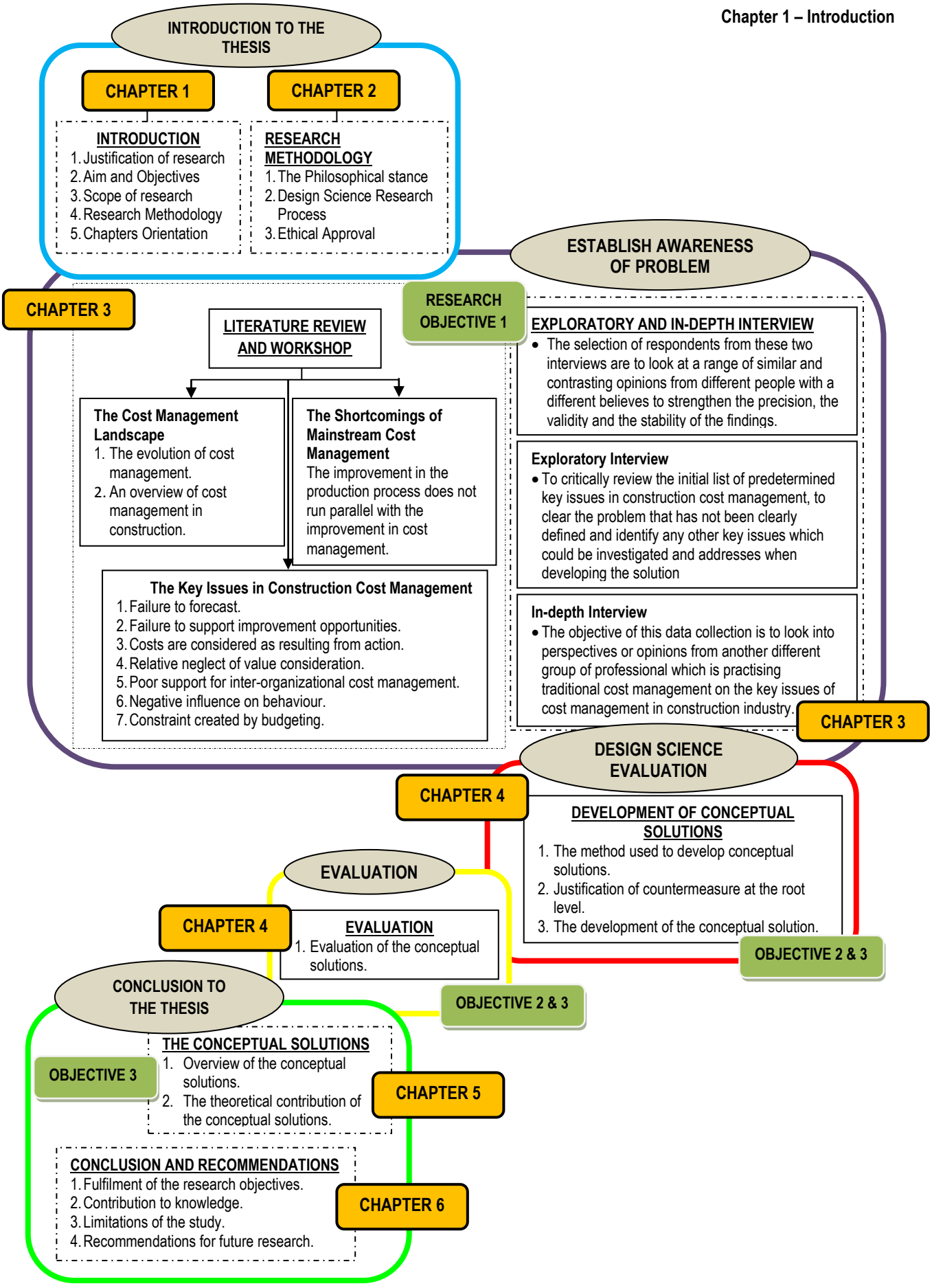


Figure 2: The relationship between research process and research objectives and research chapters

Chapter 3 - Establishing Awareness of the Problem

This chapter introduces a practical problem that has research potential, and is important and unique as revealed through literature searches and workshop. It reviews the extant literature concerning the landscape of cost management and construction cost management by investigating the evolution of cost management in general and specifically in relation to the construction industry. This is an attempt to categorise the information gathered that will then be developed through anomaly detection concept for the formulation of the hypothesised key issues. It identifies and discusses the provisional key issues in construction cost management, which are the fundamental discoveries based on the literature review and workshop. The findings from two types of interview, i.e. exploratory interview and in-depth interview are also presented in this chapter. The objective of the exploratory interview is to critically review the initial list of predetermined key issues in construction cost management, to clarify any problem that has not been clearly defined and identify any other key issues which could be investigated and addresses when developing the solution. Whereas, the objective of the in-depth interview is to look into perspectives or opinions from another different group of professional which is practising traditional cost management on the key issues of cost management in construction industry. The selection of respondents from these two interviews are to look at a range of similar and contrasting opinions from different people with a different believes to strengthen the precision, the validity and the stability of the findings. The findings are also used to identify any other causes which could be investigated and addresses, test and refine one or more aspects of a final study during the preparation of the conceptual solutions.

Chapter 4 – Design Science Evaluation

This chapter demonstrates how the development and evaluation of the conceptual solutions took place. It presents the solution which is an innovation to construction solution for solving a domain problem identified. The key issues identified earlier have been analysed to the root cause and followed with an inference of countermeasure to each of root cause (conceptual solution) and synthesis of the (practical) solutions.

Chapter 5 - The Conceptual Solutions

This chapter presents the summary of this research which includes an overview of the conceptual solutions that followed with a discussion concerning the theoretical contribution of the research findings. It comes from a holistic perspective by presenting the main findings and outcomes of this research study.

Chapter 6 - Conclusion

This chapter is the conclusion of this research study and it started with an explanation of the fulfilment of the three research objectives. Next, the contributions to knowledge are articulated, as well as limitations and constraints of this research, along with recommendations for further research.

Appendices

A body of separate supplementary material that is collected and appended at the end of the thesis that is to clarify or to give further details.

Bibliography

A list of the sources used as references in this research which includes book, conference papers and journal papers used in this research study. It is to give credit to other authors whose works that have been consulted in this research and to make it easy for a curious reader to make further readings in the sources being used in this research study.

1.8 Summary

This chapter presents the outline of this study by understanding its context, and key issues which led to the initiation of this research. It included the research aim, research objectives and brief explanation on the research strategy being chosen to conduct the research. Following from this, the next chapter will critically review and discuss the literature that is concerned with the research methodology for this study.

INTRODUCTION	ESTABLISH AWARENESS OF PROBLEM	DESIGN SCIENCE EVALUATION	CONCLUSION
Chapter 1 - Introduction to the Research Study	Chapter 3 - Establish Awareness of Problem	Chapter 4 – Development and Evaluation of Conceptual Solutions	Chapter 5 – The Conceptual Solutions
Chapter 2 - Research Strategy			Chapter 6 – Conclusions and Recommendations

Figure 3: The structure of the thesis

2 THE RESEARCH METHODOLOGY

2.1 Introduction to the chapter

This chapter describes in detail Design Science Research (DSR), which is the research paradigm used for this study. The chapter also examines different research processes available in DSR for choosing the suitable one in order to discover and eliminate or reduce the practical and technological problem relevance to the research area and to establish its link to the theoretical explanation. The design activities that have been described as the bringing-to-be of the conceptual solution which interfaces in a desired manner with its environment are also being discussed here. In summary, the discussion will be as follows:

- First, the reason of choosing DSR and a general explanation on DSR is presented.
- Second, comparisons of different DSR models are discussed.
- Third, an explanation on the design cycle involved in DSR is presented.
- Finally, a detailed explanation of every step of the research used in this study is presented.

2.2 The Philosophical Grounding of Design Science Research (DSR)

The process of knowledge creation started with a substantive field of inquiry, which is called philosophy. Philosophy is primarily concerned with rigorously establishing, regulating, and improving the methods of knowledge creation in all fields of intellectual endeavour (Partington, 2002). In philosophical inquiry, the facts, the theory, the alternatives and the ideals are brought together and weighed against each other in creation of knowledge and legitimize knowledge. Philosophical thinking propagates around the four principles of metaphysics, logic, epistemology, and ethics (Annas, 2000, Partington, 2002)

Through this thinking, knowledge is created by cutting, classifying, differentiating, naming, labelling, drawing out and constructing social reality from an initially undifferentiated flux of interactions and sense impressions. These isolated parts of social reality are then identified, labelled and causally linked to other parts of won experiences in order to form a coherent system of explanation (Partington, 2002) through the process of selective abstraction, identification and recombination. Next, the knowledge needs to be validated in order to be accepted and to bind it into a community (Peirce, 1960) and it has to be relevant too (Aken, 2005). New knowledge can only confirm or falsify an existing theory because theory can never be proved to be true (Fellows and Liu, 2009).

There are many varieties of philosophical approaches for "ways of knowing", which have commonly been divided into positivism, interpretivism, realism, critical theory, hermeneutics and phenomenology. Usually, the selection of research strategy and the methods for research activities depends on the research philosophical stances (Saunders et al., 2009). Unfortunately, such divisions did not distinguish another research paradigm that is centered toward practical problem solving which is Design Science Research (DSR).

This research study has selected DSR as the philosophical approach based on the characteristic of construction management and economics, i.e. Mode 2 knowledge production, which is explained in detail in the following paragraph. A comparison between two common philosophical approaches with DSR is tabulated in Table 2 to illustrate the difference in the way DSR views the world.

Table 2: Philosophical Assumptions of Three Research Perspectives

(Vaishnavi and Kuechler, 2007)

Research Philosophy			
Basic Belief	***Positivist***	***Interpretivist***	***DSR***
Ontology	A single reality Knowable, Probabilistic	Multiple realities, socially constructed	Multiple, contextually situated alternative world-states Socio-technologically enabled
Epistemology	Objective; dispassionate, Detached observer of truth	Subjective (i.e., values and knowledge emerge from the researcher-participant interaction)	Knowing through making: objectively constrained construction within a context Iterative circumscription reveals meaning
Axiology: what is value	Truth: universal and beautiful; prediction	Understanding: situated and description	Control; creation; progress (i.e., improvement); understanding

In the research field of construction management and economics (CME), a large number of different topics are being studied and therefore the output of the research consists of contributions from different scientific disciplines, resulting in a multidisciplinary characteristic of construction management and economics knowledge (Voordijk, 2009). This is parallel with the characteristic of Mode 2 knowledge production (Nowotny et al., 2003) which is multidisciplinary and aims at solving complex and relevant field problems. With this kind of characteristic, the ultimate objective of construction management and economics knowledge is to advance design solutions for complex and relevant field problems in the specific context of the design, production and operation of the built environment (Voordijk, 2009), instead of being an explanatory science that only develops knowledge by describing, explaining and possibly predicting (Aken, 2005).

Currently, much of the academic research in construction management and economics is based on the approach of descriptive knowledge (explanatory science) (Voordijk, 2009), which is theory-driven, with

a core mission to develop valid knowledge by understanding the natural or social world, or more specifically - describing, explaining and possibly predicting and producing shared understanding (Aken, 2005). Whereas, being characterized as a Mode 2 (design mode) knowledge production, the epistemological characteristics (context of application, trans-disciplinary, diversity of the sites, highly reflexive and quality control (Nowotny et al., 2003)) of construction management and economics research are less clearly compatible with explanatory science (Voordijk, 2009).

Therefore, construction management and economics may be improved if it would also include prescriptive or solution-oriented knowledge where the result from scientific justification (predicting, understanding or explaining phenomena) can be used in designing solutions to complex and relevant field problems. The development of prescriptive knowledge is rather field-problem driven and solution-oriented with a core mission to develop knowledge that can be used by professionals in the field in question to design solutions to their field problem by describing and analysing alternative courses of action in dealing with field problems.

With this type of characteristic and the problem on how to tackle the issue of methodological underpinnings of CME (Voordijk, 2009, Runeson, 1997, Seymour et al., 1998, Rooke et al., 1997), which have been debated in academic publications recently, DSR is suggested to bridge the gap. Considering that construction cost management as one of the components of construction management and economics, the argument for the DSR paradigm is relevant also for its research activities.

This is also supported by a quote from Simon (1996), who argues that design sciences can be relevant for research in organization and management because

> *Everyone designs who devises courses of action aimed at changing existing situations into preferred ones. The intellectual activity that produces material artefacts is no different fundamentally from the one that prescribes remedies for a sick patient or the one that devises a new sales plan for a company or a social welfare policy for a new state.*

Furthermore, by looking into the history of DSR, it turns out that it has some of its roots in management accounting and a closely related (Piirainen and Gonzalez, 2013) research method called “constructive research” since 20 years ago (Kasanen et al., 1993). Until now, constructive research and DSR have been widely used and provide an established approach in the area of management accounting. Considering that the practice of construction cost management in every construction project are similar with accounting practice (art of organizing, maintaining, recording and analysing financial activities), DSR can be considered relevant as a research methodology.

After reading different reference books on research methodology, it is realised that there is no one best way for undertaking research project. The important thing is that the researcher needs to be aware of the choices made and how these choices will impact upon what can be found out later. This means that the researcher will be able to make an informed choice about the strategies, approaches and methods that are most suitable to the research project and be able to justify the choices. As for this study, DSR has been chosen as the philosophical approach for discovering and identifying opportunities and problems relevant to cost management in construction industry and directly inventing or creating new or improved conceptual means to address those problems and thus to establish a link to the theoretical explanation at the end of the process. The inspiration to choose DSR as the philosophical approach is based on discussions in the following paragraphs.

2.3 An Introduction to Design Science Research

Research is defined as the systematic investigation into and study of materials and sources in order to establish facts and reach new conclusions (Soanes and Stevenson, 2008). Three characteristics of research are listed below (Walliman, 2009):

- Gaining experience is an uncontrolled and haphazard activity, while research is systematic and controlled.
- Reasoning can operate in an abstract world, divorced from reality, while research is empirical and turns to experience and the world around us for validation.
- Unlike experience and reason, research aims to be self-correcting. The process of research involves rigorously testing the results obtained, and methods and results are open to public scrutiny and criticism.

DSR is a research procedure for producing innovative construction intended to solve problems faced in the real world and, by that means, to make a contribution to the theory of the discipline in which it is applied (Lukka, 2003). In addition, March and Smith (1995) looked at it as a way that seeks to explore new solution alternatives to solve problems, to explain this exploratory process and to improve the problem-solving process and serve human purposes. Saunders et al. (2009) explained that from the design science perspective, the main purpose of academic management research is to develop valid knowledge to support organisational problem solving in the field. That support can be direct, instrumental or more indirect – giving general enlightenment on the type of problem at hand. Basically, the mission of DSR is to develop scientific knowledge to support the design of interventions or artefacts by professionals and to emphasise its knowledge-orientation. A design-science is not concerned with

action itself, but with knowledge to be used in designing solutions, to be followed by design-based action (Aken, 2004).

The first important characteristic of DSR is that it is motivated by problem-solving and the second distinguishing characteristic is the prescriptive nature of the outcome of a research program. Based on Lukka (2003), the constructive research approach:

1. Focuses on real-world problems felt relevant to be solved in practice
2. Produces an innovative construction meant to solve the initial real-world problem
3. Includes an attempt for implementing the developed construction and thereby a test for its practical applicability
4. Implies a very close involvement and co-operation between the researcher and practitioners in a team-like manner, in which experiential learning is expected to take place
5. Is explicitly linked to prior theoretical knowledge, and
6. Pays particular attention to reflecting the empirical findings back to theory.

The distinction between "natural science" and "science of the artificial" (also known as design science) is clearly stated by Simon (1996) as follows:

A natural science is a body of knowledge about some class of things – objects or phenomena – in the world (nature or society) that describes and explains how they behave and interact with each other. A science of the artificial, on the other hand, is a body of knowledge about artificial (man-made) objects and phenomena designed to meet certain desired goals.

As such, it can be said that knowledge created by natural scientists give opportunity to design scientists to exploit in their attempts to develop technology and provides substantive tests of the claims of natural science research (March and Smith, 1995). Mathematical algorithms, new mathematical entities, technical sciences, computer science and clinical medicine provide a few of theoretical examples of research in DSR (Lukka, 2003, Kasanen et al., 1993).

There are many excellent models of the research process of DSR (Jarvinen, 2004, Lukka, 2003, Peffers et al., 2007, Kasanen et al., 1993, March and Smith, 1995, Vaishnavi and Kuechler, 2007, Hevner, 2007) being reported in high impact journals. A comparison of research steps among those models is shown in Table 3. Based on Table 3, it can be argued that the core process involved in DSR

are 1) establishing awareness of problem – as highlighted in blue colour; 2) DSR (development of the artefacts and evaluation) – as highlighted in green colour; and 3) theory building – as highlighted in purple colour. Therefore, a detail discussion on these three steps is explained in the following section.

Table 3: A Comparison of DSR Steps According to Literature

(Source: adapted from Rocha et al.(2012))

(Note: 1. Establishing Awareness of Problem- blue colour; 2.Design Science Evaluation–green; 3. Theory Building-purple)

Lukka (2003)	March and Smith (1995)	Kasanen et al (1993)	Vaishnavi and Kuechler (2007)	Hevner (2007)
Find a practically relevant problem with potential for theoretical contribution		Find a problem with practical relevance and that also has research potential	Awareness of the problem	Problem and opportunities
Assess the likelihood for long-standing research collaboration with the target organisations				
Obtain an understanding of the problem from a practical and theoretical perspective		Obtain an understanding of the topic		
Innovate a solution idea and develop a solution that solves the problem at hand	Create things that serve human purposes	Innovate, namely construct a solution	Suggestion of a tentative design	Build, design artefacts and processes
			Further development of the tentative design and implementation	
Implement the solution and test how it works	Evaluate the performance of things in use	Demonstrate that the solution works	Evaluation of the design against previously defined criteria	Evaluate
Identify and analyse its theoretical contribution		Present its connection to theory and the research contribution	Conclusion	Additions to knowledge base
		Assess the scope of application of the solution		

2.3.1 Establish Awareness on the Problem

This kind of research study begins by identifying and representing opportunities and practical problems in an actual application environment. It starts by looking into the process involved in The Realm of Inquiry. A study on the existing knowledge, under the direction of theory, is being carried out to generate proposals or hypothesised solutions. The information included in here is the contextual background of the research, where existing theories are housed and which acts as a precursor to the research process. Theory use at this stage is to formulate a hypothesis of a kind of approach to reduce the identified problem (Venable, 2006) and also to understand and address the problem(s), i.e. the requirements for the research. *Relevance cycle* is engaged between theory use and building process,

where formulation of a new knowledge (hypothesised solution) that needs to be tested, correlates to abductive reasoning. Formulation of a prototype to the solution invention represents the researcher's understanding of the problem(s), which corresponds to the business needs.

This stage is also known as problem investigation where information about the problem is being asked and understood without yet changing it. The objectives of this stage are to describe the problem, to explain it, and possibly to predict what would happen if nothing is done about it (Wieringa, 2009). There are four categories of how problem is investigated and each of these leads to different emphases in the problem investigation process (Wieringa, 2009):

- Problem-driven investigation – stakeholders experience problems that need to be diagnosed before solving them. Important tasks in problem-driven investigation are describing problematic phenomena, formulating and testing hypothesis about their causes and identifying priorities for problems to be solved.

- Goal-driven investigation – considers a situation in which there are may be no problem experienced but where there are nevertheless reasons to change the world in agreement with some goals. Important tasks in all cases of solution-driven problem investigation are describing stakeholder goals, defining and operationalising them, and identifying priorities of goals.

- Solution-driven investigation – technology is in search of problems that can be solved with it. Problem investigation in this case consists of making an inventory of goals and of current technology, and in identifying functionality and performance requirements for new technology.

- Impact-driven investigation – also called evaluation research, which focuses on the outcome of past actions rather than preparing for the design of future solutions. Important tasks in evaluation research are describing solutions implemented earlier, identifying their impacts and explaining these impacts in terms of properties of the implemented solutions, identifying relevant stakeholder goals, translating these into criteria and applying these to the impacts.

As for this study, it falls under the category of problem-driven investigation, which starts with identifying the problems within the research area.

This section also provides information for evaluating the solution invention by defining the acceptance criteria for the ultimate evaluation of the research results (Hevner, 2007), which includes the following information:

- Past experiences and expertise that define the state-of-the-art in the application domain (consist of the people, organisational systems, and technical systems) of the research,
- The existing artefacts and processes found in the application area
- Design and evaluation theories and methods

The information in here is also used to help in justifying the theory building because the results of the evaluation need to be fed back to the theory building activity for confirming and disconfirming existing theories. This involves the *rigor cycle*. Where results disconfirm existing theories, new or extended theories may be put in their place. If new organisational benefits or undesirable organisational or societal impacts are found, new theories may be put forward. It is desirable that such new theories should be integrated with existing theories (Venable, 2006). The solution is always related to and contrasted with the existing approaches (Venable, 2006).

2.3.2 Design Science Evaluation

DSR involves the process of building the artefact as the solution to or alleviating the practical problems, evaluating the artefact and subsequent feedback to refine the design further. This cycle can be described as generating design alternatives and evaluating the alternatives against requirements until a satisfactory design is achieved (Simon, 1996, Venable, 2006). The core idea of the hypothesised solution invention is thought out and fleshed out in detail here (Venable, 2006). The activities may involve development of notations for diagrams, description of steps, stages and others. Once built, the solution invention is still hypothesised until it is evaluated. The development of a solution may be just a small refinement (s) of an existing solution or it may be the invention of a wholly new and complex solution (Venable, 2006).

To build the research product, inputs for requirements and defining acceptance criteria for the ultimate evaluation of the research results (Hevner, 2007) are taken from Theory Use process explained in Section 2.3.1 where r*elevance cycle* is involved. Next, the hypothesised solution (research product) will go through the *design cycle*, where the evaluation process on the produced solution is taking place. To evaluate this solution, the information that has been described in Section 2.3.1 is used again and multiple iterations of *design cycle* are engaged. The iteration process will depend on the feedback from the environment, from field testing and might also be a restatement of the research requirements as discovered from actual experience (Hevner, 2007). This process acts as a feedback to refine the design further and will be passed back to the building process for improvement. This cycle will stop

until satisfactory design is achieved. This shows that *design cycle* is dependent on *relevance cycle* and *rigor cycle*.

2.3.3 Theory Building

In DSR, the research object is a *'mutandum'* (Agrawal et al., 1998), where one is more interested in what can be. Based on Bunge (1967), philosophy of technology, the typical research product can be called technological rule. Technological rule can be defined as 'an instruction to perform a finite number of acts in a given order and with a given aim (Bunge, 1967). It is also defined as a chunk of general knowledge, linking an intervention or artefact with a desired outcome or performance in a certain field of application (Aken, 2004). A tested technological rule is one whose effectiveness has been systematically tested within the context of its intended use (Aken, 2004).

In the evaluation of the performance of a Solution, is important to determine why and how the solution works or does not work within its environment. Such research applies natural science methods to theorizing and justifying and building and evaluating the artefacts that have the design science intent (March and Smith, 1995). Theories explicate the characteristics of the artefact and its interaction with the environment that result in the observed performance. This requires an understanding of the natural laws governing the artefact and those governing the environment in which it operates. Furthermore, the interaction of the artefact with its environment may lead to theorizing about the internal workings of the artefact itself or about the environment. In the following, the four deliverables of the design science research output (March and Smith, 1995) are presented:

i. Constructs/Concepts – form the vocabulary of a domain. They constitute a *conceptualization* used to describe problems within the domain and to specify their solutions. Conceptualizations define the terms used when describing and thinking about tasks. They can extremely valuable to designers and researchers.
ii. A model is a set of propositions or statements expressing relationships among constructs. In DSR, models represent situations as problem and solution statements. A model can be viewed simply as a description, that is, as a representation of how things are. Natural scientists often use the term model as a synonym for theory, or propose models as weak or incipient theories, in that they propose that phenomena be understood in terms of certain concepts and relationships among them. In DSR or IT framework, the concern of models is utility, not truth (in natural science, theories is concern on truth). Such a model is a solution component to an information requirements determination task and a problem definition component to an information system design task – The Entity-Relationship Model, for example.

iii. Methods – is a set of steps (an algorithm or guideline) used to perform a task. Methods are based on a set of underlying constructs (language) and a representation (model) of the solution space. Although they may not be explicitly articulated, representations of tasks and results are intrinsic to methods. Methods can be tied to particular models in that the steps take parts of the model as input. Methods are often used to translate from one model or representation to another in the course of solving a problem. Further, methods are often used to translate from one model or representation to another in the course of solving a problem.

iv. Instantiations – is the realization of an artefact in its environment. Instantiations operationalize constructs, models, and methods. However, an instantiation may actually precede (head/come first) the complete articulation (communication) of its underlying constructs, models, and methods. In IT system, it may be instantiate using intuition and experience. Instantiations demonstrate the feasibility and effectiveness of the models and methods they contain. It can be called "an empirical discipline". It provides working artefacts, the study of which can lead to significant advancements in both design and natural science.

2.4 A Revised Framework for Design Research Activities – Method used in this Research Study

2.4.1 Critical remarks on the common DSR methodology

The methods for carrying out DSR are of recent origin and still under discussion. One critical shortcoming is that the method has not much to say from where the suggestion, or concept, for the solution comes, and how it will be developed towards the practically functioning artefact. Another problem is that the theory connection is presented to occur via the designed and built artefact – isn't there anymore direct way of developing theory through DSR?

For adjusting and expanding this part of the methodology, methods from problem solving, philosophy of science and product development are introduced next.

2.4.2 Additional methods

The problem solving process used in the Toyota Production System is presented in Figure 4. The dominant idea is that when starting from the problem situation, there needs to be a multi-level analysis towards the root cause of the problem, and then the countermeasure should be focused on eliminating this root cause rather than any superficial cause. As shown in Table 4, otherwise there is a great degree of similarity between the generic DSR approach and the Toyota's Practical Problem-solving approach.

However, pinpointing a cause for a phenomenon has equalled explanation since Aristotle (Losee, 2001). Indeed, the method of 5 Why's can also be seen as a procedure for finding a hypothetical causal theory for the thing to be explained.

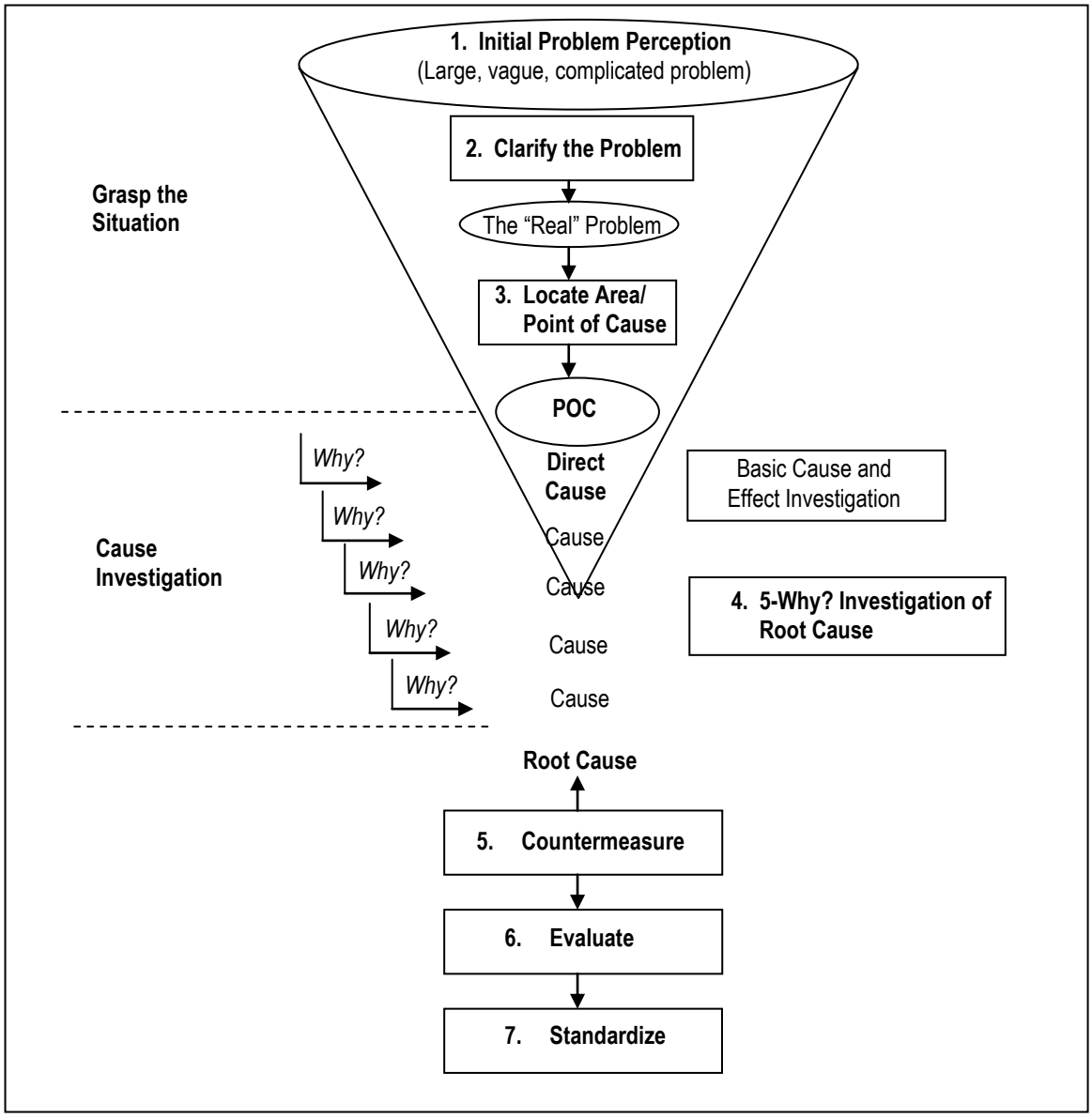


Figure 4:Toyota's Practical Problem-solving Process
(Source: Liker (2004))

Table 4: Similarity between DSR and Toyota's Practical Problem-solving

	DSR	Toyota's practical problem-solving
PROCESS STEPS	Establish awareness of problem	Grasp the situation
	Development	Cause investigation
		Countermeasure
	Evaluation	Evaluate
	Theory Building	Standardize

But how does one proceed in finding causes? The philosopher Peirce (1997) has suggested that a specific reasoning type of abduction is used. For him, abduction is the process of forming an explanatory hypothesis and it is the only logical operation that introduces any new idea. The logical form of abduction is as follows:

The surprising fact, C, is observed

But if A would be true, C would be a matter of course

Hence, there is reason to suspect that A is true.

The connection of problem solving to the philosophy of science can be extended further. The philosopher Laudan (1977) claims that one of the hallmarks of scientific progress is the transformation of anomalous and unsolved empirical problems into solved ones. In an applied science like construction management, this means, not only that an explanation for the problem is found, but also that first conceptual and then embodied, practical solutions are provided.

How does one proceed from explanation of a problem to the countermeasure? The literature contains very little on this, but it is suggested that this is roughly similar to an abductive inference, leading to a hypothetical solution at the conceptual level. Thus, the target of this research has been found.

However, a conceptual solution cannot be accepted without justification through evaluation. In normal DSR, one would build a solution and try it out in practice. However, here, it is sufficient to point out existing practical (that is they are clearly working in practice) solutions that are compatible with the conceptual solution; the conceptual solution is evaluated through them.

But is there any novelty in the conceptual solutions if there already are practical solutions corresponding to them? The practical solutions, not belonging to the mainstream, may be isolated and not necessarily fully developed; an explicit conceptual solution helps in systematically developing more advanced solutions. Also, the conceptual solution provides an explanation to the corresponding practices, needed when diffusing these.

2.4.3 Revised framework

Having referred to a few DSR research process models available in the academic journal, the researcher has chosen to work around the research process proposed by Vaishnavi and Kuechler (2004) as in Figure 5 and Hevner (2007) as in Figure 6: which are well known to most of the researchers, who adopt DSR. A general model that shows how knowledge is being generated and accumulated as in Figure 7: is also being used to produce the revised DSR process. Based on these

two models of research process framework and the process of generating and accumulating knowledge, this research proposes a revised framework as in Figure 8: to address shortcomings and better understanding. The reason for these selections are because the core process concluded based on the comparison done as shown in Table 3 are similar with the model suggested by Vaishnavi and Kuechler (2004) and Hevner (2007).

In this revised framework, the research process is divided into three main activities which include Section 1: Establish Awareness of Problem, Section 2: Design Science Evaluation; and Section: 3: Evaluation. These three sections house different activities, multiple research methods and paradigms. Three design cycles are involved too, i.e. *relevance cycle, design cycle* and *rigor cycle*.

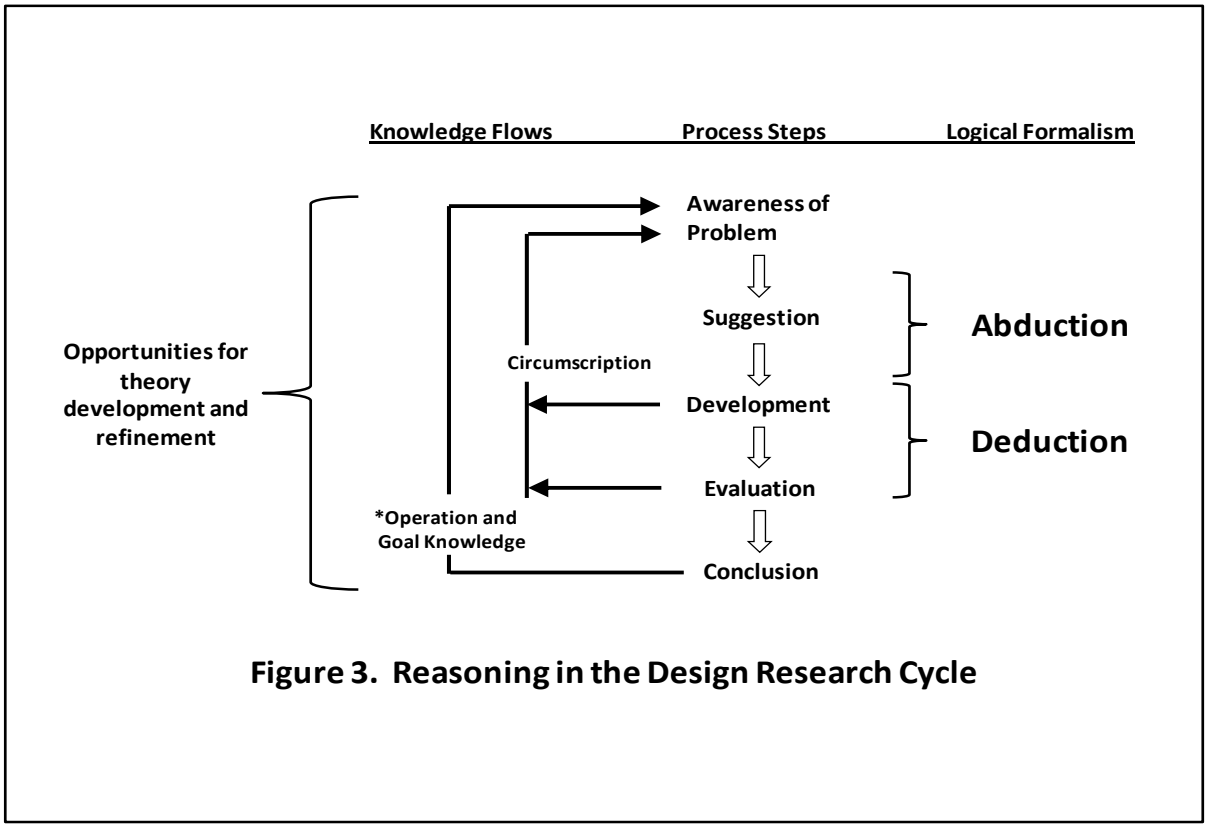


Figure 5: General Methodology of DSR
(Source: Vaishnavi and Kuechler (2007))

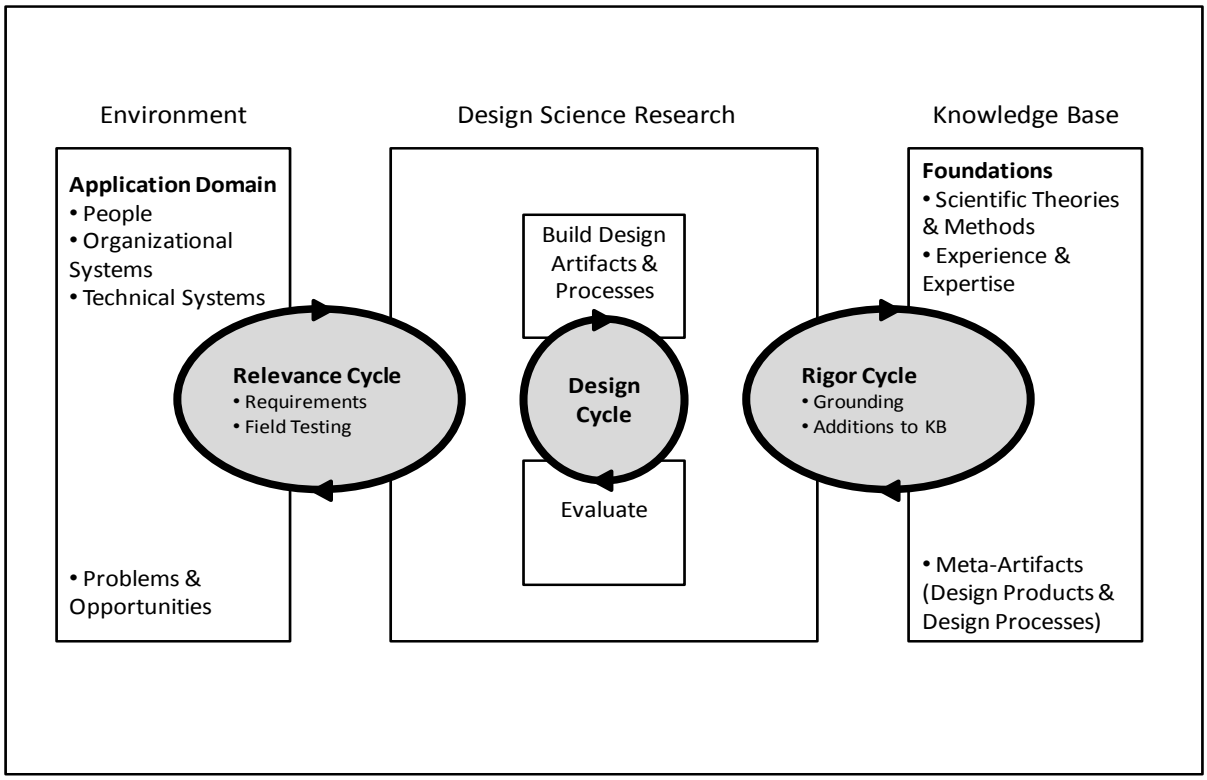


Figure 6: Design Science Research Cycles

(Source: Hevner(2007))

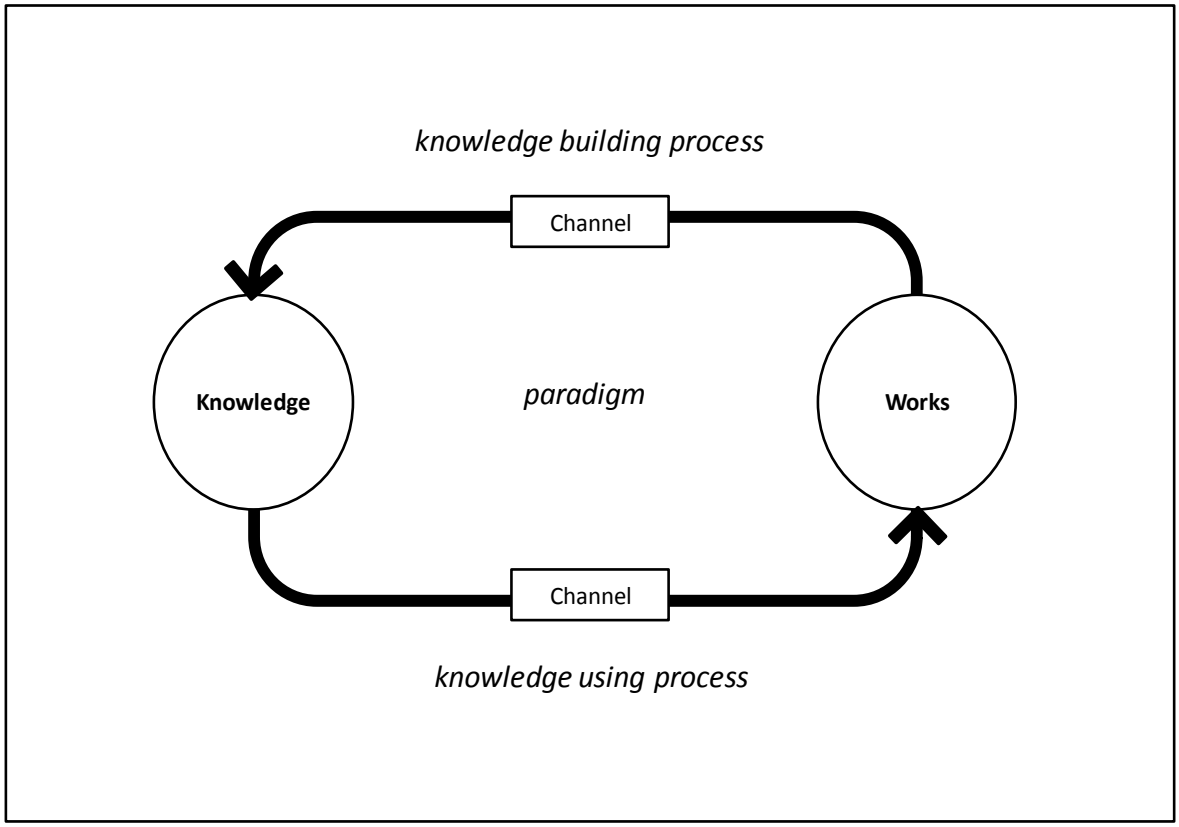


Figure 7: A General Model for Generating and Accumulating Knowledge

(Source: Hevner (2007))

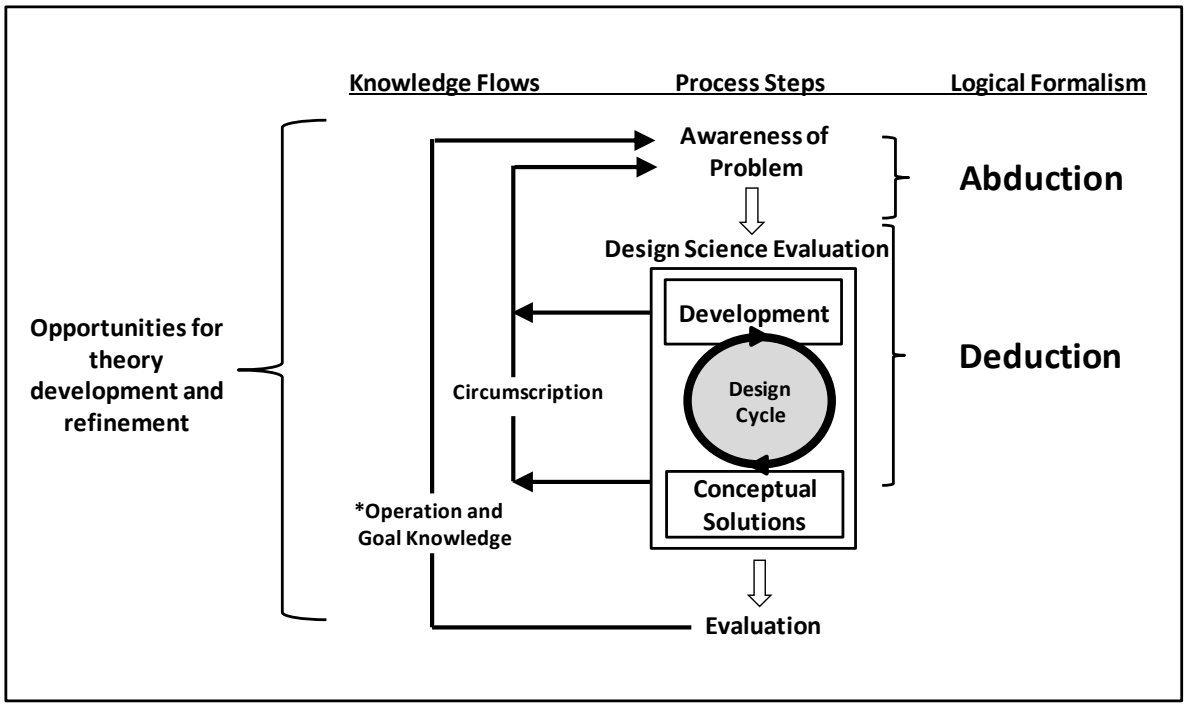


Figure 8: Revised DSR Process

(Source: Adapted from Vaishnavi and Kuechler (2007) and Hevner (2007))

2.4.3.1 Establish Awareness of Problem

Three types of research methods were used in order to establish awareness of the problem in this research study, namely literature review, a workshop and interviews. The following sections described in detail how those methods were carried out.

2.4.3.1.1 Literature Review and Workshop

In order to establish awareness of problem, literature review is carried out at the initial stage of the study to actually achieve at least one of the following purposes (Hart, 1998):

- Distinguishing what has been done from what needs to be done
- Discovering important variables relevant to the topic
- Synthesising and gaining a new perspective
- Identifying relationship between ideas and practice
- Establishing the context of the topic or problem
- Enhancing and acquiring the subject vocabulary

- Understanding the structure of the subject
- Relating ideas and theory to applications
- Identifying the main methodologies and research techniques available.
- Placing the research in a historical context to show familiarity with state-of the-art developments.

Literature review is a process of getting to know what is already known in the research area. It is also a process of engaging in scholarly review based on the researcher reading and understanding of the work of others in the same field. Furthermore, it is also a process of interpreting what have been written and using their ideas to support a particular viewpoint or argument (Bryman, 2008). Below are the purposes of exploring the existing literature:

- To identify what is already known about this area.
- To identify what concepts and theories those are relevant to this area.
- To identify what research methods and research strategies have been employed in studying this area.
- To identify are there any significant controversies.
- To identify are there any inconsistencies in findings relating to this area.
- To identify are there any unanswered research questions in this area.

Next, a workshop was conducted with experts that have different professional background but have the same interest in construction cost management. The title of the workshop is 'Shortcomings of Traditional Cost Management: What Should be Done?' This workshop was carried out to achieve two (2) objectives, i.e. to look at some major issues in cost management along its history and identifying its shortcomings and to propose some solutions in order to overcome the drawbacks in traditional cost management.

There were 5 speakers presenting different topics during the workshop as per listed below:

1. First speaker: Mrs. Mahanim Hanid, Topic: Shortcomings of Traditional Cost Management Overview

2. Second speaker: Professor Farzad Khosrowshahi, Topic: Proactive Cash Flow: Forecasting & Management

3. Third speaker: Mr. Mohan Siriwardena, Topic: Quantity Surveying Approach to Project Management

4. Fourth speaker: Mr. Gerard Wood. Topic: Current Problem of Cost Management for Quantity Surveyor

5. Fifth speaker: Professor Lauri Koskela, Topic: Production Theory As the Basis of Cost Management

20 participants with different background of knowledge participated in this workshop and active discussions were happening on that day. This was to have an insight about what is happening at the current practice in the construction industry.

2.4.3.1.2 Exploratory Interview and In-depth Interview

The following steps were to conduct an exploratory study and in-depth study through interviews. These two types of interview, i.e., exploratory interviews and in-depth interviews were carried out at the beginning of this research study in order to establish awareness of the problems in the research area. In spite of many choices for sources of evidence to this research study, the researcher has picked interview to be used in this research study because interview allows focusing directly on the relevant topics and also provides perceived causal inferences and explanations.

Exploratory interviews were conducted to critically review the initial list of predetermined key issues in construction cost management, to clarify a problem that has not been clearly defined and identify any other key issues which could be investigated and addresses when developing the solution. There were six (6) interviewees selected from a group of professional that involved in the management of cost in a construction company and very actively involved in the implementation of lean construction in construction project. A group of professional in lean construction had been selected because this study has used manufacturing as the analogy and the group of professionals in this area has a goal of improving the cost management that is in line with the aim in manufacturing.

As for in-depth interview exercise, respondents are selected from a group of professionals that are involved in traditional construction as the interviewees. There are three (3) interviewees selected from a group of professionals that is actively involved in the management of cost in a construction project. The objective of this data collection is to look into perspectives or opinions from another different group

of professional which is practising traditional cost management on the key issues of cost management in construction industry.

These two interviews are to look at a range of similar and contrasting opinions from different group of people with different views with the exploratory interview done previously to strengthen the precision, the validity and the stability of the findings. Both interviews were done by gathering views from the experts on the current issues that are facing the construction cost management and on any other areas which could be investigated and addressed when developing the study.

The choice of two different group of respondent is made on conceptual grounds and not on a representative grounds (Miles and Huberman, 1994). The choices arrayed on a continuum that include contrasting group and unique properties of group. Each group has a few properties that share with many others, some properties that shares with some others and some properties that share with no others. This will enable deeper understanding and gives more confidence to the researcher that the emerging theory is generic because the researcher has seen it work out and not work out in predictable ways. This is similar with 'multiple comparisons groups' used in grounded theory work.

The process of data collection and data analysis were involved in this stage and these two processes and the development and verification of propositions are very much an interrelated and interactive set of processes that allow the researcher to recognise important themes, patterns and relationships as data is collected. There are two approaches to data collection and qualitative analysis, i.e. either from a deductive or an inductive perspective. The decision depends on whether one is seeking to use existing theory (theoretical sensitivity) to organise and direct the data analysis towards building up a theory or to start collecting data for exploratory purpose to see which themes or issues to follow up and concentrate on for theory to emerge from the process of data collection and analysis. However, in practice and in this research study, the approach is likely to combine elements of both.

As for this study, initially, the categories and codes which were used to analyse data was cultivated via a comprehensive literature review, i.e. theoretical sensitivity. This is evident in the emerging interpretative and illustrative framework of the seven key issues. These seven key issues were used as the means to start and direct the analysis of the data collected from exploratory interviews and in-depth interviews. Even though a predetermined set of seven key issues were derived from theory, the data gathered in exploratory interviews and in-depth interviews were analysed and examined first to assess which themes emerge from the data. Next, the findings were be compared with the predetermined seven key issues. By implementing this technique, such analytical rigour is taken care of, which does not rely solely on the researcher's interpretation.

2.4.3.1.2.1 Data Collection

Generally, there are two types of interview for collecting data, i.e:

1. Standardised – interviewer-administered questionnaires
2. Non-standardised
    - One to one [face to face, telephone interview and internet and intranet-mediated (electronic interview)]
    - One to many (Group interviews, e.g. focus groups; internet and intranet medicated (electronics) group interviews, e.g. focus groups)

Saunders et al. (2009) reported that interviews can also be categorised into to three (3) types namely, structured interviews, semi-structured interviews and in-depth interviews which is described in detail below based on the information gathered from Saunders et al. (2009) and Creswell (2007). A semi-structured interview has been chosen as the data collection methods for exploratory study and in-depth study.

A. Structured Interviews

Structured interviews use questionnaires based on a predetermined and 'standardised' or identical set of questions and we refer to them as interviewer-administered questionnaires. The interviewer reads out each question and then record the response on a standardized schedule. Usually with pre-coded answers. While there is social interaction between the researcher and the participant, such as during the preliminary explanations that need to be provided, the researcher should read out the questions exactly as written and in the same tone of voice so that no bias is indicated. This type of interview are used to collect quantifiable data and they are also referred to as 'quantitative research interviews'

B. Semi-structured Interviews

For this type of interview, a list of themes and questions need to be prepared earlier by the research before conducting the interview. However, the interview questions may vary from interview to interview. Some questions that might not be relevant in particular interviews will be omitted and additional questions may be required to explore the research question and objectives given the nature of events within particular organizations. The order of questions asked may also be varied depending on the flow of the conversation. The data received from the interviewee will be recorded by audio-recording the conversation or perhaps note taking. This type of interview is also labelled as participant interview,

where the interviewer directs the interview and the interviewee responds to the questions of the researcher (Saunders et al., 2009).

C. In-depth interviews

It is an informal process. These are used to explore in depth a general area of interest. There is no predetermined list of questions to work through in this situation, although one needs to have a clear idea about the aspect or about events, behaviour and beliefs in relation to the topic area. Sometimes it is called 'non-directive'. It is also labelled as the informant interview since it is the interviewee's perceptions that guide the conduct of the interview.

2.4.3.1.2.2 Data Analysis

The type of data collected for this research study is qualitative data which refers to all non-numeric data or data that have not been quantified. Based on Saunders et al (2009), there is no standardised procedure for analysing qualitative data. However, it is still possible to group those data into three main types of processes, i.e. summarising of meanings, categorisation of meanings and structuring of meanings using narrative. These same three processes were also discussed by Miles and Huberman (1994) as the processes of analysing data, which is shown in Table 5. The detail explanations are written in the following sections. For this research study, all of these three processes are used in combination for supporting the interpretation of the data collected. However, they can be also used on their own.

Table 5: Types of Processes for Analysing Qualitative Data.
(Source: Adapted from Saunders et al (2009) and Miles and Huberman (1994))

	Saunders et al (2009)	Miles and Huberman(1994)
TYPES OF PROCESSES	Summarising of meanings	Data reduction
	Categorisation of meanings	Data display
	Structuring of meanings using narrative	Conclusion and verification of summary

It was reported by Bryman (2008) that one of the most notable developments in qualitative research in recent years has been the arrival of computer software that facilitates the analysis of qualitative data. The researcher has also taking the benefit that can be offered by the computer software program by choosing it as an aided tool in qualitative data analysis for this research study. There are numerous computer software applications available in the market in assisting data analysis derived from interview, which include MAZQDA, NUD.IST (commonly known as Nvivo), ALAS.ti, Decision Explorer, Microsoft Visio, and others. As for this study, NVivo will be used as an aid to analyse the interview data as it can

help to organise, explore and speed up the time taken for doing the data analysing of unstructured data. The step-by-step procedure for undertaking the data analysis on the usage of computer software is adapted from a list presented by Miles and Huberman (1994).

Qualitative research, which is only involved with non-numerical data, requires the data to be classified and analysed through the use of conceptualisation. All of the processes and aids involved in this process allow the researcher to interact with the data in order to comprehend them, integrate related data drawn from different transcripts and notes, identify key themes or patterns from them for further exploration, develop and/or test theories based on these apparent patterns or relationships and draw and verify conclusions (Saunders et al., 2009). The process involves using computer software program in analysing the data were tabled out in Table 7 and Table 8. All of the steps are precise procedures to be followed in relation to each of the stages of the general processes of analysing qualitative data mentioned earlier. This precise procedure was then grouped to the three general processes of analysing qualitative data to distinguish the interlinkage between them.

During analysis, the non-standardised and complex nature of the data that have been collected need to be condensed (summarised), grouped (categorised), restructured or identified the relationships between categories as a narrative to support meaningful analysis. This is to understand the meaning behind it towards developing theory from the data (Saunders et al., 2009). The process of analysing the data occurs during the collection of data as well as after it (Kvale, 1996) as it involved generating categories and reorganising data according to them, or designing a suitable matrix and placing the data gathered within its cells. This process continues and may lead to revising the predetermined categories and continue to rearrange as the searching of meaning in the data set continues until key themes and patterns or relationship are found from the rearranged data. The predetermined categories were supported by multiple forms of evidence from the data collected and the data collected portrayed multiple perspectives about each category (Creswell, 2007).

In analysing qualitative data the research was actually engaging in the process of moving in analytic circles rather than using a fixed linear approach where one enters with data of text or images and exits with an account or narrative (Creswell, 2007). This is best understood by looking at Figure 9. The interactive cyclical process is also supported by Miles and Huberman (1994) and is best shown in Figure 10.

A. Summarising of Meanings.

In exploratory and in-depth interviews, the interviews are audio-recorded and subsequently transcribed to reproduce as a written (word-processor) account using the actual words. Next, the process of Summarising of meanings will be started after the process of transcribing the interview transcripts have finished. It involves a production of a summary of the key points that emerge from the interview transcripts. It summaries long statements into briefer statements in which the main sense of what has been said or observed is rephrased in a few words (Kvale, 1996). As for this research, the data collected during the interview processes need to be summarised with a variety of safeguards, against tunnel vision, bias and self-delusion in order to resist data overload and date vagueness. Non-verbal communications which are given through the indication of the tone in which it was said need to be taken care as well.

B. Categorisation of Meanings

The process of categorising data involves two activities, i.e. developing categories and attaching these categories to meaningful chunks of data (Saunders et al., 2009). The later activity is also called the process of unitising data. It involved attaching meaningful 'bits' or 'chunks' from the data collected to the appropriate category or categories that have been devised earlier. Based on Saunders et al. (2009), the unit of data was referred to as a number of words, a line of a transcript, a sentence, a number of sentences, a complete paragraph or some other chunk of textual data that fits the category.

Strauss and Corbin (2008) suggested that there are three main sources to derive names for these categories which includes the following:

- Utilising terms that emerge from data collection
- Based on the actual terms used by respondents.
- Derive from terms used in existing theory from the literature.

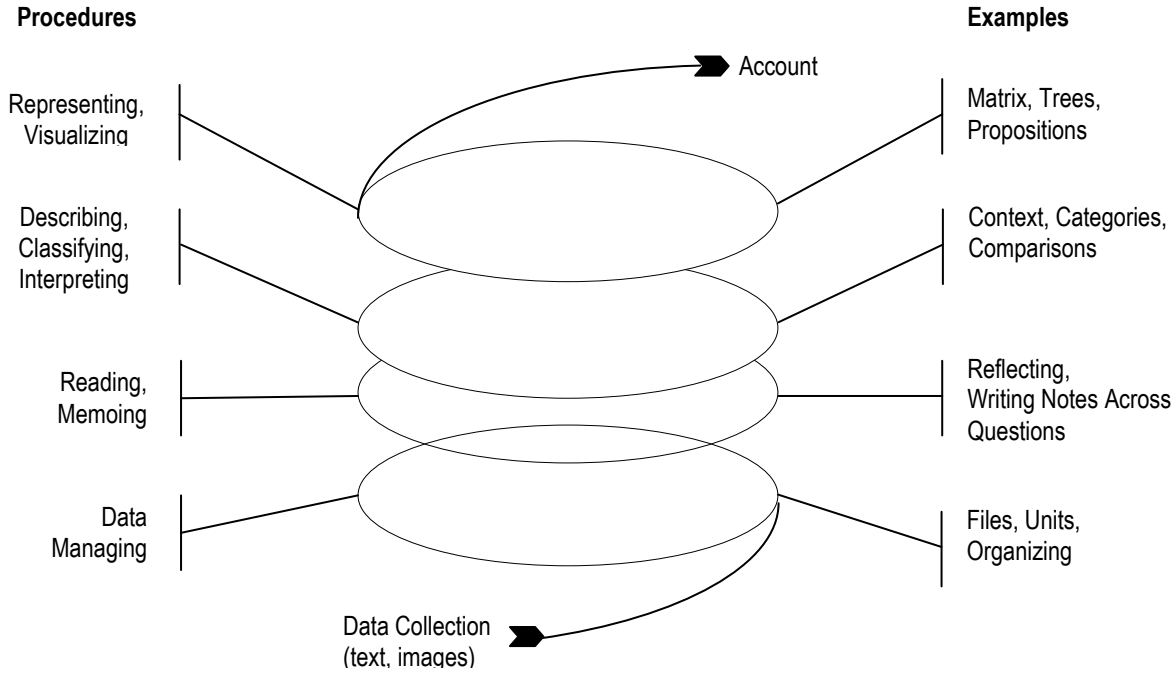


Figure 9: The Data Analysis Spiral
(Source: Creswell (2007))

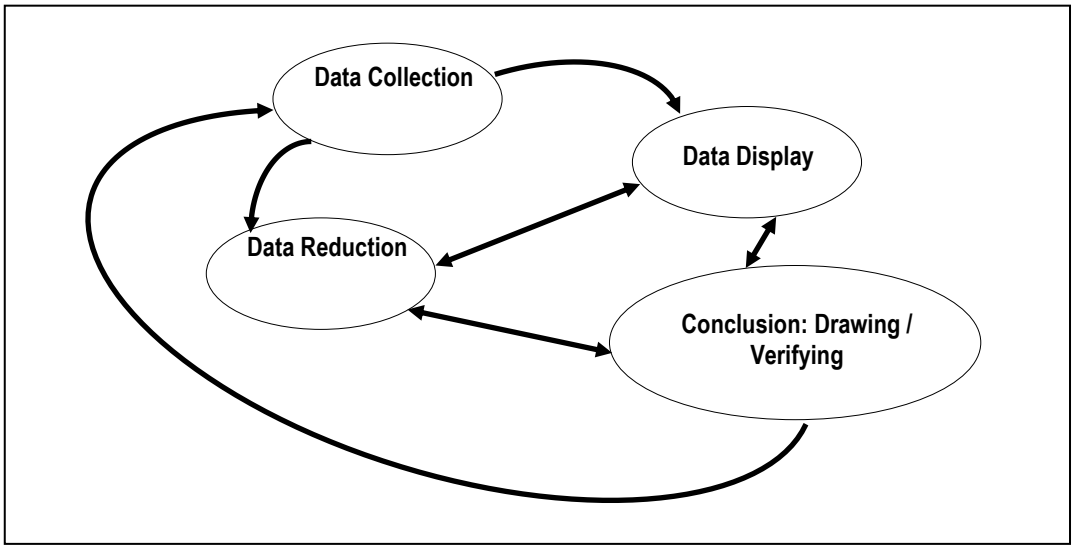


Figure 10: Components of Data Analysis: Interactive Model
(Source: Miles and Huberman(1994))

These categories or codes can represent the following information (Creswell, 2007):

- Represent information that researchers expect to find before the study
- Represent surprising information that researchers did not expect to find

- Represent information that is conceptually interesting or unusual to researchers (and potentially participants and audiences)

Categorisation of meanings may come from two sources, either from data collection or via comprehensive literature review. The predetermined seven key issues were the codes that emerge from a comprehensive literature review, and it was then used to guide the process of data analysis during empirical work. This emergent structure, i.e. the seven key issues, was guided by the purpose of the study as articulated in the research objectives. However, the predetermined seven key issues do not discontinue new key issues to grow further during the process of data analysis of empirical work. Next, the data collected from exploratory interview and in-depth interview are then analysed to distinguish for any new codes (if any) to emerge from it.

The categories developed must be meaningful in relation to the data (internal aspect) and to the other categories (external aspect). As mentioned in Creswell (2007), a popular form of analysis involves identifying five to seven general themes for classification. Basically, the categories developed initially are likely to be descriptive and will develop a more hierarchical approach to the categorisation as the analysis further develops. This will also helped in indicating emerging analytical linkages between those categories and interpretation of the data (Strauss and Corbin, 2008). In this research study, the analytical linkages that emerge from exploratory interview findings were shown in Figure 21 and Figure 22. In addition, Figure 23 shows the analytical linkages that emerge from in-depth interview findings.

However, the researcher is in the opinion that the process of unitising data to the category and devising categories are two processes that run parallel. While reducing and rearranging the data into a more manageable and comprehensible form, the emergent of codes or labels can be identified. From here, the data that was summarised is actually the chunks of data that should be attached to the emergent of codes of label that emerge from it. Instead of building up the category first, in the researcher's opinion the chunks of data is actually used to devised the category and therefore should be straight away be linked to the categories being devised from it. There are many kinds of analytical techniques being proposed in many reference books for reducing and rearranging the data, which are shown in Figure 6.

Template Analysis

In this research study, the categorisation of meanings was done by using template analysis. The information in this section is based on books written by Saunders (2009) and King (2012). In template analysis, a template that includes a predetermined list of codes or categories that represent the themes that were developed through theory is essential. During the process of analysing the data, data are

coded by attaching units of data to these categories. This process is done until the whole data is being assigned to the relevant codes or categories. As data is coded, the template will be subject to revision because some of the codes will be revised and even changes to their position or level in the template hierarchy. There are four ways of revising a template outline by King et al. (2004) as listed below:

Table 6: Analytical Techniques based on Different Research Approaches.
(Source: Adapted from Saunders et al (2009) and Miles and Huberman (1994))

APPROACHES TO QUALITATIVE ANALYSIS	Deductively	Inductively
ANALYTICAL TECHNIQUES	Pattern matching	Data display and analysis
	Explanation building	Template analysis
		Analytic induction
		Grounded theory
		Discourse analysis
		Narrative analysis

- Insertion of a new code into the hierarchy as the result of a relevant issue being identified through data collection for which there is no existing code.
- Deletion of a code from the hierarchy of it is not needed.
- Changing the scope of a code, that is altering its level within the hierarchy
- Reclassifying a code to a different category.

Template analysis combines a deductive and inductive approach to qualitative analysis in the sense that codes are predetermined and then amended or added to as data are collected and analysed. This method allows codes or categories to be shown hierarchically to help the analytical process.

C. Structuring of Meanings Using Narrative

This is the process where a decision is made to understand the meaning what the data brings and give a conclusion. It actually starts from the beginning of the process of qualitative data analysis and at the final stage of the process, a final conclusion will be made and it is usually a conclusion that the researcher has been predetermined earlier at the start of the research study. There are many strategies to generate meaning from the data which include noting patterns, themes (1), seeing plausibility (2), clustering (3), making metaphors (4), counting (5), making contrast/ comparisons (6), partitioning variables (7), subsuming particulars into the general (8), factoring (9), noting relations between variables (10) and finding intervening variables (11) (Miles and Huberman, 1994)

The strategy adopted has a connection to the following strategy adopted and the researcher believes that the second strategy adopted is a continuation from the first strategy adopted. Basically in this study, the first strategy used to generate meaning to the data collected is by noting patterns, themes. There is another strategy listed above that the researcher believed has the similarity with the first strategy adopted, i.e. clustering. Generating meaning of the data started by noting recurring patterns, themes that will be pulled together from many separate pieces of data collected during both interviews. This is interrelated with template analysis process, where coding is needed in analysing data. Once the process of the coding the data has finished, counting and making contrast and comparisons to the categories or code will be followed. The counting strategy can provide the benefits of seeing what we have in the data, verifying a hypothesis and protecting against bias. Whereas, making contrast and comparison can help in generating new ideas to the research study.

2.4.3.1.2.2.1 Step-by-step Procedure for Data Analysis Using Computer Software for Exploratory Interview

The following provides the detail explanations of the steps taken to analyse data that was collected during exploratory interview. The step-by-step procedure written by Miles and Huberman (1994) was referred to and a comparison among the general step-by-step procedure for data analysis by Miles and Huberman (1994) and the steps taken in this research study was summarised in Table 7.

A. Summarising of meanings (Step1 – Step 5 as referred to in Table 7)

First of all, each of the interviews was recorded and each recorded interviews was saved in a different file using a surrogate name to keep it anonymous so that the respondent cannot be identified. This is to make sure that all information obtained in connection with this study be treated as privileged and confidential. Next, transcribing of the recorded interviews was taken place before filtering of the data can be done which are shown in Figure 11 & Figure 12. Once the process of transcribing has finished, the researcher can now locate relevant segments of text using his/her analytical lens as in Figure 13. This is to help the next process which is constructing the categories for helping in grasping the real situations or problems at the field.

B. Categorisation of Meanings (Step 6 – Step 9 as referred to in Table 7)

Basically, after summarising of meanings has completely being done, then only the process of codifying and categorizing of data can be started. This is to segregate, re-group and re-linked the data for consolidating meaning and explanation and assigning them either under emerging key issues or provisional key issues that were developed through theory. The template analysis started here, where

a template that consist a list of the categories that represent the concepts (key issues) that were revealed through theory were being prepared at the initial stage of the process. Next, this predetermined list of the categories was then be amended or added to as data are collected and analysed. This process is done through NVivo until the whole data is being assigned to the relevant key issues, which are shown in Figure 15. Part of Figure 16 (in grey colour) shows the flow of the process of turning the code into theory.

C. Structuring of Meanings Using Narrative (Step 10 – Step 13 as referred to in Table 7)

At the end of the process, a tactic for generating the meanings from the analysed data were taking place and these were done through a few techniques such as noting patterns, themes, comparing and contrasting and counting. From here, a comparison between the provisional list of key issues and symptoms and the emerging key issues and symptoms is identified which can be seen in Figure 21 and Figure 22. The number of respondents who talk about each key issues and symptoms can portray the number of cognition under each key issues and symptoms, which is shown in tables in Section 3.6.2.4. This is also for making sure, which key issues and symptoms are important, significant or recurrent.

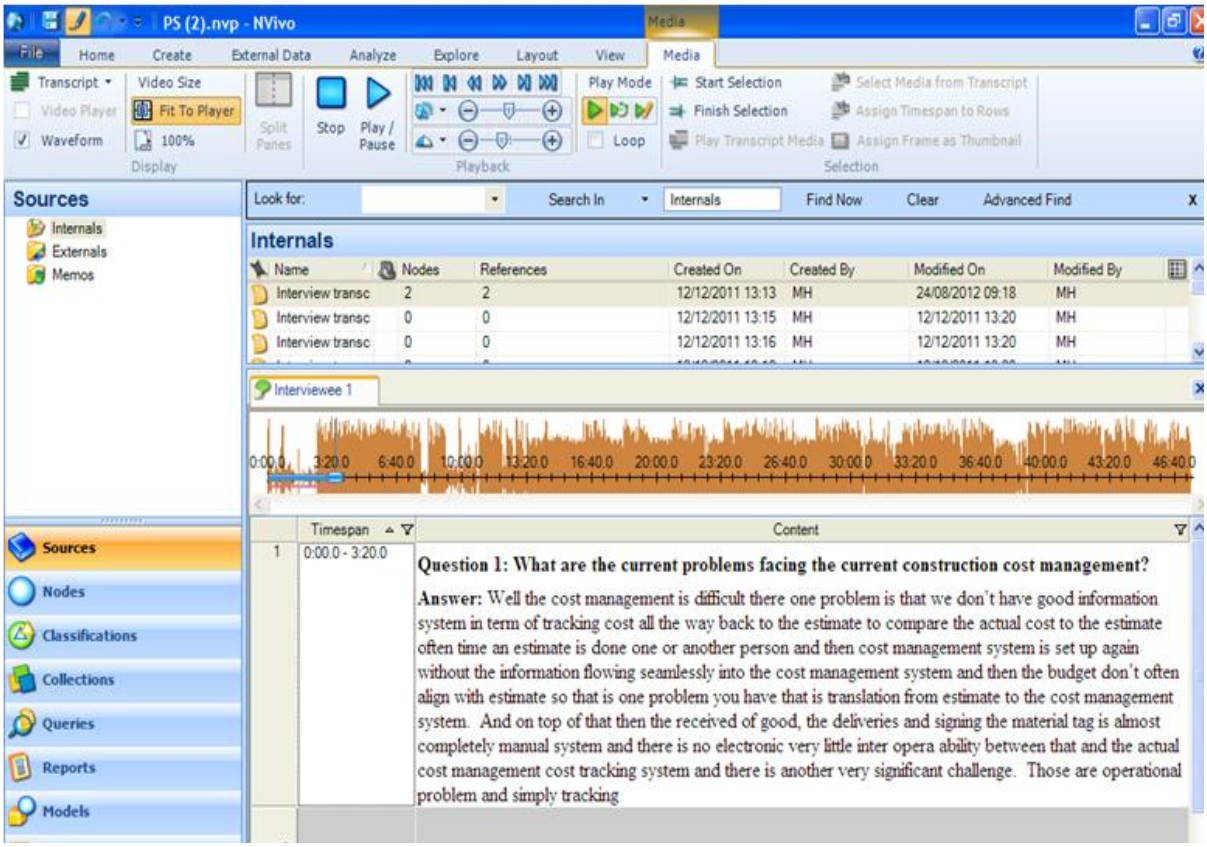
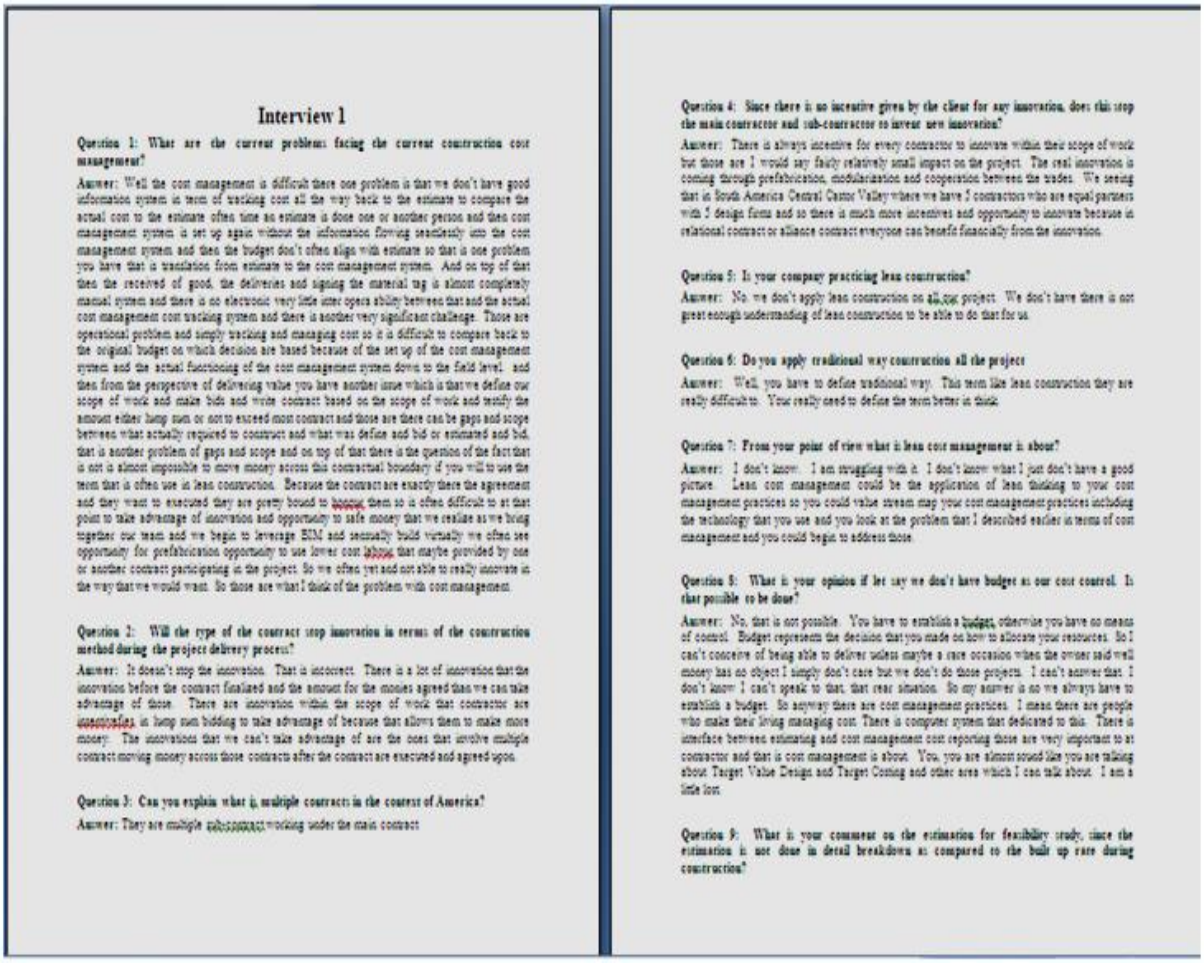


Figure 11: Screen Shot of Transcribing Recorded Interview using Nvivo.



Interview 1

Question 1: What are the current problems facing the current construction cost management?

Answer: Well the cost management is difficult there one problem is that we don't have good information system in term of tracking cost all the way back to the estimate to compare the actual cost to the estimate often time an estimate is done one or another person and then cost management system is set up again without the information flowing seamlessly into the cost management system and then the budget don't often align with estimate so that is one problem you have that is translation from estimate to the cost management system. And on top of that then the received of good, the deliveries and signing the material tag is almost completely manual system and there is no electronic very little inter opera ability between that and the actual cost management cost tracking system and there is another very significant challenge. Those are operational problem and simply tracking and managing cost so it is difficult to compare back to the original budget on which decision are based because of the set up of the cost management system and the actual functioning of the cost management system down to the field level. and then from the perspective of delivering value you have another issue which is that we define our scope of work and make bids and write contract based on the scope of work and mostly the amount either lump sum or not to exceed most contract and those are there can be gaps and scope between what actually required to construct and what was define and bid or estimated and bid. that is another problem of gaps and scope and on top of that there is the question of the fact that is not is almost impossible to move money across this contractual boundary if you will to use the term that is often use in lean construction. Because the contract are exactly there the agreement and they want to executed they are pretty bound to honor them so is often difficult to at that point to take advantage of innovation and opportunity to safe money that we realize as we bring together our team and we begin to leverage BIM and mutually build virtually we often see opportunity for prefabrication opportunity to use lower cost labor that maybe provided by one or another contract participating in the project. So we often yet and not able to really innovate in the way that we would want. So those are what I think of the problem with cost management.

Question 2: Will the type of the contract stop innovation in terms of the construction method during the project delivery process?

Answer: It doesn't stop the innovation. That is incorrect. There is a lot of innovation that the innovation before the contract finalized and the amount for the monies agreed than we can take advantage of those. There are innovation within the scope of work that contractor are encouraged in lump sum bidding to take advantage of because that allows them to make more money. The innovations that we can't take advantage of are the ones that involve multiple contract moving money across those contracts after the contract are executed and agreed upon.

Question 3: Can you explain what is multiple contracts in the context of America?

Answer: They are multiple subcontract working under the main contract

Question 4: Since there is no incentive given by the client for any innovation, does this stop the main contractor and sub-contractor to invent new innovation?

Answer: There is always incentive for every contractor to innovate within their scope of work but those are I would say fairly relatively small impact on the project. The real innovation is coming through prefabrication, modularization and cooperation between the trades. We seeing that in South America Central Center Valley where we have 5 contractors who are equal partners with 5 design firms and so there is much more incentives and opportunity to innovate because in relational contract or alliance contract everyone can benefit financially from the innovation.

Question 5: Is your company practicing lean construction?

Answer: No we don't apply lean construction on all our project. We don't have there is not great enough understanding of lean construction to be able to do that for us.

Question 6: Do you apply traditional way construction all the project

Answer: Well, you have to define traditional way. This term like lean construction they are really difficult to. Your really need to define the term better in think.

Question 7: From your point of view what is lean cost management is about?

Answer: I don't know. I am struggling with it. I don't know what I just don't have a good picture. Lean cost management could be the application of lean thinking to your cost management practices so you could value stream map your cost management practices including the technology that you use and you look at the problem that I described earlier in terms of cost management and you could begin to address those.

Question 8: What is your opinion if let say we don't have budget as our cost control. Is that possible to be done?

Answer: No, that is not possible. You have to establish a budget, otherwise you have no means of control. Budget represents the decision that you made on how to allocate your resources. So I can't conceive of being able to deliver unless maybe a rare occasion when the owner said well money has an object I simply don't care but we don't do those projects. I can't answer that. I don't know. I can't speak to that, that rear situation. So my answer is no we always have to establish a budget. So anyway there are cost management practices. I mean there are people who make their living managing cost. There is computer system that dedicated to this. There is interface between estimating and cost management cost reporting those are very important to at contractor and that is cost management is about. You, you are almost sound like you are talking about Target Value Design and Target Costing and other area which I can talk about. I am a little lost.

Question 9: What is your comment on the estimation for feasibility study, since the estimation is not done in detail breakdown as compared to the built up rate during construction?

Figure 12: Screen Shot of the Interview Transcript

1. Interviewee	:	A person from which informations were obtain for this research study. It is a **participant interview**
2. Location	:	Location of the citation in the transcript (Q - Question, L-Line)
3. Citation	:	The important say of the interviewee
4. CC	:	The group that was produce in the literature review findings (common causes)
6. Interpretation	:	Explaining the citation using my own words in order to understand what the interviewee trying to explain.

Common causes	Key Issues
G1 - Assumptions on how cost emerge	BI1 - Failure to forecast
G2 - Assumptions on management need for cost information	BI2 - Failure to pinpoint improvement opportunities
G3 - Assumptions on conditions or context of cost management	BI3 - Costs are shaped by action rather than result from action
G4 - How contract is formulated and payments arranged	BI4 - Relative neglect of value consideration
	BI5 - Poor support for inter-organizational cost management
	BI6 - Negative influence on behaviour
	BI7 - Budget in dynamic situations

	Interviewee	Location	Citation	Interpretation	Big issues featured	IGLC CC
1	1	Q1L2	Don't have good information system in term of tracking cost all the way back to the estimate to compare the actual cost to the estimate	it is difficult to compare back to the original budget on which decision are based	BI1	G3
2	1	Q1L4	Cost management system is set up again without the information flowing seamlessly	Cost management system is set up again without the information flowing seamlessly from the estimate that was prepared earlier -Translation from estimate to cost management system.	BI1	
3	1	Q1L5	Budget don't often align with estimate		BI1	
4	1	Q1L7	The deliveries and signing the material tag is almost completely manual system and there is no electronic very little interoperability between that and the actual cost management cost tracking system	Very little interoperability between material deliveries and the actual cost management cost tracking system	BI	
5	1	Q1L11	Set up of the cost management system and the actual functioning of the cost management system down to the field level	The operational problem and the problem to compare back to the original budget on which decision are based are because of things said in citation column	BI	
6	1	Q1L16	Delivering value - There can be gaps and scope between what actually required to construct and what was define and bid or estimated and bid		BI4	
7	1	Q1L18	Move money across this contractual boundary		BI5	
8	1	Q1L19	Because the contract are exactly there the agreement and they want to executed they are pretty bound to honour them so is often difficult to at that point to take advantage of innovation and opportunity to safe money that we realize	Not able to really innovate in the way that we would want because pretty bound to honour the contract	BI	G4
9	1	Q2L1	There is a lot of innovation that the innovation before the contract finalized and the amount for the monies agreed		BI	
10	1	Q2L3	There are innovation within the scope of work that contractor are insentivefies in lump sum bidding		BI	
11	1	Q2L5	The innovations that we can't take advantage of are the ones that involve multiple contract moving money across those contracts after the contract are executed and agreed upon		BI	
12	1	Q4L2	The real innovation is coming through prefabrication, modularization and cooperation between the trades.		BI	

Figure 13: Search and Retrieval for Filtering the Data

Table 7: Step-by-step Procedure for Data Analysis using Computer Software for Exploratory Interview

(Source: information adapted from Miles and Huberman (1994) and Saldana (2009))

Process of Analysis	Miles and Huberman(1994)	This research study
Summarising of meanings	Step 1. Making notes in field	Step 1. Record each interview session using recorder.
	Step 2. Writing up or transcribing field notes	Step 2. Transcribing the recorded interview for preparing interview transcript. (Figure 11 and Figure 12
	Step 3. Editing: correcting, extending or revising field notes	Step 3. Editing: re-listening for the second time and correcting, extending or revising the interview transcripts.
	Step 4. Coding: attaching key words or tags to segments	
	Step 5. Storage: keeping text in an organised database	Step 4. Storage: keeping text in an organised database.
	Step 6. Search and retrieval: locating relevant segments of text and making them available for inspection	Step 5. Search and retrieval for filtering the data: locating relevant segments of text and making them available for inspection where the researcher's will wear his/her analytical lens. The researcher perceives and interpret the data based on what filters covers that lens, which depends on the researcher academic discipline and experiences. (Figure 13)
Categorisation of meanings	Step 7. Data 'linking': connecting relevant data segments with each other, forming categories, clusters or networks of information	Step 6. Codify and categorizing: data was segregated, grouped, regrouped and re-linked to consolidate meaning and explanation and assigned them either under emerging key issues or provisional list of key issues developed through theory. This was done manually and using NVivo. Figure 14 shows how the data was codified and categorised manually and Figure 15 shows the process using Nvivo until the whole data is being assigned to the relevant key issues. Figure 16 illustrated how the process works. This is where the process of template analysis started, where a template that consist a list of the categories that represent the concepts (key issues) that were revealed through theory were being prepared at the initial stage of the process.
	Step 8. Memoing: writing reflective commentaries on some aspect of the data, as a basis for deeper analysis.	Step 7. Memoing: writing reflective commentaries on some aspect of the data, as a basis for deeper analysis.
	Step 9. Content analysis: counting frequencies, sequence or locations of words and phrases	Step 8. Template analysis: Combine with Step 6.
	Step 10. Data display: placing selected or reduced data in a condensed, organised format, such as a matrix or network, for inspection.	Step 9. Data display: placing selected or reduced data in a condensed, organised format, such as a matrix or network, for inspection.
Structuring of Meanings Using Narrative	Step 11. Conclusion: drawing and verification: aiding the analyst to interpret displayed data and to test or confirm findings	Step 10. Conclusion: drawing and verification: aiding the analyst to interpret displayed data and to test or confirm findings
	Step 12. Theory building: developing systematic, conceptually coherent explanations of findings; testing hypothesis	Step 11. Theory building: developing systematic, conceptually coherent explanations of findings; testing hypothesis
	Step 13. Graphic mapping: creating diagrams that depict findings or theories	Step 12. Graphic mapping: creating diagrams that depict findings or theories
	Step 14. Preparing interim and final reports.	Step 13. Preparing interim and final reports.

CONTENT IN THE ISSUES	COMPLY		CONTRADICT		NEW	
FAILURE TO FORECAST						
Decide on relatively detailed issues at the beginning of the project delivery process for the preparation of tender documents. There is a high possibility that the detail issues will change along the project delivery process.			Interviewee 1	Naïve conception that you used don't have change or you don't have much change with lean project and change management is suggested to be used to solve this problem. Is not possible to foresee every condition until tend perfection to the point where they will be no contingency needed.	Interviewee 1 & 3	Cost tracking - back checker in order to check on the validity of the estimate because budget (where decision are based) don't often line with estimate and no information flowing seemlessly exist. This create problem for cost control, i.e. the translation from estimate to production plan (control tool)
			Interviewee 4	I mean is the variation that you expecting cost to occur I think is very much tie to how you manage your design process.	Interviewee 3	return on investment - are people prepare to invest more in during that sort of production planning and conjunction with the preparation of estimate where they may or may not get the work.
cost is just understood to be there						
unethical practices						
cost data inherit waste	Interviewee 6	Claims are a standard contract item as are defects/snags - This is an acceptable situation in construction industry				
	Interviewee 6	The final account is never the same as the tender price				
	Interviewee 2	Many projects cost more than they should, and many of those same projects do not result in satisfied customers; so waste is greater than necessary and value is less.	Interviewee 1	Estimate in detail is not a question that you can't estimate in detail just the question that you are forecasting. This can be overcome by experience people (which are enough of those people) and technology		
	Interviewee 3	The information collected is outdated				
	Interviewee 5	Almost nobody was actually using the information. Even more then that they found that they had many2 people in that function and what they were spending a huge amount of time doing thing that nobody care about.				
	Interviewee 3	There is no similarity between the estimate and what you want to manage production. Estimate should not be used directly over into the control budget and re-allocating the estimate based on production plan should be prepared as the control budget.				
FAILURE TO PINPOINT IMPROVEMENT OPPORTUNITIES						
Early commitments to design solutions can lead to making wrong decisions that might leads to suboptimal solutions, quality defects and rework and this indirectly will increase resource consumption and generate wastes in the process			Interviewee 1	Naïve conception that you used don't have change or you don't have much change with lean project and change management is suggested to be used to solve this problem		
Cost data inherit waste						
Focused more on direct labor time instead of overhead cost						
COSTS ARE SHAPED BY ACTION RATHER THAN RESULT FROM ACTION						
To make the design converge to an acceptable overall project cost rather than letting the cost reflect the design	Interviewee 1	Not able to really innovate in the way that we would want because pretty bound to honour the contract.	Interviewee 1	The innovations that we can't take advantage of are the ones that involve multiple contract moving money across those contracts after the contract are executed and agreed upon	Interviewee 1	Relational contract or alliance contract everyone can benefit financially from the innovation.
	Interviewee 3	It doesn't mean you can't achieve better outcome if you have a contract that does know how to optimize but if you have a contract that is enabler is makes it much much easier				
RELATIVE NEGLECT OF VALUE CONSIDERATION						
The only problem is that they do not know where and how to do it.	Interviewee 1	Delivering value - There can be gaps and scope between what actually required to construct and what was define and bid or estimated and bid				
	Interviewee 1	Move money across this contractual boundary				
	Interviewee 4	moving money across boundary - deliver greater value to through scope increases funded by cost savings				
	Interviewee 5	How does value arrive When value arises? – The mechanism and moment which value arises. When and where it happens. Trying to move it from very abstract view to find what is the mechanism where it happens. When is the moment that the value is created/when is the value exist/arrive? – transaction of value.				
POOR SUPPORT FOR INTER-ORGANIZATIONAL COST MANAGEMENT						
many-tiered supplier networks create a major addition in transaction cost until it reach the final customer			Interviewee 1	I believe that those can be that there will be more than enough gains to pay for that investment by streamlining delivery and supply chain practices through the application of lean thinking so right now there is tremendous ways because of just interoperability issues between different		
NEGATIVE INFLUENCE ON BEHAVIOUR						
There are contractors who expend more effort on generating profit from claims than from improved construction methods (Rooke et al., 2004)	Interviewee 1	Do result from poor estimate by contractor and they try to look for every opportunity to make a claim. Solution - claims are not allowed and not entertain.				
BUDGET IN DYNAMIC SITUATIONS						
each and every activity involved in the product delivery process will be benchmarked with a budget	Interviewee 2	local optimization, incompatible with project optimization because of costs are managed against budgets, as if the work being funded by those budgets was independent, one from another	Interviewee 1	Always have to establish budget		
NEW BIG ISSUES						
					Interviewee 2	Performance improvement initiatives are interrupted by the business cycles
					Interviewee 3 (similar with interviewee 2 above)	Different objective between client and contractor. Client tries to minimise cost and contractor tries to increase profit. Contractor are not going to reduce cost/time for the benefit of the project by sacrifying their profit unless the benefit from those savings can be shared between client and contractor
					Interviewee 6	Remove the reliance of project decision making on cost issues and move cost and cash flow into a production support role.
					Interviewee 5	The reality of people decision is not on the table.
					Interviewee 4	Uncertainty on the material price volatility - Because of price fluctuation because of worldwide demand and we can't predict very well.
					Interviewee 4	they buy future

Figure 14: Manually Codifying and Categorizing Data from Exploratory Interview

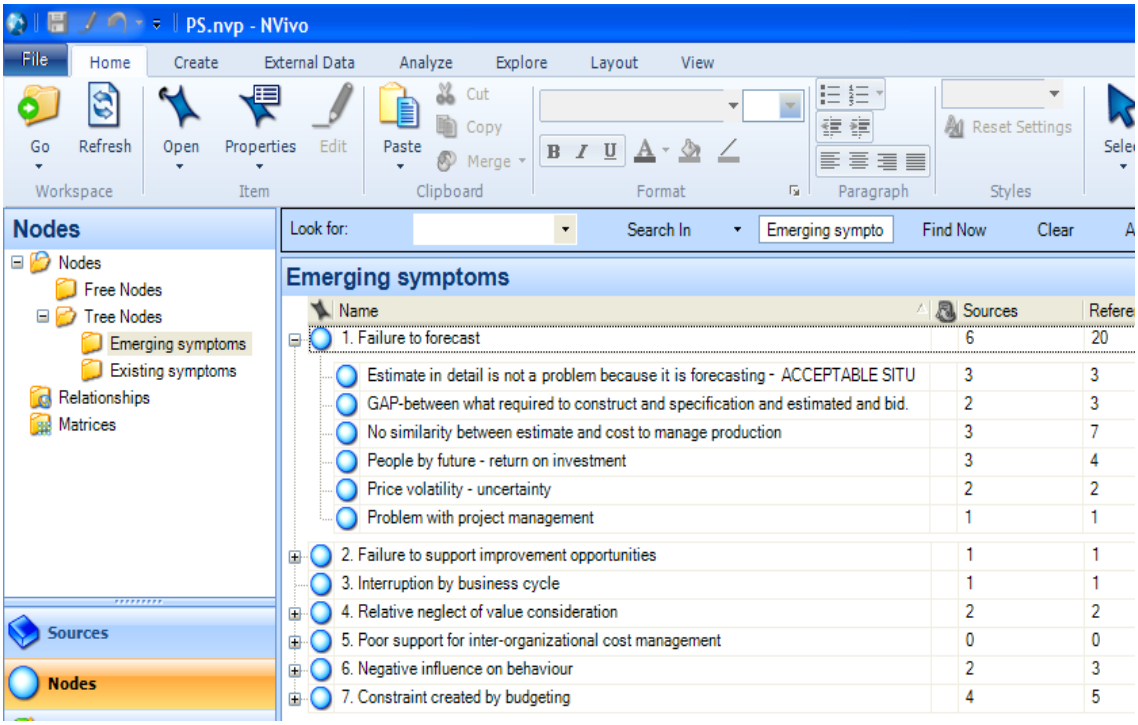


Figure 15: Screen shot of exploratory interview (emerging symptom) template analysis in Nvivo 9 showing the nodes for key issue failure to forecast

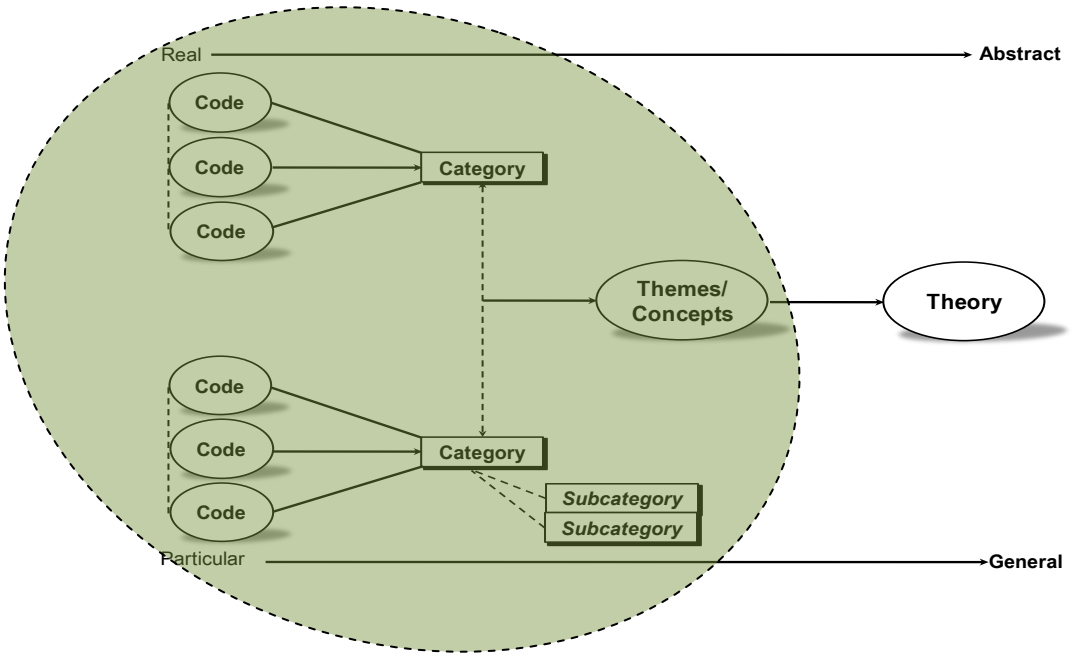


Figure 16: A streamlined codes-to-theory model for qualitative inquiry
(Source: Saldana (2009))

2.4.3.1.2.2.2 Step-by-step Procedure for Data Analysis using Computer software in Qualitative Studies for In-Depth Interview

Fundamentally, the same method of analysis in exploratory interview was being used for analysing the data gathered in 'in-depth' interview. Table 8 presented the detail step-by-step procedure used in this research study which has been improvised from the original procedure suggested by Miles and Huberman (1994) to suit this exercise. Basically, the difference in terms of the steps taken is that the data collected from the interview is straight away assigned to the template that consist a list of the key issues and symptoms that were emerged during the exploratory interview and developed through theory. Next, this predetermined list of the categories was then be amended or added to as data are collected and analysed. This process is done through NVivo until the whole data is being assigned to the relevant key issues. To analyse data that was collected during in-depth interview, the step-by-step procedure written by Miles and Huberman (1994) was referred to. Table 8 shows a comparison among the general process of data analysis, step-by-step procedure by Miles and Huberman (1994) and the steps taken in this research study. The detail explanations on the process involved was included too.

A. Summarising of Meanings (Step 1 – Step 4 as Referred to in Table 8)

The process taken for analysing the data is similar with a discussion in analysing data for exploratory interview.

B. Categorisation of Meanings (Step 5 – Step 8 as Referred to in Table 8)

For in-depth interview, the process of categorisation of meanings was totally done through NVivo after the process of summarising of meanings. The template analysis started here, where the template that consists the list of emerging key issues from the exploratory interview and provisional key issues that were developed through theory being prepared first. Next, the data was being assigned under the relevant categories until the whole data is being assigned to the relevant key issues. This predetermined list of the categories was then be amended or added to as data are collected and analysed. The segregation, regrouping and re-linking of the data were done while reading through the transcript prepared earlier.

Table 8: Step-by-step procedure for data analysis using computer software for In-depth Interview

(Source: information adapted from Miles and Huberman (1994) and Saldana (2009))

Process of Analysis	Miles and Huberman(1994)	This research study
Summarising of meanings	Step 1. Making notes in field	Step 1. Record each interview session using recorder
	Step 2. Writing up or transcribing field notes	Step 2. Transcribing the recorded interview for preparing interview transcript. ((Figure 11)
	Step 3. Editing: correcting, extending or revising field notes	Step 3. Editing: re-listening for the second time and correcting, extending or revising the interview transcripts.
	Step 4. Coding: attaching key words or tags to segments	
	Step 5. Storage: keeping text in an organised database	Step 4. Storage: keeping text in an organised database.
	Step 6. Search and retrieval: locating relevant segments of text and making them available for inspection	
Categorisation of meanings	Step 7. Data 'linking': connecting relevant data segments with each other, forming categories, clusters or networks of information	Step 5. Codify and categorizing: data was segregated, grouped, regrouped and re-linked to consolidate meaning and explanation and assigned them either under emerging key issues or provisional list of key issues developed through theory. This was done manually and using NVivo. Figure 14 shows how the data was codified and categorised manually and Figure 15 shows the process using Nvivo until the whole data is being assigned to the relevant key issues. Figure 16 illustrated how the process works. This is where the process of template analysis started, where a template that consist a list of the categories that represent the concepts (key issues) that were revealed through theory were being prepared at the initial stage of the process.
	Step 8. Memoing: writing reflective commentaries on some aspect of the data, as a basis for deeper analysis.	Step 6. Memoing: writing reflective commentaries on some aspect of the data, as a basis for deeper analysis.
	Step 9. Content analysis: counting frequencies, sequence or locations of words and phrases	Step 7. Template analysis: Combine with Step 6.
	Step 10. Data display: placing selected or reduced data in a condensed, organised format, such as a matrix or network, for inspection.	Step 8. Data display: placing selected or reduced data in a condensed, organised format, such as a matrix or network, for inspection.
Structuring of Meanings Using Narrative	Step 11. Conclusion: drawing and verification: aiding the analyst to interpret displayed data and to test or confirm findings	Step 9. Conclusion: drawing and verification: aiding the analyst to interpret displayed data and to test or confirm findings
	Step 12. Theory building: developing systematic, conceptually coherent explanations of findings; testing hypothesis	Step 10. Theory building: developing systematic, conceptually coherent explanations of findings; testing hypothesis
	Step 13. Graphic mapping: creating diagrams that depict findings or theories	Step 11. Graphic mapping: creating diagrams that depict findings or theories
	Step 14. Preparing interim and final reports.	Step 12. Preparing interim and final reports.

C. Structuring of Meanings Using Narrative (Step 9 – Step 12 as Referred to in Table 8)

The process taken for analysing the data is similar with a discussion in analysing data for exploratory interview.

2.4.3.2 Design Science Evaluation

The creation of the conceptual solutions is carried out based on findings of the root cause and then developing the conceptual solution.

2.4.3.2.1 Root cause analysis

The development of the solution to the research problems were tackled using one of the categories under The Toyota Way. There are 14 management principles that constitute the "Toyota Way" and these key principles derive the techniques and tools of the Toyota Production System and the management of Toyota in general. All these principles have been categorised under 4 categories (Liker, 2004) shown in Figure 17. Those categories include problem solving, people and partners, process and philosophy. The method used for the development of the solution to the research problems comes from 'Problem Solving' category, which involves determining the root cause of problems and providing effective countermeasures.

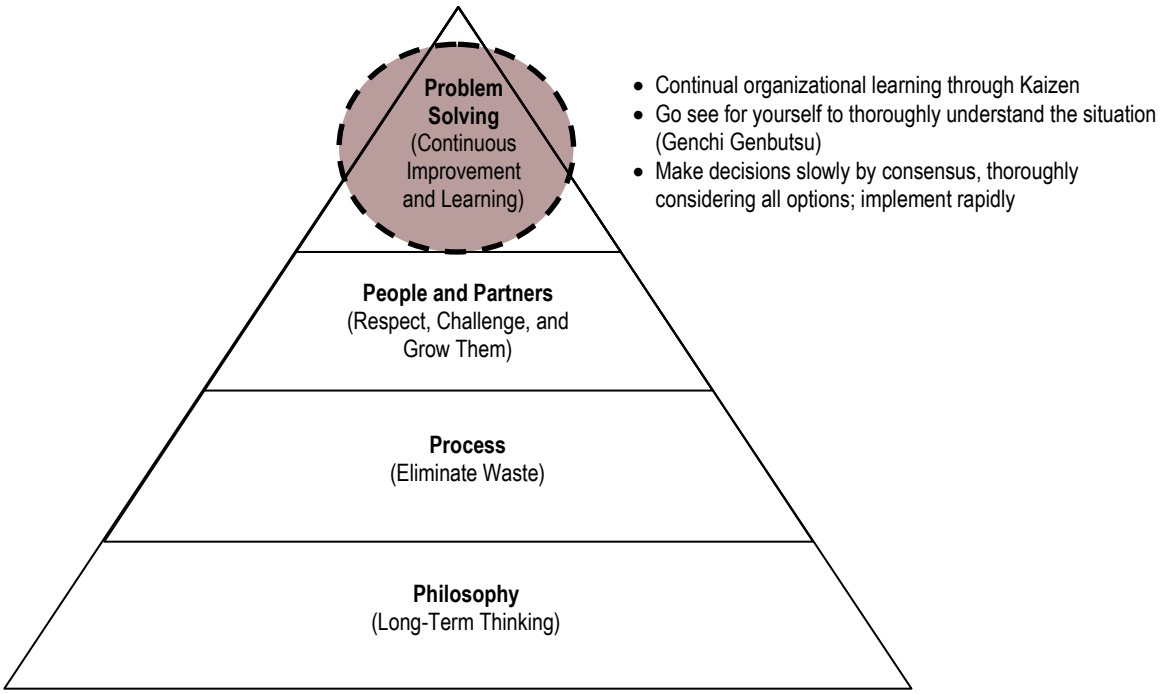


Figure 17: A "4 P" model of the Toyota Way.
(Source: Liker (2004))

Getting to the root cause of the problems were determined using an integral part of kaizen which is the Toyota's famous 5 - 'Why' analysis. The 5 - 'Why' is a method to pursue the deeper, systematic causes of a problem in order to find correspondingly the right countermeasures. The countermeasures for the initial level of problem are completely different with the deepest level of problem if deeper digging is made and this can prevent a whole range of similar problems from occurring again in the future. The countermeasures taken are the countermeasures at the deepest level of cause that is feasible and at the level that will prevent reoccurrence of the problem. This was done by asking 'Why' five times which requires a level of detailed thinking and analysis and the process of doing it was described by Taiichi Ohno (Liker, 2004) as a process that requires identifying "….'root cause' rather than 'source'; the Root Cause lies hidden beyond the source". The process of asking 'Why' started with asking the first 'Why' and then asking 'Why' again from the answer/answers that occur. It was mentioned in Liker (2004) that this process of asking ''Why'' leads upstream in the process.

Bear in mind that before the 5 - 'Why' analysis was carried out, identifying the 'practical problem solving' is required to be done first for clarifying the problem and grasping the real situation of the problems. The identification of the 'practical problem 'is described in detail in Chapter 3 and Chapter 4.

2.4.3.2.2 Development of the conceptual solution

Based on the root cause, the conceptual solution is reached

- Through a creative leap, abduction,
- Abstracting from practical, initial solutions observed in the field, or
- Taking advantage of the ideas forwarded in the interviews.

In all cases, a conceptual solution needs to be persuasive regarding its ability to eliminate the root cause.

2.4.3.3 Evaluation of Solution

In DSR, evaluation is usually empirical and will use methods from the natural or the social sciences depending on the nature of the problem and/or solution (purely technical or at least partially social or organisational).

In contrast, a conceptual solution will be evaluated in terms of its effectiveness and efficacy in generating practical solutions. There cannot be a definitive evaluation of this in the framework of this

research, but the existence of initial, and in practice working solutions will give a sufficient ground for evaluation.

2.5 The Difference between Conceptual Solutions and (Embodied) Practical Solutions.

A comparison between a conceptual solution and an embodied solution is presented in Table 9, for identifying the differences between these two types of solutions and for understanding the content needed in each type of the solution. A clear definition is needed, given the central role both types of solutions have in this research.

2.6 Ethical Approval

This research is guided by the university's code of ethics that provides a statement of principles and procedures for the conduct of the research work, highlighting what is and what is not considered ethical. In line with the requirements of the university's code of ethics, an ethical approval has been secured by the researcher prior to the data collection stage. The ethical approval covers matters related to privacy of possible and actual participants; voluntary nature of participation and the right to withdraw partially or completely from the process; consent of participants; maintenance of the confidentiality of data provided by individuals or identifiable participants and their anonymity; and reactions of participants to the way in which the researcher seeks to collect data, including embarrassment, stress, discomfort, pain and harm.

2.7 Summary

The credibility of the research findings is an important aspect of any research success and is influenced with the appropriate selection of research methodology. Research methodology is the overall approach to be used in the research process from the theoretical groundwork to the collection and analysis of the data. In this context, this chapter has presented and justified the research methodology adopted for this research study in developing conceptual solutions that meet the needs of the problems identified in the domain. In doing so, this chapter has elaborated the process involved in the theoretical groundwork related to the adoption of the research philosophies, process and techniques for data collection and analysis as well as for designing and evaluating solutions with details of appropriate justifications. Although the aforementioned research methodology is not the only suitable design for similar research undertaken, it has been deemed as most suitable in view of the aim, objectives and questions of the research at hand.

The next chapter will critically review and discuss the literature related to the study for identifying and representing opportunities and practical problems in an actual application environment. Problem investigation was carried on for clarifying and grasping the real situation in order to understand the problem without yet changing it. Therefore, having the establishment of awareness towards the actual problem in the application environment in the next chapter will provide an insight into understanding the focus of the research and for ensuring it moves towards the right direction until the research aim is achieved.

Table 9: The differences between two types of solutions

	Conceptual Solution	Embodied Solution
Explanation	Conceptual design is a thought process of generating and implementing the fundamental ideas that characterize a product or system. It is a process of transition from a need that has been stated and analyzed to form the design specifications or requirements list (Wikipedia, 2013a). Conceptual solution also can be described as the reasoning stage that accepts as input the description of the problem to be solved (the solution being the unknown) and produces as output a description of solution(s) that attempts to minimize the unknown, so subsequent stages (embodiment and detail design, prototyping, testing, etc.) will be mostly technical in nature and will use existing and available knowledge. In other words, it can be said that conceptual design now becomes: what reasoning process or strategy will take us from the input to the output (i.e., will add known things to the unknown) in a way that will produce more robust and innovative artefacts, Conceptual solution can be just a few sentences describing the main ideas or working principles to be implemented, or it may include a fairly elaborate graphical layout of the structure of the solution (Tools, 2013). It is the early design activities in the design process.	An embodied solution is a process from function to form and it involves the transition of the abstract functional structure to the concrete material structure to be developed (Roozenburg and Eekels, 1995). It is technical in nature (Tools, 2013). Embodied solution consists of an outline design proposal which embodies decisions on the geometry and material of the new product which deals with physical feasibility and it is ready for production. It also has physical effect and form the design features. In addition, it has a function structure that equipped with intended behaviour of a material system and it shows what internal functions must be realized by elements, so that the system as a whole can fulfil its external overall function. Finally, if it is made and used, it is actually part of the material reality (Roozenburg and Eekels, 1995).
Examples	**Example taken from The Realm of Cost Management (Task: Life cycle costing).** *The Purpose:* It is an accounting method designed to look both at the capital cost and maintenance cost for calculating relatively long life of buildings costing for avoiding nasty surprises down the track (Kuhn and Hacking, 2012).	**Example taken from The Realm of Cost Management (Task: Life cycle costing).** *The Procedural Techniques:* Life-cycle costing involves analyzing fixed and variable costs, the equivalency and worth of money over time for investments, the mechanics of accounting and cash flow, comparisons of optional equipment, and the taxing elements. Life-time cost computations must take into account federal and state income taxes affecting investment tax credits, depreciation, and balance sheet expenses (Kriegel et al., 2009).

3 ESTABLISHING AWARENESS OF THE PROBLEM

3.1 Introduction to the chapter

This chapter introduces a practical problem that has research potential, and is important and unique as revealed through literature searches. It reviews the extant literature concerning the landscape of cost management and construction cost management to identify the practical relevance to the outside world, i.e. the construction industry. Accordingly, it is structured as follows:

- First, it discusses the key definition of construction cost management by briefly synthesising the meaning of cost management generally and from the perspective of construction industry.
- Second, it explores the landscape of cost management by investigating the evolution of cost management in general and specifically in relation to the construction industry. This is an attempt to categorise the information gathered that will then be developed through anomaly detection concept to become the provisional key issues.
- Third, it takes and explores the landscape of construction management from the point of view of management science and tries to see the missing links that causes problems in the current situation.
- Finally, this chapter identifies and discusses the key issues in construction cost management, which are the fundamental discoveries based on the literature review.

3.2 The Key Definitions

The following sub-section addresses the key definitions within the context of this research, especially the definition of cost, cost management and construction cost management as found in current literature. All of these definitions, from eleven sources, have provided a basis and a guideline in terms of the subject area when searching for relevant sources of references for this thesis.

3.2.1 Definition of Cost

Generally, Soanes and Stevenson (2008) define cost as 'the effort or loss necessary to achieve something'. In construction terms, Kirkham (2007) defines cost as the amount of money that the client expects to hand over to a builder, usually during and on completion of the building (the total price that the builder wants for completing his work).

3.2.2 Definition of Cost Management

The term 'cost management' is not a well-defined term. It builds on both cost accounting and management accounting, but goes beyond the two (Agrawal et al., 1998). The difference between these two is clarified by Anthony (1989), who explained that management accounting is different to cost accounting as the latter was taught in two fundamental ways, i.e. cost accounting texts deals entirely with numbers, while management accounting recognises that human beings use those numbers (accounting information) and the objectives are to assist managers and to influence their behaviour. One criterion is "goal congruence" – inducing managers to act in such a way that while achieving their personal goals they also help to achieve the goals of the organisation. Management accounting teaches the behavioural factors in the budget process, i.e. participative budgeting, personal responsibility, controllability, engineered costs versus discretionary costs, the approved budget as a bilateral commitment, tight and loose budgets, and acting on variances under various circumstances. The theme in management accounting is "different cost constructions for different purposes" and it deals with non-monetary information in addition to dollar amounts and future estimates including historical data (Anthony, 1989, p.3).

BusinessDictionary (2012) defines cost management as the management of cost related activities achieved by collecting, analysing, evaluating and reporting cost information used for budgeting, estimating, forecasting and monitoring costs. Whereas, Tanaka et al. (1993) define cost management as the process that involves initiating and making decisions which will improve the cost-effectiveness of an organisation by understanding the concepts of cost, discussed above, within the context of their own business.

Furthermore, Brinker (1996) defines cost management as a set of techniques and methods for controlling and improving a company's activities and processes, its products and services. In addition, Maskell (2009) describes cost and management accounting as being used internally to help the company's managerial control and improve the business. Although accounting standards are associated with these tasks, there is no legal requirement to perform these tasks in any particular way or to perform them at all. A company can do as much or as little cost and management accounting as it wishes and it can be done in any way it wants. Furthermore, cost accounting practices are seldom the same in different companies (Agrawal et al., 1998).

There is a confusion of overlapping terminology and meanings within cost management literature. The lack of a universal area and definition of cost management is, in part, due to the way the concept of cost management has been practiced and the multidisciplinary origin and evolution of the concept. In

effect, as will be explained in the following section, the concept of cost management has been considered from different points of view in different bodies of literature. All the relevant sources of reference in the subject area of cost management, cost accounting and management accounting have been used to further develop this research. As a consequence, many labels can be found in the literature review referring to cost management as a result of some of contrasting approaches to cost management existing in the literature.

3.2.3 Definition of Construction Cost Management

In the context of the construction industry, Ashworth and Hogg (2007) have written a chapter on cost management that includes interim valuations, variations and claims, the preparation and agreement of the final account, cost control and reporting final accounts. From the point of view of Kelly and Male (1993), construction cost management is defined as a service where the primary emphasis is on cost reduction or substitution. It is also defined as a service that synthesizes traditional quantity surveying skills with structured cost reduction or substitution procedures using a multi-disciplinary team.

3.2.4 Key Definition

Based on all the definitions stated above, the researcher has defined cost management, from her point of view, as a set of techniques and methods for controlling and improving a company's activities and processes, its products and services to achieve cost effectiveness (cost reduction, value improvement and substitution); by collecting, analysing, evaluating and reporting cost information in budgeting, estimating, forecasting and monitoring costs in order to assist in initiating and making decisions. Therefore, cost management systems in construction companies must be dynamic, proactive and able to support different decision-making processes, in order to protect the business from the harmful effects of uncertainty. Their main objective should be to generate information to support decision-making, mainly concerned with cost reduction, value improvement and financial management.

3.3 The Cost Management Landscape

This section will systematically review the literature on mainstream cost management and emerging issues, dating back to 1977, with the aim of identifying the historical evolution of cost management role, its landscape and shortcomings. The study is based on the analysis of a large number of publications on cost management (books, journal articles, and conference papers) found using the Google Scholar search engine and relevant databases.

3.3.1 The Evolution of Cost Management

From the literature review, it is believed that the evolution of cost management methods happened along the timeline and this can be viewed in Table 10, which demonstrates how cost management methods have progressed from the medieval era through to the 20th century. Following the changes in peoples' lifestyle and needs from desiring only the basic needs in their life to demanding more complex living standards may have contributed to this evolution. People's desires these days are believed to be linked to their status and lifestyle. This has created demand for high quality products with a variety of options. Furthermore, these needs have created complex and huge markets that change the trend of supply and demand that denies the use of the old style of production system. In addition, intense global competition is another reason that may contribute to the changes in the graph of supply and demand that denies the use of the old style of production system.

Therefore, there are changes in the way the production system operated (internal information required, problems with overheads and method or process of production used) and the characteristics of the production system itself (from few standardised products with high direct labour content characterised by products to lower direct labour content). These scenarios have led to development in the production process itself; from a simple production system to a more complex technical production system (from labour reliance to an automated production system) to cater to current demand. However, despite the environmental, managerial and technological changes that have occurred in the last few decades, existing cost management systems tend to be very similar to those that have been used since the mid-twenties.

In analysing the development of cost management, the first step taken in this research is to systematically review the literature on mainstream cost management and emerging issues dating back to 1977 with the aim of identifying the historical evolution of cost management roles and its shortcomings. The issues discussed in this section started with the earliest issues about cost management and moved on to the current issues of 2009.

It can be conveyed that the current practices in management accounting existed since the 19th century in textile companies, steel and other heavy manufacturing companies, petroleum companies, railroads and retailers (Anthony, 1989). Anthony (1989) mentioned that the closest approximation to the current practices in management accounting was in the 1940s business curriculum where the subject of cost accounting was taught at higher learning institutions in United States of America. The terminology is not much different from that used today, but the topics taught were definitely different. He also claimed that the first text material on management accounting was written by Bill Vatter in his paperback entitled

Managerial Accounting, published by Prentice-Hall in 1950. In the 1930s and 1940s, Professor Ross G. Walker taught an elective course called Budgetary Control at Harvard Business School that contained the main ingredients of today's course – an emphasis on management uses of information and on behavioural consideration in the management control function (Anthony, 1989). It was also mentioned that the system, which had been installed in Ford Motor Company in 1950s by Bob McNamara, who was a controller at that time, was taught by Professor Ross G. Walker. The subject of management accounting became a required course at Harvard Business School during the major curriculum revision that occurred immediately after World War II and Anthony (1989) believed that this was the beginning of management accounting.

In 1984, the present era of intense global competition has lead U.S. companies towards a renewed commitment to excellence in manufacturing. Attention to the quality of products and processes, the level of inventories, and the improvement of work-force policies has made manufacturing, once again, a key element in the strategies of companies intending to be world-class competitors. However, there remains a major - and largely unnoticed - obstacle to the lasting success of this revolution in the organisation and technology of manufacturing operations. As noticed by Kaplan (1984), most companies are still using the same cost accounting and management control systems that were developed decades ago for a competitive environment drastically different from that of today. He further added that poorly designed or outdated accounting and control systems can distort the manufacturing performance.

Kaplan (1984) stated that measurement systems for today's manufacturing operations must consider quality, inventory, productivity, innovation and work force. In summary, the financial measures generated by traditional cost accounting systems provide an inadequate summary of a company's manufacturing operations. Today's global competition requires that non-financial measures such as those mentioned before should be used in the evaluation of a company's manufacturing performance. Companies that achieve satisfactory financial performance but show stagnant or deteriorating performance on non-financial indicators are unlikely to become or long remain world-class competitors.

Present cost accounting and management control systems rest on concepts developed almost a century ago when the nature of competition and the demands for internal information were very different from what they are today. Now, when companies make arbitrary allocation of corporate expenses to divisions and products, accounting systems may provide even less valid cost data than did the cost accumulation systems in use 50 years ago (Kaplan, 1984). In general though, an accounting model in 19th Century derived for the efficient production of a few standardized products with high direct

labour content, will not be appropriate for an automated production environment where the critical success factors are quality, flexibility and the efficient use of expensive information workers and capital (Kaplan, 1984).

In addition, Kaplan (1984) mentioned that it is doubtful whether any company can be successfully run by numbers alone. Furthermore, it is certainly a fact that the numbers being generated by today's systems provide little basis for managerial decisions and control (Kaplan, 1984). Managers require both improved financial numbers and non-financial indicators of manufacturing performance because no measurement system, however well designed, can capture all the relevant information. Any operational system must be supplemented by direct observation in the field. Accounting and financial executives must redirect their energies, and their thinking, from external reporting to more effective management of their companies' tangible and intangible assets. Yesterday's internal costing and control practices cannot be allowed to exist in isolation from a company's manufacturing environment if the company wishes to flourish as a world-class competitor.

In 1987, Kaplan and Johnson (1987) emphasised that management accountants have been criticised for their inability to innovate and these perceptions continue to persist in light of the relatively low success rate in implementing 'new' management accounting innovations such as activity based costing and the balanced scorecard (Cobb et al., 1992). It is evident that in 1988 the costs of direct labour and materials, which are the most important production factors, could be easily traced to individual products (Kaplan, 1984). Distortions from allocating factory and corporate overheads by burden rates on direct labour were minor and the expense of collecting and processing data made it hard to justify more sophisticated allocation of these and other indirect costs. In the 20th century, product lines and marketing channels have proliferated. Direct labour now represents a small fraction of corporate costs, while expenses covering factory support operations, marketing, distribution, engineering, and other overhead functions have exploded; but most companies still allocate these rising overheads and support costs to their diminishing direct labour base or, as with marketing and distribution costs, not at all. These simplistic approaches are no longer justifiable, especially given the soaring costs of information technology. Current, intensified global competition and radically new production technologies have made accurate product cost information crucial to competitive success (Cooper and Kaplan, 1988).

Table 10: Cost management method progression throughout history

(Source: Adapted from TANIS (1996))

Timeframe	State of Affairs	Methodology
Medieval Era	• Determination of the amount of taxes that were taken by kings • Determining the amount of taxes used in pricing the products people traded during antiquity • In China since 1100 BC - Government auditing, budgetary accounts, expenditure control and periodic reporting • To record every transaction of purchasing wool, the labour expenses and cost of dyers • For the needs of the management of the organisation in controlling the flow of materials and funds and for pricing decisions	• 1318 – Cost bookkeeping • 1350 – Established 2 books, i.e. the results of trading or mercantile activity and the central work-shop data. • 1368 – the book of raw wool purchased , the labourers wage book and the dyers wage book • 14th Century - Product costing • Industrial accounting • Double-entry bookkeeping • Accounts were used in costing products in a very simple way • Very simple forms of cost accounting • 15th Century-control of the cost factors used in production and in the different processes and double entry form • 16th Century-simple forms of cost finding and 8 books that were kept in double entry form • 17th Century – Batch costing • 18th Century – Superior cost management for decision making
19th Century	• Large business enterprises such as cotton and textile mills, iron, steel works etc. appeared with an extensive use of machinery in industrial production • Cotton and textile industries – to reflect the cost flow of the manufacturing process and to co-ordinate, control and increase the efficiency of the conversion process, material and labour utilisation • Iron, steel and metal working industries and railroads – to evaluate and control the internal processes.	• Cotton and Textile industries – integrated with a double entry system that produced a trial balance on a bi-monthly basis • Iron, steel and metal working industries and railroads – element of cost, i.e. material, labour and overhead cost
20th Century	• To evaluate the overall profitability of the company by assessing the efficiency of processes • Making decisions and the behavioural factors that affect managers who use those numbers	• The system was designed to assign costs to products and product lines • Various costing procedures for evaluating cost for financial reports • Direct and indirect costs in strategic product pricing decisions. • Cost information – different costs should be for different purposes. • Cost concept in association with capital budgeting, inventory and cost-volume-profit decision models which were relevant for decisions made by individual manager. • Little innovation occurred until the 1980s.

Until recently little was known about the current state of management accounting practice; and Anthony (1989) stated that information about management accounting practices was abysmally poor and almost all information is anecdotal. However, much progress has been made in research and the teaching of management accounting during the past 20 years (Horngren, 1989). Although the foundation was laid in the nineteenth century, management accounting, as a formal subject on the curriculum, dates back only to the 1940s. Thereafter, new ways of thinking about the topic and new techniques for applying the basic ideas have been developed (Anthony, 1989). Although changes are taking place, firms to a

large extent, continue to rely on outmoded accounting methods (Bright et al., 1992). This lack of innovation was also described by Kaplan (1986) as 'accounting lag' that needs to be minimised in order to keep management accounting relevant to the changing information needs of managers.

After all the shortcomings of traditional of cost management reported between the year 1984 until 1992, Spicer (1992) has claimed that in recent years there has been a remarkable resurgence of interest in both the practice and theory of cost and management accounting. Two factors seem to account for this resurgence. First, it arises from the considerable changes, which have taken place in the business environment as global competition has accelerated the pace of technological change, and the economic deregulation of industry in many countries. These changes have resulted in many pressures and strains on the organisation and management of business organisations and their cost and management accounting systems. Second, the recent writings of Robert S. Kaplan on the direction of management accounting research have been influential (Spicer, 1992).

However, the Drury et al. (1993) survey reported that apart from the implementation of activity based costing by 4% of organisations and the greater use of non-financial measures suggested, most of the organisations have not made any significant changes. Furthermore, Garg et al. (2003) claimed that in today's economic environment, new initiatives aren't high on companies' priority lists and in fact, nearly 80% agreed that implementing new management accounting initiatives is of low to medium priority. In a recent article about cost management, written by Mark Freebairn in the year 2009, he described accounting as starting its life as a reactive function and the main focus at that time was on checking, accounting, paying bills and having wonderful penmanship. Gradually, the role developed, and businesses started to see the value of analysis of historical data. This lived in the world of finance and so the function began to split and created the management and financial accounting function. The very best management accountants started to play with the numbers and to see if the trends they could spot would help them predict what would happen next (Freebairn, 2009).

3.3.2 An Overview of Cost Management in Construction

An analogy from the scenario happening in the manufacturing industry is taken into the construction industry where it is assumed that the innovations in construction production systems and innovations in construction cost management do not run parallel. Therefore, in the subsequent task, the objective of this exercise is to classify the research that has been done in the area of construction cost management in order to review the research status and to link it with the analogy adopted. This indeed will help in finding the gaps and directing the future direction of this research.

The study will look at the issues being discussed and actively researched in this area dating from 1983 until 2010 with the aim of contributing to a framework for the categorisation of literature linked to cost management in construction. The study is based on the analysis of a large number of publications relating to construction cost management which includes books, journal articles and conference papers using relevant databases. Following an extensive literature review, the research activities on construction cost management can be categorised into eighteen (18) divisions which include procurement, cash flow, cost data, economic evaluation method for measuring economic performance, project management, building price indices, cost-benefit analysis, planning and scheduling, earn value method, design, risk, claims, quality, roles of quantity surveyor, safety, lifecycle costing and costs-in-use, cost control and estimation. This evidence is based on the study of twelve (12) literature review papers, twenty eight (28) papers that present empirical study, twelve (12) papers that propose a new way of cost management and forty seven (47) papers that present an empirical study and propose a new way of cost management.

All the issues that have been discussed in those 18 divisions are shown in Table 11, where it was discovered that there are 16 issues being discussed in area of cost management, which include accuracy, integration, decision making/investment, management, unbalancing bid, forecasting, cost reduction, sharing and integration of knowledge, payment, environment, building material, repetitive activities, scheduling, time constraint, internationalisation and maintenance. The biggest issue being discussed regarded the accuracy of cost management that has led to the creation of various techniques for solution.

Another literature review survey that refers only to papers which were presented at the International Group of Lean Construction (IGLC) Conference, from 1999 until 2010, also has been conducted. IGLC was chosen because it is the biggest conference for researchers from all over the world, who are actively involved in lean construction matters. Therefore, a large number of research works, under this topic, can be found in IGLC conference papers. The researcher has decided to use lean principles as the organisational mechanism to look at the whole range of problems embedded in construction cost management: which include the entire set of activities entailed in creating and producing a specific building, from concept through detailed design to actual availability, from the initial intention and production scheduling to delivery, and from raw materials produced far away and out of sight directly into the hands of the client.

Lean principles are about production and have proved to be successful in manufacturing. Given the analogy of manufacturing used in this study, the status of the implementation of lean construction in

construction cost management was studied. It is also known that the group of professionals in this area, namely the International Group for Lean Construction, has a goal that is in line with the aim of improved cost management "is to better meet customer demands and dramatically improve the AEC process as well as product. To achieve this, we are developing new principles and methods for product development and production management specifically tailored to the AEC industry."

The result of the literature review that refers only to papers which were presented at the IGLC indicates a slight difference from the findings indicated in Table 11. The research status within this group indicated that the use of lean principles in construction cost management only started in 1999. It is also believed that after more than eleven (11) years of use in the construction industry, the number of divisions and issues studied are still small and not diverse. The research findings can be divided into eight (8) divisions which include: lean principles; target costing, kaizen costing and activity-based costing (ABC); economic evaluation method; cost planning; cost control; overhead costs; cost reduction and innovation. The status of research activity in construction cost management that relates to lean principles shows that researchers were keen to focus more on the development and improvement of existing techniques by using lean principles. Very little research has been undertaken in other areas. Various angles have been explored in the research study in order to improve the performance of the traditional construction cost management. Seven (7) issues, as shown in Table 9 have been identified in the literature review

It seems that accuracy is the biggest problem in this area; based on the literature review findings shown in Table 11 and Table 12. Decision making is also an important aspect that has captured the attention of many researchers. It is agreed that high accuracy in forecasting is very important in order to make the right decision to create large profit margins for the customer. Based on the problems identified, many improvement and development techniques and processes have been proposed for achieving cost effectiveness (cost reduction, value improvement and substitution) for accurate decision making and investment.

3.3.2.1 An Analytical Taxonomy in Construction Cost Management

Starting from the year 1983, many issues have been highlighted in research studies in the area of construction cost management. Some of these studies and guidance were built on the findings from previous studies, and some were developed and tested for the first time. The research studies have been classified into eighteen (18) divisions that include procurement, cash flow, cost data, economic evaluation method for measuring economic performance, project management, building price indices, planning and scheduling, cost-benefit analysis, earn value method, design, risk, claims, quality, roles of

quantity surveyor, safety, life cycle costing/costs-in-use, cost control and estimation. Further elaboration on the research findings are presented in the following paragraphs.

Procurement

The first finding from research undertaken in the area of procurement is that procurement is used to regulate the performance of contractors and not to install construction materials. By doing so, this results in an overall lower first cost to the owner and increases the quality of the work (Kashiwagi and Savicky, 2003). Another research in this area, touched on the accuracy between estimates and tender that creates excessive discrepancy that may lead to disruption of construction and budget programmes (Wilson et al., 1987).

In addition, three (3) researches highlighted the same issue about unbalanced bidding. Arditi and Chotibhongs (2009) presented a model that allows owners to detect and reject unbalanced bids, and deters bidders from unbalancing such bid. Whereas, Cattell et al. (2008), proposed a model incorporating all three standard effects of item price loading: namely, front-end loading, individual-rate loading, and back-end loading, that gives the effect of determining the optimum pricing for a project's component items. Another solution is a method that optimises the allocation of overall project profits to individual activities by considering the financial parameters of a project (bid mark-up and projected cash flow), in conjunction with lowering the exposure to possible financial disorder in the project, resulting from limited monetary resources available to the project and from badly developed project cash flows (Christodoulou, 2008).

Cash Flow

Ten (10) researches have been undertaken between 1986 and 2010 in this sub-division. The problem identified by the researchers was the inaccuracy of predictions to project cash flow. Cheng et al. (2010) have used artificial intelligence approaches to make reliable predictions regarding cash flows to enhance project cost management. Tucker (1986) has identified this problem in a large building project and has used mathematical formulation and analogy between the probability of failure in reliability theory and the probability of payment during construction as a solution. In the same year, another study has identified that the nomothetic approach is not accurate in representing cash flow because it does not reflect the individual projects and cannot be used for forecasting (Kenley and Wilson, 1986). Banki et al. (2008) have highlighted the limited time for a detailed pre-tender cash flow forecast and proposed simpler and quicker techniques by producing a standard curve for each project group.

Table 11: The cost management status

Issues	Authors	Frequency
Accuracy	Wilson et al. (1987), Tucker (1986), Kenley and Wilson (1986), Flanagan and Norman (1983), Yin and Liu (2008), Krigsvoll (2007), Moon et al. (2007), Powell (1986), Hyari et al. (2009), Ã–Kmen and Ã–ZtaÅž (2010), Beeston (1986), Xie and Huang (2007), Wang and Zou (2008), Hallowell (2010), Johnson and Sherif (1987), Bird (1987), Lai (2010), Guo et al. (2010), Arja et al. (2009), Cheng et al. (2009), Kong et al. (2008a), Wu et al. (2008), Li et al. (2009), Saito et al. (1991), Cheng et al. (2010), Aibinu and Pasco (2008), Morrison (1984), Li-Chung (2010), Liu et al. (2009b), Liu et al. (2009a), Jablonowski and MacEachern (2009), Liu and Napier (2010), Chou and O'Connor (2007), Shi and Li (2008), Cusack (1985), Newnes et al. (2008), Flanagan and Norman (1983), Tseng et al. (2009), Girmscheid (2007)	38
Integration with value, benefit, quality and risk in cost management	Vertenten et al. (2009), Xu and Ieee (2009), Kunhee et al. (2009), Jang and Skibniewski (2009), Higuchi and Macke (2008), Carter and Keeler (2008), Villar and Lopez (2008), Rosenfeld (2009), Brandon (1984), Dolacek-Alduk et al. (2009), Selles et al. (2008), Benjaoran (2009), Flanagan et al. (1987), Cheung et al. (2008), Wallace (1987)	15
Decision making / Investment	Marshall (1985), Scott (1984), Marshall (1987), Cheng and Wu (2007), Ji and Li (2009), Kong et al. (2008b), Sungmin and Caldas (2009), Gerbrandt and Berthelot (2007)	8
Management	Lu et al. (2007), Ireland (1985), Li et al. (2008), Abdallah (2007), Dukic et al. (2007), Yakubu and Sun (2007), Gao and Li (2007), Yang and Zhang (2007)	8
Unbalancing bid	Ali and Elazouni (2009), Qingbin et al. (2010), Chen et al. (2008), Arditi and Chotibhongs (2009), Cattell et al. (2008), Christodoulou (2008)	6
Forecasting	Taylor and Bowen (1987), Huntington and Ksaibati (2009), Chou (2009b), Chou (2009a)	4
Cost reduction	Kashiwagi and Savicky (2003), Nakamura et al. (2009), Xiao et al. (2009)	3
Sharing and integration of Knowledge	Gray (1986), Wang et al. (2008b), Xiao et al. (2008)	3
Payment	McDonald (1984), Zhao et al. (2009)	2
Environment	Pellegrini-Masini et al. (2010), Xiao et al. (2008)	2
Building material	Mei and Guo (2009), Wang et al. (2008a)	2
Repetitive activities	Liu and Wang (2009)	1
Scheduling	Liu and Wang (2008)	1
Time constraint	Banki et al. (2008)	1
Internationalization	Kim et al. (2008)	1
Maintenance	Bromilow and Pawsey (1987)	1

Table 12: The status of cost management papers in IGLC conference

Issues	Authors	Frequency
Improvement and preparing for the usage of modern cost management (ABC, Kaizen costing, target costing, reducing supplier in the supply chain and performance measurement tools) in construction industry	Simões et al. (2008), Jacomit et al. (2008), Pennanen and Ballard (2008), Robert and Granja (2006), Granja et al. (2005), Ballard (2006), Sobotka and Czarnigowska (2008), Kim and Ballard (2001), Xiao and Guo (2009), Marchesan and Formoso (2001), Zimina and Pasquire (2010), Miller (1992), Simões et al. (2008), Robert and Granja (2006)	14
Decision making (accuracy in estimating, economic performance, information flow, integration of techniques, development for improvement from the point of view of lean principles)	Abreu and Neto (2008), Morton and Ballard (2009), Nguyen et al. (2008), Kim and Ballard (2001), Xiao and Guo (2009), Marchesan and Formoso (2001)	6
Initial steps on the implementation of lean setting in cost management with the objective to improve the current traditional techniques	Orrechia and Howell (1999), Alarcón and Ashley (1999), Xiaolin (2007)	3
Cost reduction	Xiaolin (2007), Forsberg and Saukkoriip (2007)	2
Improvement in cost control	Kern and Formoso (2004), Gong and Tian (2009)	2
Improvement in the allocation of overhead	Kim and Ballard (2002)	1
Waste reduction (by increasing productivity)	Forsberg and Saukkoriip (2007)	1

The issue highlighted in another research is about managing cash flow of more than one project which has repetitive activities. It emphasised that projects with more than one activity need to conduct project cash flow forecast circularly (Lu et al., 2007), whereas projects with repetitive activities use a two-stage profit optimisation model for linear scheduling problems using constraint programming (CP) (Liu and Wang, 2009). Liu and Wang (2008) also highlighted that resources incur activity costs and should be considered in the preparation of project cash flow.

Another issue concerns unbalancing bids. Ali and Elazouni (2009) try to tackle this issue by having balanced expenditure with available cash. Whereas, Qingbin et al. (2010) try to solve the issue related to extra interest expenses because of additional overdraft by identifying feedback loops in project cash flows and a system dynamics model is developed for project cash flow management. Another research has proposed using factoring account receivables for construction project financing in order to overcome cash flow fluctuation (Chen et al., 2008). Optimising the allocation of overall project profits to individual activities by considering the financial parameters of a project, in conjunction with lowering the exposure to possible financial disorder in the project is another solution proposed (Christodoulou, 2008).

Cost Data

Flanagan and Norman (1983) discussed the accuracy and monitoring of quantity surveyors' price forecasting for building work and suggest having feedback mechanisms of previous forecasts. The accuracy of the estimate can also be enhanced by proposing the use of the Construction Project Cost Information Platform scheme and running a model that satisfies modem project management's requirement and using an information platform which covers the project life cycle (Yin and Liu, 2008). Another way to obtain an accurate estimate is by having extended use of BIMS, with the development of Information Delivery Manuals (IDMs) for environmental assessments, energy calculations and LCC (Krigsvoll, 2007). Moon et al. (2007), proposes a probability model to support the functionality of OLAP (On-Line Analytical Processing) that could help to project more reliable construction costs because the costs of different classes of buildings differ from one another and they change over time relative to one another (Powell, 1986).

Economic Evaluation Method for Measuring Economic Performance

All these three (3) studies aim to find solutions to help investors to make the right decisions in their business planning. Marshall (1985) has tried to find alternative ways of economic evaluation besides payback, which include intangible benefits (residual costs). Whereas, Scott (1984) researched

alternative procedures for economic evaluation of minor works and Marshall (1987) studied economic evaluation in the narrow context of methods of capital investment analysis applied to building investments.

Project Management

Ireland (1985) studied the role of managerial actions in achieving the objectives of reducing cost, reducing time and increasing quality performance on high-rise commercial building projects, whereas Li et al. (2008) highlighted that modem construction project management should not only pay attention to vertical management at every stage of the life-cycle, but also emphasise horizontal linkages for every element of integrated cost management.

Building Price Indices

Researchers have examined a number of forecasting techniques from a hierarchy of forecasting techniques and assess their suitability via the vehicle of the BER building cost index (Taylor and Bowen, 1987). In addition, BCIS Online provides services that include measuring price movement, benchmarking, market research, statistical analysis, forecasting, and impact studies, are broken down into five key areas, i.e. construction, maintenance, rebuilding, consultancy and insurance (BCIS, 2013)

Cost-benefit Analysis

The survey results by Kunhee et al. (2009), showed that the additional cost of the outreach programme was outweighed by the savings achieved from reduced road user delay costs ona 4.5km highway project that initially received strong objection from the road user. Another research by Jang and Skibniewski (2009) has tackled the issue of illustrating labour savings associated with construction materials handling by comparing manual and sensor-based material tracking.

A cost-benefit analysis for planning rehabilitation efforts of deteriorating structures is proposed where proper planning of rehabilitation allows the lifetime of a structure to be extended as long as the expected costs for such efforts outweigh the expected future benefit (Higuchi and Macke, 2008). Carter and Keeler (2008) researched the use of the green roof (using vegetation on a rooftop) for restoring the environmental integrity of urban areas and identified that even though it is more expensive, it gives a better account of the green roofs' total costs and benefits to society and to the private sector.

Planning and Scheduling

Hyari et al. (2009) have provided the planners of repetitive construction projects with an automated set of optimal time-cost trade-off solutions. The output of the model is a set of optimal solutions that represent the trade-off between time and cost that result in cost-effective and speedy delivery.

Earn Value Method (EVM)

In accordance with national planning, valuation with bill quantity (VBQ) will be the main valuation mode of the construction project in future and Xu and Ieee (2009) have analysed the price compositions and characteristics of a construction project under VBQ by using EVM to control construction project costs. Vertenten et al. (2009) have explored the concept of Earned Value and how it is related to Project Control and Project Management which focused more on the South African environment since private industry is now implementing Earned Value Performance Management (EVPM) for major projects, which are large, complex or geographically disperse. Currently, sophisticated and complex ICT development is not yet applicable to the small and-medium-sized contractors. Therefore, Benjaoran (2009) has taken the initiative to use a collaborative approach to develop a new efficient cost control system on the earned value concept using available ICT tools which are familiar and easy-to-learn. A collaborative approach can ensure the diffusion of technology to these companies.

Design

Gray (1986) has conducted research that takes the knowledge used by the contractor and makes it available to the design team through an Intelligent Knowledge Based System (IKBS), a model that can predict Time & Cost.

Risk

Cost estimation is an important task in construction projects. Since various risk-factors affect the construction costs, the actual costs generally deviate from the estimated costs in a favourable or an adverse direction (Ökmen and Öztaş, 2010). There are three (3) researches discussing estimation and the need to use risk allowance in order to increase the estimation precisions. Beeston (1986) used the Monte Carlo Method to help in the calculation of this estimation, Ökmen and Öztaş (2010) proposed the Correlated Cost Risk Analysis Model (CCRAM) to analyse the construction costs using uncertainty when the costs and risk-factors are correlated. Whereas, Xie and Huang (2007) have presented a novel model of risk analysis of construction cost based on intelligent information processing (IIP) technology.

Furthermore, research on the risk evaluation is carried out by exploring steps and methods of risk analysis on construction project cost. This is to provide a fluctuating range of the investment budget in order to evaluate the possibility of carrying out such practice under various factors that affects the investment amount (Cheng and Wu, 2007). Whereas, Wang and Zou (2008) have carried out research which tries to identify the major cost-overrun risks and have identified that matters related to human aspects and project participants are the major causes. They also developed strategies to manage them.

Claims

In 1984, McDonald (1984) found that an owner who cannot obtain proper and timely performance by his contractor is bound to suffer extensive financial damages. Therefore, the owner should be fully aware of his duties to sensibly evaluate any claim against the contractor and minimise his damages in the event of the contractor's breach of contract in order to avoid incurring an unrecoverable loss. In China, unlike the situation in the international construction market, there is fierce competition among contractors due to the irregular operation of the construction market, therefore, little consciousness of claims and so forth means the contractors do not utilise the lever of claims well enough. Zhao et al. (2009) analysed how to select the most appropriate methods to computing claim amounts and fulfil the aim of integrated management in order to accelerate the development of construction claim in China and enhance Chinese companies' international competitiveness.

Quality

Quality costs are an effective tool to measure the continual improvement in a quality management programme (Villar and Lopez, 2008). Rosenfeld (2009) has studied how to determine the optimal level of investment in quality by construction companies and his findings reaffirm that investing in quality is a worthy effort.

Monetary value for quality (hidden quality cost) is very subjective and therefore client and consultant should be made clearly aware of the level of quality during the initial stage to avoid a lack of understanding between both parties; and it is also apparent that the cost consultant lacks refined techniques for both describing and evaluating the possibilities open to his client at an early stage (Brandon, 1984). Two (2) researches have proposed a solution to this problem by formulating a quality cost management model by defining the quality cost structure and characteristics of individual components and the proportion of quality costs in the total contract price of projects (Dolacek-Alduk et

al., 2009). Whereas, Selles et al. (2008) developed a quantification proposal for those quality costs that construction companies cannot estimate through objective criteria.

Another research by Villar and Lopez (2008), touched on the issue of design, where it proposes an approach for measuring and tracking Quality Costs in the Design of Construction Projects (QCDCP), based on the Process Cost Model (PCM) and on the Projects Design Methodology of the Technical University of Catalonia (MDP-UPC).

Roles of Quantity Surveyor

The role of the Quantity Surveyor needs to be changed from a technically-based process to a scientifically-based discipline. The paradigm shift is seen as the need to move from a deterministic stance, where cost models and price forecasts are based upon 'single-figure' presentations to a more honest representation of reality in which price variability is explicitly considered (Bowen and Edwards, 1985). The estimators' task has been made more difficult by the changes in industry structure because of the extent to which the use of sub-contractors has grown in recent years in the UK by reviewing the growth of small firms, who in the main act as sub-contractors (Abdel-Razek and McCaffer, 1987).

Safety

In recent years, incident rates have declined as a result of improvements in safety management. However, little is known about the cost-effectiveness of these strategies. The results indicate that the most cost-effective safety programme elements are subcontractor selection and management and upper management support and commitment. Alternatively, the least cost-effective elements are the employment of a full-time safety manager and record-keeping (Hallowell, 2010).

Life Cycle Costing and Costs-in-use

A research on life cycle costing started in 1987, by Bromilow and Pawsey (1987), where they reviewed the nature and incidence of maintenance and other operations from records of past projects detailing what has been done to each building and using this as a basis to infer future needs. This is followed by Johnson and Sherif (1987) who have developed an understanding of how life-cycle cost models might be more appropriately applied to improve university research facility performance. In the early stage, Bird (1987) carried out a literature survey on the topic of costs-in-use to identify the client interest in building running costs, principles and problems of costs-in-use and research programme & objectives.

Various methods were integrated with life cycle costing to enhance its function. Flanagan et al. (1987) researched the use of various risk management systems that can be incorporated in life cycle costing

that will identify the source of the ambiguity in the decision advice and can better inform the decision making process. Cheung et al. (2008) proposed a life-cycle cost (LCC) management methodology that integrates corrosion deterioration and fatigue damage mechanisms. Whereas, Wallace (1987) considered the development of design team communication, particularly conflict development, in relation to the essential incompatibilities between capital cost minimisation and cost-in-use optimisation objectives and how this relates to design team development.

To further enhance this technique, Lai (2010) has researched the significance of whole-life costs for building operation and maintenance (O&M) and outlines a framework of improvement measures. A lack of effective information sharing platforms existing in life-cycle management (LCM) has been identified and a virtual prototyping (VP)-based communication and collaboration information platform is proposed by using DASSAULT software (Guo et al., 2010). Arja et al. (2009) have proposed new formulae for integrating factors causing uncertainty into the calculation of LCC and cost indicators are suggested for the LCC evaluation of similar buildings. Xiao et al. (2008) studied the income and cost of construction engineering which has a lengthy construction period and requires large investment during the entire life cycle; and uses the information to estimate the value of the construction engineering to determine the rationality of construction engineering and further control the environmental pollution engineering to determine the rationality of construction engineering and further control the environmental pollution.

It has an important place in business planning and investment where the most common characteristic of all the methods described in capital investment analysis is considering benefits (savings) and costs over the project's life cycle or study period (Marshall, 1987). Eight (8) steps involved in making an economic evaluation are presented in this study. It is also used to demonstrate the economic considerations undertaken in evaluating alternative road design and construction methods (Gerbrandt and Berthelot, 2007). From an environmental perspective, Pellegrini-Masini et al. (2010) have carried out a research study to investigate the technical and social aspects of reducing the CO2 emissions of UK domestic housing by researching the whole life costs of three sets of energy demand reduction technologies for existing housing.

Nakamura et al. (2009) have researched stock management to maintain the long life of irrigation facilities and this contributes to efficient budget implementation through the reduction of rehabilitation and the renewal of projects expense. Cho (2008) presented an overview of recent progress of Life-Cycle Civil Engineering (LCCE) in Korea with a critical review of the state-of-the-practice, and the

recent research & development of models and methodologies in LCC analysis, design, and management of civil infrastructures, with emphasis on bridge structures.

Cost Control

These two (2) researches integrate whole life cycle costs for cost control. On the premise of ensuring the design quality, the whole life cycle cost can be reduced in the optimal target by using value analysis. Based on the analysis of the cost in every phase of the construction project life cycle, this study builds on the estimation model of life cycle cost (Xiao et al., 2009). Another research used life cycle-oriented analysis that takes account of maintenance and operating costs and calculation of investment volume. As such, not only the cost side is analysed, but the marketing side of the property is also studied. This research has presented a holistic, probabilistic cost control model as a solution (Girmscheid, 2007).

Two (2) researchers studied the importance of material cost. Mei and Guo (2009) identified that material cost accounts for 60% -70% of the total capital cost and this study claimed that material cost management in construction enterprises is the key to the cost control of the construction project. Wang et al. (2008a) also confirmed that the material cost accounted for 70% of the total project cost. This research applies the theory of logistics management in the control of the material costing and results in controlling the whole process of the material procurement, transport, store, portage and so on, which affects various logistic activities realising the best harmony and cooperation.

Wang et al. (2008b) integrated the information of cost data, operators, computer hardware and software and corresponding methods to organise the scattered cost data and have dynamic control of the method of construction project costs. This would allow possible decision makers to have real-time dynamic project costs.

Yakubu and Sun (2007) identified the common project control practices, the factors that affect the control of cost and time and the important factors affecting the ability to effectively control cost and time of construction projects. It was therefore recommended that construction companies not only need to apply appropriate cost and time control methods but also need to consider and manage the potential impact of "project control inhibiting factors". Furthermore, Gao and Li (2007) proposed concrete measures for cost control during the entire process of a real estate development project which contains four stages: decision-making, design, construction and sales. Yang and Zhang (2007) built an analysis of management of costs at each stage of capital construction and management of each item. They produced a construction model for the whole process of each capital construction item and acquired

proof and analysis about the principles and correlative requirement of the construction model, thus reaching a target which places items under scientific management and controls rational costs.

Estimation

There are 29 researches being carried out under this sub-division. Many researchers have focused on the issue of accuracy and have developed various methods as solutions to the problems (Cheng et al., 2009b, Kong et al., 2008a, Wu et al., 2008, Li et al., 2009, Saito et al., 1991, Cheng et al., 2010, Aibinu and Pasco, 2008, Morrison, 1984, Li-Chung, 2010). Many new techniques have emerged to enhance the accuracy of estimation (Liu et al., 2009b, Liu et al., 2009a, Jablonowski and MacEachern, 2009, Liu and Napier, 2010, Chou and O'Connor, 2007, Shi and Li, 2008). With sophisticated and complex ICT development, many researchers have proposed the use of technology in the task of estimation (Cusack, 1985). This has improved the working environment and also helps in project management (Abdallah, 2007, Dukic et al., 2007).

A new concept is emerging of integrating and incorporating many new aspects in the traditional method of estimating (Newnes et al., 2008). Currently, people are looking at things differently and this is also happening in estimating where precision is the ultimate goal and not accuracy (Flanagan and Norman, 1983, Beeston, 1986). The meaning of accuracy is how close a measure is to the real value (Mondofacto, 2012a), whereas precision, is the number of decimal places to which a number is computed (Mondofacto, 2012b). With a precise estimation investors can make the right decisions for their business planning (Ji and Li, 2009, Kong et al., 2008b, Yun and Caldas, 2009). Precision helps contractors to be financially successful in international projects (Kim et al., 2008). There are another five (5) studies which focus on several issues of estimation in transportation projects (Huntington and Ksaibati, 2009, Chou, 2009b, Chou, 2009a), problems of unbalanced bids (Cattell et al., 2008) and allocation of contingency.

3.3.2.1.1 Discussion

Figure 18 demonstrates the status of research activities in the area of construction cost management based on literature findings gathered from 103 academic journal papers that have been published between the 20th century and 21st century. Comparisons in research activity have been made between these two (2) eras and have shown that the research under the category of the roles of QS, economic evaluation methods, and design and building price indices has declined in 21st century, whereas research activity in the rest of the sub-divisions has increased. In the 20th century, researchers were

interested most to study cost management under the topic of life cycle costs whereas the situation changed in the 21st century, where estimation was the most researched sub-division.

However, Figure 19, which shows the research activities in current years, indicates that no research activity was undertaken in terms of the roles of QS, economic evaluation methods, design and building price indices. Very little research and no progress were shown in terms of research activity undertaken in the areas of procurement, claims, safety and planning and scheduling between 2003 and 2010. Project management, tendering, cost data, earn value method, cost-benefit analysis quality and risk show higher research activity compared with the group previously discussed. However, comparing the research activities in 20th century and 21st century, the growth of the research activities in current years is very slow. The research activity in cost control, cash flow, life cycle cost and estimation has gradually increased since 2003. Estimation shows the highest number of research activities in the cost management area between 2008 and 2010. However, life cycle costing marks the highest research activities in 2007. This shows that researchers have shifted their interest from cost control to estimation over its entire life (whole life cost) based on the frequency of research activities shown.

Issues that were discussed in all of the sub-divisions can be classified in different groups which the researcher has categorised into 16 groups, which include lower first cost, accuracy, individualism, internationalisation, integration, decision making, managing more than one project, repetitive activities, repetitive projects, unbalancing bid, fluctuation, resources, balanced expenditure, saving, labour, environment and maintenance. Most of the issues discussed centred on accuracy in cost management and has led to various techniques being proposed as solutions.

Figure 18: The status of cost management research activities between 20th century and 21st Century.

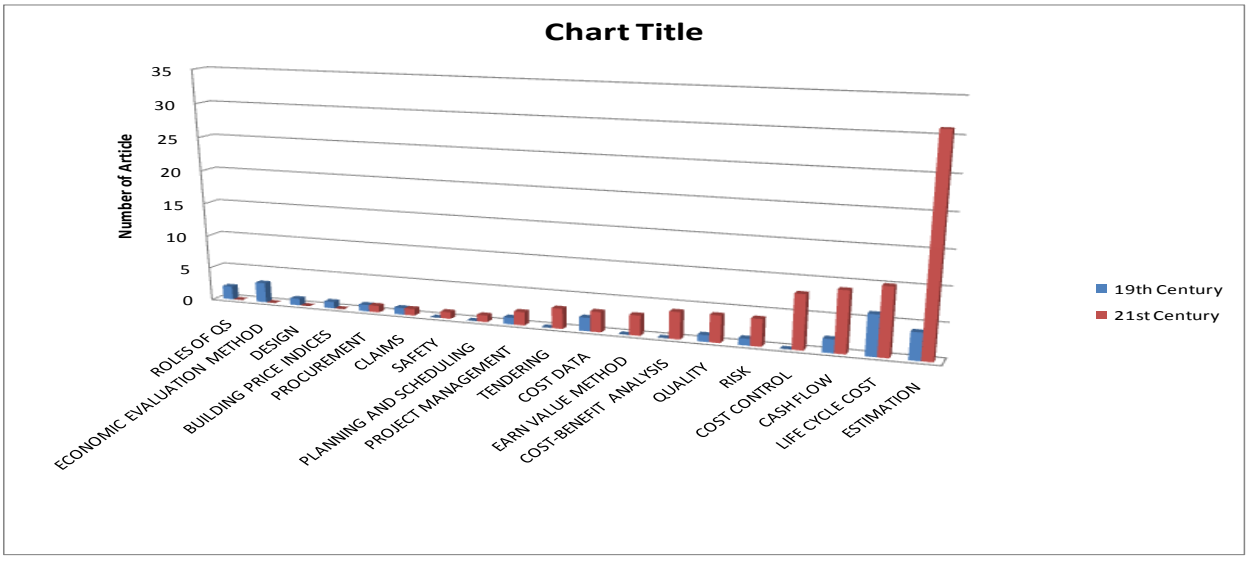
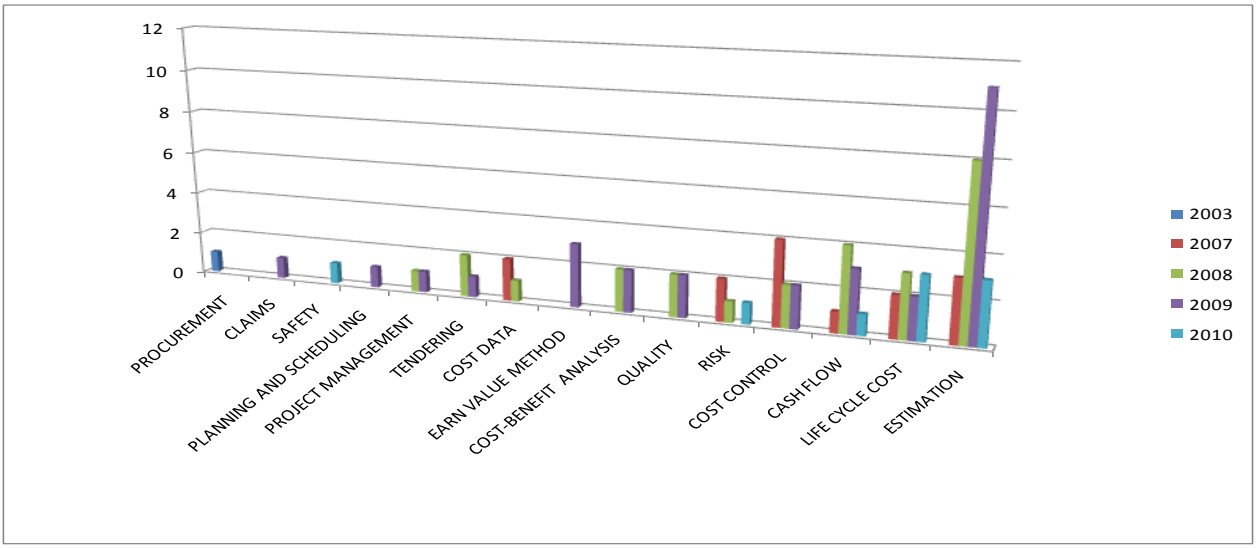


Figure 19: The current situation of research activities in the cost management research area.



3.3.2.2 An Analytical Taxonomy in Cost Management Research in IGLC

This section discusses all the papers presented at the IGLC Conference. A group of people founded The International Group for Lean Construction (IGLC) in 1993. It is a network of professionals and researchers in architecture, engineering, and construction (AEC) who feel that the practice, education, and research of AEC needed to be radically renewed in order to respond to the challenges ahead. They have called their mission 'Lean Construction'. Their goal in line with this mission "is to better meet customer demands and dramatically improve the AEC process as well as product (Tommelein, 2002). To achieve this, we are developing new principles and methods for product development and production management specifically tailored to the AEC industry, but akin to those defining lean production that proved to be so successful in manufacturing". Therefore, a literature review referring to all papers related to cost management in this conference is necessary.

It was only in 1999 that research in the area of cost management started to receive attention from the people interested in lean construction. Therefore, starting from the year 1999, many issues have been highlighted in research studies in the area of construction cost management. Some of these studies and guidance were built on the foundations of findings from previous studies, and some were developed and tested for the first time. The research findings can be divided into eight (8) divisions which include: lean principles; target costing, kaizen costing and activity-based costing (ABC); economic evaluation method; cost planning; cost control; overhead costs; cost reduction and innovation. Further elaboration on the research findings are presented in the following paragraphs.

Lean Principles

Starting in 1999, the issue of money in lean construction began to increase. Two (2) papers were found in the Proceedings of Seventh Annual Conference of the International Conferences on Lean Construction, 1999. The first paper was considered to be a first step in considering money in the lean setting and considering the problems that existed in cash flow by using various lean techniques to overcome those problems (Orrechia and Howell, 1999). Another paper in the 1990s evaluated the impact of lean production strategies on project costs and scheduling. In 2007, another research study on the application of lean principles in mainstream cost management in the construction industry was carried out. In this paper, lean principles were used to decrease project costs and also compare the main differences in cost management between lean construction and traditional thinking and presents cost management processes and control methods. Finally basic works which must be established in a construction project is proposed (Xiaolin, 2007).

Target Costing, Kaizen Costing and Activity-based Costing (ABC)

This scenario has led to many studies in construction cost management adopting the techniques of manufacturing cost management in construction industry cost management. Three (3) popular methods that are frequently used are target costing, kaizen costing and ABC. These are modern construction cost management methods that were co-opted from the manufacturing industry. As an initial step in the transference to target costing, this study analysed the applicability of target costing concepts and principles to the development of a project and also studies the information flow in order to analyse the supply chain as a business (Simões et al., 2008).

To improve the usage of target costing in the construction industry, Jacomit et al. (2008), have conducted a study that compared the flowchart in manufacturing and with case studies in the construction industry. None of the cases studied covers a completed target costing implementation as envisioned in manufacturing and further development for improvements are suggested. Another research has evaluated the extent to which target costing applied to construction projects matches up with the target costing methodology used in product development. The study also presents a building information model to define expected cost that uses customer requirements for the spaces and site conditions as initial information and develops the life cycle costs of the spaces (Pennanen and Ballard, 2008).

Integration of more than one modern construction cost management system was also use in order to increase the performance of the cost management system. believe that an integration between target

and kaizen costing to be a promising strategy to increase profit margins, efficacy of production processes and relationship with suppliers. The case study results show cost reductions of around 13% compared with previous cost data from the company for these facilities. A further two studies that integrate these two systems aims to develop a framework that provides a basis for a total cost-management system during the project's life cycle (Granja et al., 2005) and a study to integrate target costing into the project definition phase of project delivery, where it is widely agreed that the project definition phase is often ill performed (Ballard, 2006). A study by Sobotka and Czarnigowska (2008) integrated target costing with public-private partnership (PPP) to shrink the actual cost of the product (a built facility) to target level during the product planning process and production.

To support the need for further research into target costing, one study implemented target costing at the design stage with the aim of designing to target costs (Ballard and Reiser, 2004) and a study on target cost control was carried out (Zhao and He, 2009). It concluded with recommendations for next the steps in developing a methodology for designing to target costs in the construction industry.

Another study conducted by Kim and Ballard (2001) presented an application of ABC to the construction industry and explored the relationship between ABC and lean construction. It shows that lean project control can encompass cost control by adopting an ABC system. Other researches on ABC include an analysis of the necessity and feasibility of construction enterprises applying ABC and introducing a detailed procedure later (Xiao and Guo, 2009) and a study on the development of a cost accounting system to manage production processes in the construction industry and devised a model that integrates this system to the production planning and control process based on the new operations management paradigm and on the ABC idea (Marchesan and Formoso, 2001).

Economic Evaluation Method

This study uses Real Option Model in economic evaluation for measuring the economic performance of projects in the construction industry on environmental aspects in which uncertainty is a key characteristic (Abreu and Neto, 2008).

Cost Modelling/Cost Planning/Estimation

Morton and Ballard (2009) have proposed a new technique to achieve an accurate and feasible method for determining the expected cost directly from customer requirements; whereas Nguyen et al. (2008) have demonstrated a new technique that integrates set-based design and production system design to avoid making wrong decisions.

Cost Control

This paper discuss mainstream cost management practices in the construction industry and proposes some guidelines for improving cost control in fast, complex and uncertain construction project. Such guidelines involve the integrated application of operational cost estimating, target costing and S-curves (Kern and Formoso, 2004). Whereas, Gong and Tian (2009) studied the cost control of lean construction based on the calculated PPC principle (the principle of calculating the rate of task completion) that result in saving to the inputs of raw materials and controls the construction progress precisely.

Overhead Costs

Construction projects become complicated and fragmented so that many specialty contractors are involved. In such changed environments a general contractor's overhead costs are increasing comparable to direct costs. In addition to an increase of volume, activities consisting of overhead costs play an important role in coordinating different participants which includes different specialty contractors and clients. This research reviews traditional control of the overheads and critiques the problems thereof through the literature review, interviews with professionals, and data collection. It proposes a new overhead cost control method called profit-point analysis (PPA) applying ABC. It is followed by the presentation of a case study exemplify the new method (Kim and Ballard, 2002).

Cost Reduction

In the study of Forsberg and Saukkoriipi (2007), they highlighted that an enhanced level of labour productivity will automatically upgrade the level of value added activities and thereby can reduce waste and cut down production costs.

Innovation

Miller (1992) stated that as organisations adopt TQM and JIT and focus their efforts on improving quality, reducing cycle time and providing increased customer satisfaction, they require a new cost management system that suggests provision of information about how well activities are being performed and whether improvements are working. Reducing the number of suppliers resulting in redefinition of the unit of analysis by elimination of unnecessary cost in the entire value chain/network from raw material to customer (Zimina and Pasquire, 2010) is another way of improving the mainstream cost management.

3.3.2.2.1 Discussion

An initial implementation of lean principles in construction cost management started with two researches considering money in the lean setting in 1999. Most of the areas studied were in the application of modern construction cost management which includes target costing, kaizen costing and ABC. There are two (2) research papers studying cost control and estimation; whereas, only one study exists in each of these divisions: overhead costs and economic evaluation. A variety of issues was discussed in all of these divisions which included seven (7) issues. The issues are: i) initial steps on the implementation of lean settings in cost management with the objective of improving the current traditional techniques, ii) cost reduction, iii) improvement and preparation for the usage of modern cost management (ABC, Kaizen costing, target costing, reducing supplier in the supply chain and performance measurement tools) in the construction industry, iv) decision making (accuracy in estimating, economic performance, information flow, integration of techniques, development for improvement from the perspective of lean principles, v) improvement in cost control, vi) improvement in the allocation of overheads and vii) waste reduction (by increasing productivity)

Lean principles in construction cost management started in 1999 and after more than eleven (11) years since its application in to the construction industry, the frequency of division and the issues studied are still moderate and unvaried. The status of the research activity in construction cost management that is related to lean principles shows that more researchers were keen to focus on the development of target costing, kaizen costing and ABC. Few researchers studied any other areas. All research in cost management, which comprises eight (8) divisions, were studied from a variety of angles in order to improve the performance of traditional construction cost management.

3.4 The Shortcomings of Mainstream Cost Management

It seems that innovation in manufacturing production systems and innovations in cost management do not run parallel. Therefore, this has generated a long list of shortcomings to the existing cost management process. The changes in production systems have created a very different demand for internal information and overhead allocation. The overhead allocation, which is based on direct labour costs, has become inaccurate with a complex system because the current system depends only on low labour content; whereas the truth is that the overhead allocation has exploded in the current system because of the use of modern production system. This situation has made mainstream cost management inappropriate to derive product costs due to the inaccuracy of the estimates produced.

Therefore, it seems that all the efforts expended on the improvement of the production system do not succeed. The old cost management system is a system that works backwards by looking at past performance and giving few real pointers (if any) of how to improve in the future and does not accurately reflect the improvements made. In addition, the way the traditionalists think has resulted in wrong decisions being taken because they observe matters differently and do not realise the breakdown that exists in the production process. Most of the decision makers seem to believe that producing, irrespective of demand, was rewarded with positive variances and greater profit. Furthermore, increases in terms of pages and complexity to the rules and regulation of accounting principles (GAAP) have led to a more complicated and complex application of mainstream cost management.

Changes in market conditions have also become one of the causes for the drawback in cost management. Transformation is happening in the way companies now run their business; where demands come from all over the world and not only from the local market. The global market offers wider opportunities to these companies and production of higher quantity and quality of products is required. Therefore, again, this encourages invention of a new production system to cater to the changes in demand and a different way of managing cost management is also required to manage businesses efficiently.

A similar situation is also taking place in the construction industry. Shortcomings in cost management in the construction industry were also identified in the literature review findings. The following are a few of the shortcomings that were found: generate inaccuracy in the estimation of the project costs where it is difficult to examine precisely the effect of design changes in the production costs; and although time is a factor of major importance in construction costs, traditional cost estimating methods do not offer any reliable guidance for assessing the impact of production duration on project costs.

Therefore, it seems that generally, mainstream cost management has become mostly irrelevant for managerial purposes and weakens production because it cannot provide accurate product costs. These traditional financial measures provide an inadequate summary of a company's manufacturing operations. The systems fail to stimulate decisions that can affect the overall production result. The systems are of little help to managers in their effort to improve production performance or product-related decisions. It is believed that cost management systems must be dynamic, proactive and able to support different decision-making processes in order to protect the business from the harmful effects of uncertainty.

Cost management has become the subject of increasing interest, in recent years to academics and practitioners, and the shortcomings of mainstream cost management have received more attention since the early 1980s based on the number of research studies found in this area.

The first set of criticisms of managerial cost accounting is aimed at methods used to derive product costs. The main case against current product costing practices is that they provide inaccurate estimates of product cost, thereby failing in their function of helping management make product-related decisions. The principal arguments are: 1) costing systems in job order production require excessive tracing of costs to individual jobs, 2) overhead apportionment rates are too broad, covering wide bands of the operating cost spectrum, 3) costs that are driven by variables other than production volume are apportioned to products by volume-based rates, 4) the numerator of the apportionment rate is almost always direct labour hours or direct labour costs, even though direct labour is the driver of few overhead costs, 5) apportionment rates generally reflect the assumption that all productive resources are expected to operate at the same level of intensity (percentage of peak operating capacity), 6) costs of product-related activities outside the main manufacturing or service-providing centres – mainly R&D, marketing, selling, distribution, and warranty costs – are not identified with the products they support, 7) accounting textbooks have focused too strongly on short-term variable costs, overlooking the impact of capacity costs on strategically-oriented product decisions.

Kaplan (1984) mentioned that yesterday's accounting undermines production and Geri and Ronen (2005) believed that his paper was one of the first among many publications to depict the faults of traditional cost accounting and that the time was ripe for the rise of the new methodology which is activity-based costing which was developed by Cooper and Kaplan (1988). Cost accounting offers very important knowledge for management both at strategic and operational level. In a world of non-sustainable competitive advantage, costs have to be managed both aggressively and intelligently. A firm that fails to reduce costs as rapidly as its competitors will find its profit margins squeezed and its existence threatened. The competitive environment demands the development of sophisticated cost management practices to keeps costs down.

However, traditional managerial cost accounting is at a crucial stage in its development and traditional cost account information has become mostly irrelevant and even dangerous for managerial purposes (Plossl, 1990). Furthermore, rules and regulation have increased over the past two decades which leads to a more complicated and complex application of traditional managerial cost accounting. It is reported that generally accepted accounting principles (GAAP) have mushroomed from less than 2,000 pages to more than 12,000 pages, with many thousands more pages of supplements. Not only has

GAAP grown in size, but its complexity has also accelerated (Sharman, 2007). However, traditionalists believe that more was better and producing more irrespective of demand was rewarded with positive variances and greater apparent profit (Bicheno and Holweg, 2009). A traditionalist might automate a warehouse or favour speeding up a machine and also believes that parts are separate and that improving the parts will lead to improving the whole system.

Furthermore, some of its conceptual foundations are being scrutinised as never before and operating managers are complaining that existing systems fail to meet their needs in today's economic and technological environment (Shillinglaw, 1989). Shillinglaw (1989) also added that he isn't clear where this leads but what is clear to him is that managerial cost accounting must change if it is to be a vital force in the future. The information produced by mainstream cost management are irrelevant and harmful to a business (Maskell, 2009). According to Bicheno and Holweg (2009), traditional accounting systems were essentially backward looking, i.e. only reporting on past performance, and giving few (if any) real pointers of how to improve in the future and are not able to accurately reflect the improvements made through lean principles.

Professors Kaplan and Johnson have stated that cost accounting is the greatest enemy of productivity (Kaplan and Johnson, 1987). There are three principal shortcomings of traditional accounting systems, i.e., 1) irrelevant and harmful to a business; 2) expensive to maintain; and 3) divert the accountant's attention from more important matters (Maskell, 2009). Furthermore, Ostrenga et al. (1998) mentioned that there are three important consequences to the drawbacks of the mainstream cost management systems, i.e. 1) These systems cannot provide accurate product costs: where costs are distributed to products in a simplistic and arbitrary way that usually does not represent the real demand imposed by each product on the company's resources; 2) Such systems fail to stimulate decisions that can affect the overall production result. Managers are sometimes encouraged to accomplish short-term goals by reducing expenses on training and investments, or even by increasing the level of inventory. Although effective in the short term, these decisions can seriously affect future results (Goldratt and Cox, 1989); and 3) Cost management information provided by traditional systems is of little help to managers in their effort to improve production performance. Poor transparency allied with the lack of timeliness makes cost information ineffective in helping to identify and eliminate waste.

In discussions about the role of an accountant, it is reported that the average accountant in an American manufacturing company spends up to 75% of his or her time on bookkeeping activities and less than 10% on analysis and process improvement (Maskell, 2009). The role has been reduced to a backward-looking, reactive recording and dissemination of data that, if it could be done by a machine,

would make the accountant entirely unnecessary. Horngren (1991) argued that cost management must not be isolated from other managerial functions and should play a key role in the implementation of the company's strategies. It is reported that less than 10% of approximately five million finance function professionals in the United States are involved in audit, tax and external financial reporting (Sharman, 2007). It takes more people to do the bookkeeping activities than to do the analysis and process of improvement. Most people believe that what an "accountant" does is concerned with taxes or working at a Certified Public Accountant firm. The cause of this imbalance is the proliferation of accounting laws and regulation themselves.

Looking at the role played by cost management in the construction industry, it is reported that in the case of cost estimating in the construction industry, the information produced has the additional drawback that it is only remotely related to the way costs are incurred. Most cost methods adopted in the industry are strongly based on the standard cost method and tend to associate each cost item to a finished element, e.g. walls (m2), reinforced concrete components (m3), windows (units), obtained from design drawings (Koskela, 2000). This makes it difficult to accurately examine the effect of design changes to production costs. Moreover, although time is a factor of major importance in construction costs, traditional cost estimating methods do not offer any reliable guidance for assessing the impact of production duration on project costs (Kaka and Price, 1991, Turner, 1993, Navon, 1995).

In addition, Kim (2002) suggested that cost management systems should involve a set of processes required to ensure that a construction project is completed within the approved budget, including cost estimating, cost control and cost projection. Navon (1995) pointed out that proper consideration of the interaction between cost and time in construction projects depends on the integration of cost management systems to production management. Therefore, cost management systems in the construction industry must be dynamic, proactive and able to support different decision-making processes in order to protect the business from the harmful effects of uncertainty. Their main objective should be to generate information to support decision- making that is mainly concerned with cost reduction, value improvement and financial management. Maskell (2009) categorised the problems of traditional management accounting under five major headings, i.e.: 1) lack of relevance, 2) cost reduction 3) inflexibility 4) incompatibility with lean thinking and 5) inappropriate links to financial accounts.

3.4.1 Discussion

Based on the findings from the literature review, much has been reported about the shortcomings of the existing mainstream cost management. Most of the research findings reported the drawbacks that

existed in the manufacturing industry and a few others in the construction industry. The shortcomings reported seem to happen because of the improvement in the production process which does not run parallel with the improvement in cost management. A classification of the literature review findings regarding the drawbacks in construction cost management has been produced for a better understanding of this issue as follows:

i. In terms of the irrelevancy of the information provided by the current mainstream cost management

ii. The irrelevancy of the mainstream cost management system with today's economic and technological environment

iii. Method used currently

iv. The product value stream

v. The role of an accountant

vi. New set of rules & regulations.

Even though most of the research findings reported the poor state of mainstream cost management there are three research findings that indicate the remarkable resurgence of interest in both the practice and theory of cost and management accounting in recent years. This indicates that further development of the existing mainstream cost management is still taking place and being practised currently. These outcomes indicate that cost management in other sectors is still relevant for use at this point in time and not all industries are affected. In addition, even though a small number of new cost management systems have been introduced, few companies have participated in the initiative of implementing a new management accounting system and their effort for improving the cost management system in their company is of low to medium priority.

Based on the literature review it can be concluded that the current mainstream cost management practices are in need of improvement. This statement is true for the practise of cost management in manufacturing industries and the construction industry. Therefore, it is suggested that further research should be undertaken with a view to improving cost management on construction projects. Therefore, we can conclude that cost management in the construction industry needs renovation.

3.5 The Key Issues in Construction Cost Management

3.5.1 Introduction

The seven key issues in construction cost management, presented here, are the ultimate discoveries based on the literature review previously discussed. These seven keys issues are the result of the signs indicated by the literature review in this research area. The indication that can be interpreted from the literature review is that the researches in this area are very fragmented and that multiple, separate categories of research have been studied. This is supported by Voordijk (2009) who stated that the output of the research into construction management and economics are the contribution from different scientific disciplines, resulting in a multidisciplinary characteristic to construction management and economics knowledge because of the large number of different topics in research studies.

Fragmentation in research studies in this area happens when a large expanse of field topics is transformed in to a number of smaller categories of different topics that are isolated from each other by a matrix of construction cost management subjects unlike the original. The problem with fragmentation is that it creates the absence or the underdevelopment of connections that will change the properties of the remaining subject. This degree of fragmentation creates serious pragmatic data quality problems and has severe implications which create difficulties for making persuasive arguments. This fragmentation also generates enormous difficulties for ensuring that the focus of the categories is correct when undertaking a research study. A collateral consequence of these anomalies is that a selection must be made which requires the researcher to deal with those categories in order to decrease their scattering by improving their contiguity and grouped in to a more manageable order.

In doing so, the researcher has filtered the information gathered from the literature review with her analytical lens using the anomaly detection concept to make a meaningful synthesis of the literature review. The anomaly detection concept, also referred to as outlier detection (Kriegel et al., 2009), refers to detecting patterns in a given data set that do not conform to an established normal behaviour (Rooke et al., 1997). The patterns thus detected are called anomalies and often translate to critical and actionable information in several application domains. Anomalies are also referred to as outliers, change, deviation, surprise, aberrant, peculiarity, intrusion, etc (Wikipedia, 2013b). This concept has helped the researcher to perceive and interpret the data and give her the perception that something was wrong with the current researches into construction cost management (Kuhn and Hacking, 2012).

Awareness of anomalies offers the capacity to adjust the existing conceptual categories until the initially anomalous has become the anticipated (Kuhn and Hacking, 2012). The awareness of anomaly also

has led to the discovery (Kuhn and Hacking, 2012) of the seven key issues. Therefore, this has led to regrouping of those multiple separate categories into a more manageable order than that which marked the discovery of those seven (7) key issues and which include; failure to forecast, failure to support improvement opportunities, costs are considered as resulting from action, relative neglect of value consideration, poor support for inter-organisational cost management, negative influence on behaviour and constraint created by budgeting. In order to 'map an intellectual territory' for those seven key issues around the field of construction cost management, Table 13 presents the justification that includes the arguments for the formulation of the seven key issues and relevant articles that supported each of the issues.

Detailed explanations of each of the seven key issues are shown below:

3.5.2 Failure to Forecast

Forecasting is one of the key functions of cost estimation in construction projects. Zwikael and Smyrk (2009) have defined "project" as a form of investment in which outlays (approved by "funder") are made today with the intention of realising a flow of benefits over some future timeframe. Cost estimation is used to establish the probable cost of a future project or product, before being designed in detail and contract particulars being prepared. In this way, the client is made aware of the likely financial commitments before extensive design work is undertaken (Seeley, 1983) and it can help in providing correct input for him/her to make correct decisions on future investments. Forecasting has been discussed as part of the attempts to improve accuracy in estimating (Jaya et al., 2010, Rosenfeld, 2009, Beeston, 1986, Kenley and Wilson, 1986, Ballard, 2008). However, Flyvbjerg (2008) and Elfving et al. (2005) believe that these endeavours have not been fruitful.

Many causes of inaccuracy have been pinpointed in previous research. Traditionally, it is common for building owners to decide on relatively detailed issues at the beginning of the project delivery process for the preparation of tender documents. There is a great possibility that the detail issues at the design at this early stage will change along the project delivery process, hence, causing a considerable amount of waste in terms of time, information provided, and waste created during construction due to design faults (Elfving et al., 2005). In addition, cost is just understood to be there and the focus is on targeting for the 'expected cost' and not for 'targeted cost'. Flyvbjerg (2008), introduced the term "dark side of forecasting", points out unethical practices such as project champions / person in-charge (planner & the politicians) proceeding with projects even when inaccuracy in estimating is detected at the outset.

Currently, most of the cost data are taken from previous projects, which inherit waste. Such waste can vary in amount due to the emerging nature of waste. This fact is not acknowledged when compiling and using cost data, thereby resulting in inaccuracies in cost estimates.

Therefore, a possible countermeasure is to develop cost management approaches which account for the emergent nature of waste in the total construction process.

3.5.3 Failure to Support Improvement Opportunities

Current practices have witnessed many estimators being keener on obtaining projects to be funded and built (Flyvbjerg, 2008) rather than getting the forecast right. In addition, early commitments to design solutions have established cost at the initial stage. Locking the cost and the design reduces the opportunity to decrease the cost during construction, even though many authors have agreed that 70%-80% of product costs are committed during the concept phase (Rush and Roy, 2000). It is also highlighted that making a wrong decision at this stage is extremely costly further down the development process where product modifications and process alterations are more expensive. However, Elfving et al. (2005) and Koskenvesa et al. (2010) have a different opinion about this, and they indicate that this situation may significantly increase resource consumption and generate waste (i.e., waiting and rework) and also reduce the product flexibility.

Causes of this issue include referring to cost data from sources such as Spon's Construction Price Book and BCIS (Building Cost Information Service), where information was taken from previous projects that was believed to include inherent waste. The usage of such data seems to slow down the growth of labour productivity (Koskenvesa et al., 2010). In addition, Elfving et al. (2005) reported that decisions on early detail issues in the design might increase the probability of changes later on, which often leads to suboptimal solutions, quality defects and rework and this indirectly will contribute waste to the process. In addition, initiatives in cost reduction have focused more on direct labour time instead of overhead cost where costs are actually increasing more rapidly (Kaplan and Johnson, 1987). Koskela and Tommelein (2009) argued that cost can also be influenced along the entire project delivery and Target Value Design techniques (Kim and Ballard, 2000, Ballard and Reiser, 2004), which can influence the cost along the project delivery process, is one solution that can be adopted.

Table 13: The justification on the emergence of the seven key issues.

Key Issues	Occurrences in Literature Review	Justificationon Why is the Key Issue
Failure to Forecast	(Dolacek-Alduk et al., 2009, Cheng et al., 2009a, Wang et al., 2008a)	Forecasting is the main function of mainstream cost management and not being delivered. The anomaly is that this function is failed and lean provides the way in realizing that there are unsuspected phenomena that repeated uncovered by current research.
Failure to Support Improvement Opportunities	(Koskela and Tommelein, 2009, Elfving et al., 2005)	Mainstream cost management is a tool and in all these respects it fits with great precision the most usual image of construction cost management work. However, the missing link between ends and means created ends are given in mainstream cost management. The anomaly is that the current mainstream cost management is always being on table and it does not perform well. Lean has forwarded a new way for improvement which is not supported by the current mainstream cost management.
Costs are Considered as Resulting from Action	(Ballard, 2010, Zimina et al., 2012)	The separation of cost management process and design process has created failure to the mainstream cost management. The anomaly is that it does not make cost and value drives the design process.
Relative Neglect of Value Consideration	(Runeson, 1997, McNair et al., 2001)	Value is as important as cost in mainstream cost management and the anomaly is that yet value remains as lip service and it is not being develop.
Poor Support for Inter-organizational Cost Management	(Dubois, 2003, Cooper and Yoshikawa, 1994, Christopher and Gattorna, 2005)	The business environment of mainstream cost management has changed from being focusing on internal operation to inter-organizational operation. The anomaly is that the current mainstream cost management is not responding to this change.
Negative Influence on Behaviour	(Rooke et al., 2003, Tucker, 1986, Ali and Elazouni, 2009)	The used of mainstream cost management theory which are commonly accepted leads to outcomes which are widely believed to be usual images. The anomaly is that these scenario do create problems to the field that repeatedly uncovered by current research.
Constraint Created by Budgeting	(Ballard, 2010)	Budgeting is a core role in the mainstream cost management and the anomaly is that yet it creates problem to cost management.

Conventionally, cost control techniques are used during the design stage to enable the architect to be kept fully informed of the cost implications of all his design decisions, and throughout the construction period in order to rectify mistakes that result from the action of the parties at the early stage of the project (Seeley, 1983). This situation, which sets strategies based on the client's requirements at an early stage before the project is started, is referred to as the 'cost result from action' thinking and arguably leads to increased inaccuracy, creation of waste and also failure to achieve cost reduction.

Cost can be influenced in a positive way by the actors throughout the project delivery process. Therefore, it can be established that costs can be 'shaped by action', and it is possible to make the design converge to an acceptable overall project cost rather than letting the design reflect the cost.

Adopting target value design (Ballard, 2010), which drives the design to deliver customer values and develops the design within project constraints, can influence cost along the project delivery process, in contrast to only predicting costs at the beginning of the project.

3.5.4 Relative Neglect of Value Consideration

When browsing through the index in books (Brook, 2008, Hillebrandt, 2000, Seeley, 1983), which are related to cost management, a missing discussion of the value aspect can be witnessed. Traditionally, value has not been addressed in construction cost management; although many feel that the important criterion of value should be taken into consideration. The only problem is that they do not know where and how to do it.

Value consideration is necessary on construction projects to achieve the best value for money by eliminating unnecessary costs and functions while maintaining and optimising the performance. Studies in value have addressed the provision of 'value' but ignored the concept of value from the customer's perspective (McNair et al., 2001). Activity-based management approaches (Kaplan and Cooper, 1998) are used to divide the activities and costs of the company into value-added or non-value-added categories, but it remains unclear whether and how the customer's perspective is embedded into these approaches (McNair et al., 2001). The use of target costing (Tanaka et al., 1993) is considered to be of very limited value (Ewert and Ernst, 1999) to the overall cost management even though it relates cost to product attributes and its primary aim remains in cost minimization and value as proxy by market price is used only to define allowable costs (McNair et al., 2001).

All these techniques do not enable the identification of which activities should be emphasised and provides no assessment of specific linkages between internal cost structure and externally defined value (McNair et al., 2001). In summary, looking at the issues mentioned above, each tool mentioned fails to fully explain the complex relationship between cost and value (McNair et al., 2001).

It is suggested that the continuous monitoring of loss of value is needed by creating a better alignment between cost and value to help the company to target areas where costs can best be leveraged to improve its overall profit potential (McNair et al., 2001). It starts from the design stage through to the construction stage for the success of value and the client's requirement. Continuous monitoring of loss of value is needed because the cost management system is not aligned with the development in production processes and value is not considered in it. Benefit realisation management (Yates et al., 2009) and Choosing by Advantages (Suhr, 1999) are other alternative approaches to obtain the optimum result of project/product.

3.5.5 Poor Support for Inter-organizational Cost Management

Currently, many-tiered supplier networks exist in traditional supply chains (Cooper and Slagmulder, 2004), where the connection between key supplier's suppliers, key supplier's other customers,

customer's other suppliers' and customer's customer (Dubois, 2003) exist. These many-tiered supplier networks create a major addition in transaction cost before it reaches the final customer and it is believed that the customer carries most of the burden of cost accumulation in traditional supply chains (Kulmala et al., 2002).

The cost of purchased goods and services represents the majority of the total costs for most companies (Dubois, 2003). Therefore, outsourcing purchased goods mostly chases the lowest price for each transaction. All of the goods and services are purchased from supplier organisations and the purchases from supplier organisations are the largest single expenditure for most companies. This large share is attributable to the ambition of companies to concentrate more on their specialisation (Dubois, 2003). Furthermore, as time goes by, outsourcing of manufacturing activities has been followed by outsourcing of design and development work and therefore, suppliers are contributing to the technical development of a company (Dubois, 2003). Moreover, applying new techniques such as JIT (Just-In Time) and TQM (Total Quality Management) require the active involvement of suppliers and affects the costs and benefits of both buyer and supplier (Dubois, 2003).

The cost management problems caused by the many-tiered supplier networks can be alleviated by adopting relational oriented philosophies (Kulmala et al., 2002, Kulmala, 2004), applying open book accounting (Kulmala et al., 2002, Seal et al., 1999) and redefining of the unit of analysis (Dubois, 2003, Cooper and Yoshikawa, 1994, Christopher and Gattorna, 2005, Cooper and Slagmulder, 2004, Zimina and Pasquire, 2010, Cabral and Riordan, 1989).

3.5.6 Negative Influence on Behaviour

Several forms of negative influence from cost management systems on behaviour have been identified in literature, ranging from claim culture to manipulation of bids and performance measurements. Attitudes that relate to the occurrence of claims in the administration of contracts show that the industry has a culture that is opportunistic, prone to conflict and resistant to change (Rooke et al., 2003). People draw on whatever resources can make the best out of a bad job in order to get by and get things done to make extra profit or money (Rooke et al., 2003). There are contractors who expend more effort on generating profit from claims than from improved construction methods (Rooke et al., 2004).

Another example is the 'unbalanced bid', which has the tendency to create cash constraints for many parties, such as cash flow problems to contractor (Tucker, 1986, Ali and Elazouni, 2009, Qingbin et al., 2010, Chen et al., 2008, Elazouni, 2009), financial disorder to client (Christodoulou, 2008) and also to

both parties, when managing more than one project (Lu et al., 2007). This whole example will create a false alarm. In addition, the earned-value method, which is developed for integrating schedule and cost management, creates the opportunity for project managers to manipulate work sequences when releasing work to the field. In this situation, it may be that work assignments, not shielded from uncertainty, are released for the sake of early payment (Kim and Ballard, 2000).

The blame is not only on contractors' part but can also happen because of client behaviour. Consistently, late payments by clients have encouraged contractors to act negatively because of the resultant cash constraints problems that they have to face.

Some countermeasures were suggested Arditi and Chotibhongs (2009), Christodoulou (2008) and Cattell et al. (2008), where models were suggested to overcome the problem of the unbalanced bid. Adoption of procurement methods that discourage claims and encourage the use of open book accounting (Kulmala et al., 2002, Seal et al., 1999) are other possible solutions available.

3.5.7 Constraint Created by Budgeting

Budgeting emerged in the 1920s as a tool for managing costs and cash flow in large industrial organisations such as DuPont, General Motors and Siemens. Budgets are also used extensively in construction contexts too. Currently, a number of companies have recognised the full extent of the damage done by budgeting (Hope and Fraser, 2003b). They have rejected the reliance on obsolete data and the protracted, self-interested wrangling over what the data indicates about the future because it renders pointless interpretation and circulation of current market information, the stock-in-trade of the knowledge-based and networked company.

Having a budget in a business unit has created negative scenarios among employees in an organisation because each and every activity involved in the product delivery process will be benchmarked with a budget. This will disempowers the front line, discourages information sharing, and slows the response to market developments until it's too late (Hope and Fraser, 2003a). The usage of budget, which was first used to force performance improvements, hassled to a breakdown in corporate ethics where information is only funnelled to those with a "need to know" and not to the rest of the team (Hope and Fraser, 2003b).

In the absence of a budget, alternative goals and measures are moved to the foreground and business units and personnel performance is judged on how well their performance compares with their peers' and against world-class benchmarks that are collected and prepared by specialist firms that understand

that particular industry. The result of this adoption has created more accurate interpretation of results (Hope and Fraser, 2003b).

Traditionally, early creation of a budget has been emphasised in construction project management. However, the dynamic situations in construction projects may demand a more flexible and responsive approach to budgeting. A possible counter-measure is to develop cost management approaches which take the above into consideration.

3.5.8 Discussion

When analysing the key issues, some common causes can be identified. They can be divided into four subsections, i.e. assumptions on how costs emerge, assumptions on management need for cost information, assumptions on conditions or context in cost management and how the contract is formulated and payments arranged as shown in Table 14.

The consequences of the key issues in cost management include inaccurate price of a project/product, suboptimal solutions, quality defects and rework, reduced growth of labour productivity (Koskenvesa et al., 2010), reduced product flexibility, increased resource consumption, making wrong decisions, cost accumulation to the customer, cash flow problems and bad financial planning.

These key issues have exposed significant weaknesses in the mainstream cost management approaches. Based on the literature review findings, it seems that many parties have realised that these problems exist in the current cost management system. Yet, hardly any of the initiatives that have been put forward seem sufficient for achieving a much needed overhaul of the function, role and philosophies of the cost management system. Transparency of the cost and 'thinking out of the box' are required in order to improve the cost management system. In addition, structural changes such as improvement in training and education towards the purported changes and revision of the procurement policies are also suggested.

Effective cost management is important for the achievement of the investment put forward by the sponsor of the project. Therefore, in order to provide accurate guidance to the decision maker in initiating and making their decision, consideration of value, achievement of maximum accuracy and reduction in cost are very important to achieve in every cost estimation exercise. This paper sees that the real problem to the success of cost management is to find ways to reduce the amount of wastes that are embedded in the current construction costs. Informed by this review, the future direction of this research is to develop conceptual solutions to the current problems in construction cost management identified here.

This section has identified the rationale of the theoretical knowledge from the review of the literature and acted as a precursor to the research process. This has brought about the development of the provisional key issues that were revealed through theory. The critical literature review also helped in the establishment of in-depth understanding in the field of construction cost management for the introduction of alternative theoretical approaches to manage construction cost more efficiently and effectively.

In the following section, the study seeks a robust finding by amending or adding to the predetermined list of categories as data are collected and analysed to finalise the hypothesised key issues.

Table 14: Common causes in the seven key issues

COMMON CAUSES	OUTLINE OF COMMON CAUSES	KEY ISSUES FEATURED
Assumptions on how cost emerge	Key underlying assumption is: Costs do not cover any avoidable waste	• Costs are shaped by ACTION rather than result from action • Failure to forecast • Negative influence on behaviour • Poor support for inter-organizational cost management • Failure to support improvement opportunities
Assumptions on management need for cost information	Key underlying assumption is: Cost information is only needed for decision-making	• Poor support for inter-organizational cost management • Failure to forecast
Assumptions on conditions or context of cost management	Key underlying assumptions are: Design and production occur is a static environment. The same value will be achieved through alternative course of action.	• Relative neglect of value consideration • Budgeting in dynamic situations • Costs are shaped by ACTION rather than result from action
How contract is formulated and payments arranged	Contract or payment arrangement creates an incentive for one party to manipulate design and production to its own advantage.	• Negative Influence on behaviour • Costs are shaped by ACTION rather than result from action • Failure to forecast

3.6 Exploration of Key Issues of Construction Cost Management through Interviews

This section is aimed to present and synthesise the analysis of the empirical investigation for the primary data collection to confirm with the literature review findings in terms of the exploration of key issues of construction cost management. Initially, the aim of this task is discussed. Next, the design of the interview process for both types of interviews which include the backgrounds of the selected respondents. Next, the analysis and research findings from the exploratory interview and in-depth interview are presented for establishing awareness to the current problem in the area of construction cost management.

3.6.1 Aim of the Interview - Grasping the "Real" Problem

The exploration of the key issues of construction cost management started with an aim to grasp the "real" situation that was happening in the construction industry currently. In conjunction with the method used (The 5-'Why' Analysis) to develop the Conceptual Solutions, grasping the "real" situation needs to done before the process of 5-Why Analysis is taking place for the development of the conceptual solutions (countermeasure). This process can be referred in Figure 20. 'Grasp the situation', as what it refers to in Figure 20, is the same process of 'Establish Awareness of Problem' in DSR process that is shown in Figure 7 and Figure 8 and highlighted in Chapter 2, Section 2.4.3.1.

3.6.2 Design of the Interview Process for Exploratory Interview

The interview questions are designed through the use of provisional key issues that were revealed through theory in categorizing all information received from the respondents. Section 3.5 has listed the 7 key issues established and the same questions related all the key issues are applied in this interview for data collection. The interview sessions are conducted with the aid of a semi-structured interview questions attached in Appendix A of this thesis. In entirety, there are 2 sections within the interview questions as follows:

3.6.2.1 Section I – Interviewee's Background Information

This section begins with a series of general questions, aimed at capturing the general information of the interviewee and their current organization. In this section, the information gathered are; the interviewees' name, designation and job description, years of employment/appointment, qualification background, contact details, as well as the date of the interview for record purposes. Several questions regarding the organization where the participant is working at are also asked. These questions include the name of organization, the nature of business, whether or not the organization is a private firm or a public agency, and the number of years the organization has been established. The general information of the interviewees is important in profiling the participants included in this exploratory interview. It is also important in drawing conclusions should there be a difference of opinions among the interviewees. Although the name of participant and their organization are noted in the Participant Information Sheet, for the purpose of anonymity these names will not be published in the analysis and anywhere in this thesis as mentioned in Participant Information Sheet. This is to fulfil the ethical requirement from the University.

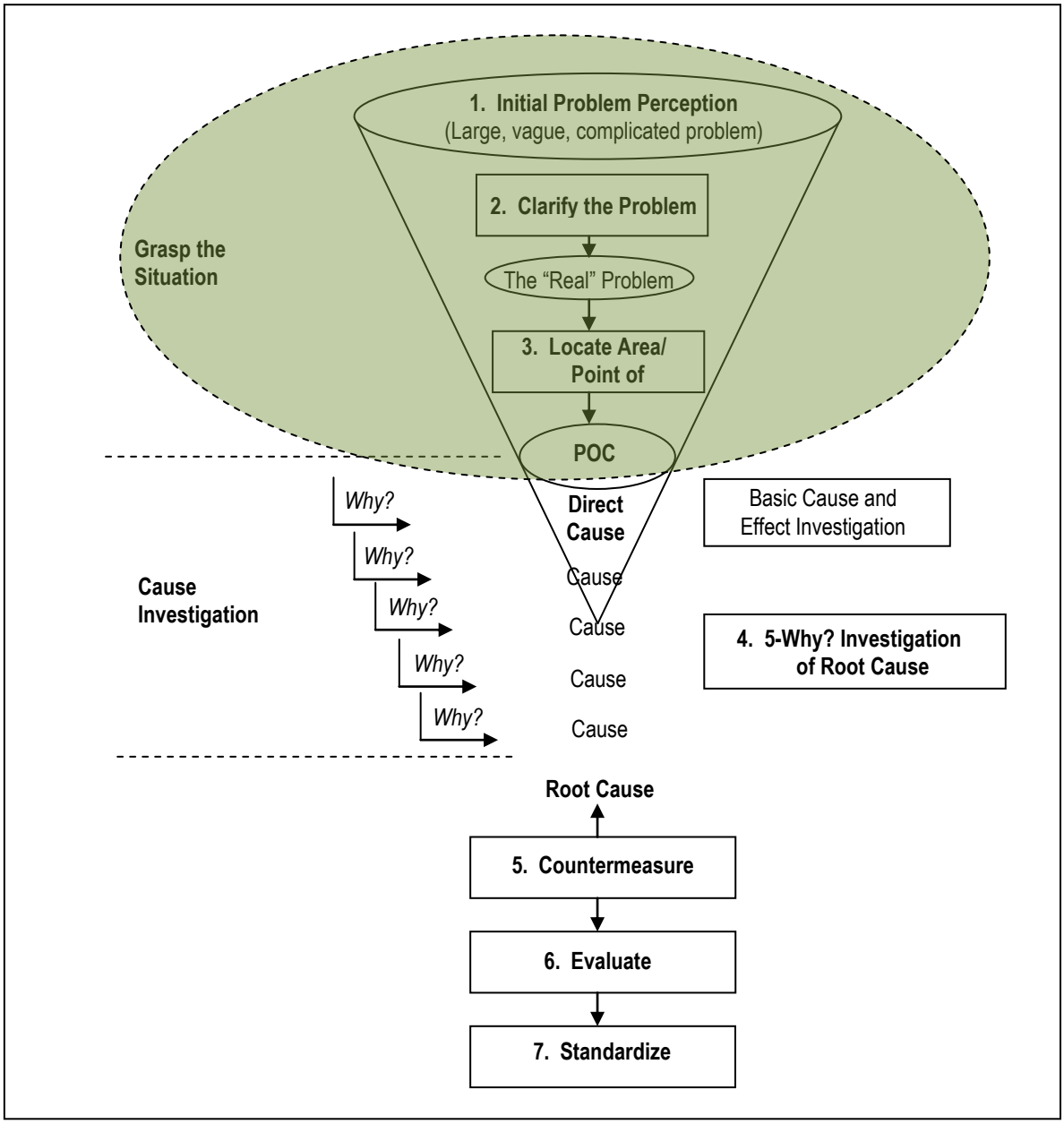


Figure 20: Toyota's practical problem-solving process – grasp the situation.
(Source: adapted from Liker (2004))
(Note: The green colour shows the stage of the process in Chapter 4)

3.6.2.2 Section II – Understanding the Status of Current Construction Cost Management and the Need of Future Improvements

In this section, the participants were asked a series of questions in relation to their experience, understanding and previous involvement (if any) in construction cost management. This section primarily seeks to determine the participant's personal opinion on their recollection of the current problems facing the traditional construction cost management which they have been involved with. The participants were also asked of lessons learnt in their experience with the problems facing the traditional construction cost management. The questions posed in this section will reveal if the

participants have different perceptions with the status of current construction cost management and the need of future improvements.

3.6.2.3 Surveyed Sample for Exploratory Interview

As mentioned in Chapter 2, Section 2.4.3.1.2, there are six (6) interviewees selected in exploratory interview from a group of professional that involved in the management of cost in a construction company and very actively involved in the implementation of lean construction in construction project. The selection of respondents are from of a group of professional in lean construction because this study has used manufacturing as the analogy and the group of professionals in this area has a goal of improving the cost management that is in line with the aim in manufacturing.

The main criteria for the respondents selected for exploratory interview are as follows; the respondents are actively involved in the industry and have been established for more than 10 years. The selections of respondents are from people that have been actively involved in the construction industry and have had more than a decade of experience. This is to make sure that they would have experienced on how policies set by the government or trends in the current construction industry that have affected their business and have led them to change the style on how they manage their projects. For the purpose of anonymity and fulfilling the ethical approval requirement, the participant shall be labelled I1, I2, I3 and so on, without any order of importance, as with the name of the company; C1, C2, C3, C4 and C5. The following Table 15 shows the details of the sample interviewed for this research.

Table 15: Detail of sample for exploratory interview

Organization	No. of Participants	Participant Labels	Managerial Level
C1	1	I1	Lean Construction Coordinator
C2	1	I2	Director
C3	1	I3	Construction Executive
C4	1	I4	Professor
C5	1	I5	Editor-in Chief
C6	1	I6	Professor

As shown in Table 15 above, the participants interviewed in this research are in the top or middle manager position due to the fact that these 2 groups are commonly involved in decision making in the construction industry. The views of top and middle management are important to this research, as they are the key person working involving in many aspects of procedure involved in construction cost management. At the data collection stage, the researcher has experienced some difficulties in conveying the findings from the theory to the participants. This could be due to the traditional mind-set

that the participants have and therefore were unable to relate their experience with the outcome from the theory.

3.6.2.4 Exploratory Interview Findings

Exploratory interview, which is fundamentally heuristic, is used to critically review the initial list of suggested key issues in construction cost management, to clear the problem that has not been clearly defined and identify any other key issues which could be investigated and addresses when developing the solution. This is to guide the investigation for further growth of the research study. This is done by gathering views from the professionals in this field that hold the same understanding with the research area proposed.

3.6.2.4.1 Failure to Forecast

The researcher seeks to determine the previous involvement of the participants in the issue of failure to forecast. Based on Table 16 there are 4 participants that have experienced with the same symptoms identified from the literature review, which included cost is just understood to be there, early commitments to design solutions can lead to making wrong decisions and cost data inherit waste.

There are 6 new symptoms identified from 5 participants. These 5 participants relate failure to forecast with estimating in detail is not a problem because it is forecasting, there is a gap between what required to be constructed and specification with estimated and bid, no similarity between estimate and cost to manage production, people buy future, price volatility and problem with project management. The participants that experienced problem in key issue failure to forecast implied that most of failure to forecast activity that they undergone having problem with project management, as described by I3, **"*often time see similarity of the estimate is not the same as the similarity that you want to manage production"*** and I1, ***"is almost impossible to move money across this contractual boundary"***. There are 6 numbers of references under these symptoms and the findings for this issues can be simplified in the following Table 16.

3.6.2.4.2 Failure to Support Improvement Opportunities

The second key issue seeks to identify what lessons or problems that the participant had encountered during the process of construction cost management that related to failure to support improvement opportunity. These lessons and problems are the symptoms contributed to the key issue and based on Table 17 there are 6 participants that have experienced with the same symptoms identified from the

literature review, which included cost data inherit waste and early commitments to design solutions can lead to making wrong decisions.

Table 16: Summary of symptom in failure of forecast

(Note: orange colour: symptom identified in literature review and exploratory interview)

Type of Symptom	Symptoms	No. of Respondents	No. of References
Key Issue: Failure to Forecast			
Existing	Cost is just understood to be there	3	5
	Early commitments to design solutions can lead to making wrong decisions	4	5
	Unethical practices	0	0
	Cost data inherit waste	3	3
Emerging	Estimate in detail is not a problem because it is forecasting – ACCEPTABLE SITUATION	1	1
	GAP-between what required to construct and specification and estimated and bid.	3	4
	No similarity between estimate and cost to manage production.	3	4
	People buy future - return on investment	3	4
	Price volatility – uncertainty	3	3
	Problem with project management	3	6

There is only one emerging new symptom identified from 3 participants and that symptom is pretty bound to honour the contract and not able to really innovate. It should be highlighted that a significant amount references are made on the problems faced with the rigid contract as indicated by I1, ***"is almost impossible to move money across this contractual boundary"*** and I4 ***"Then I have been talking about moving money across boundary and the challenges you may find is that something is less expensive and then from the thing is less expensive you want to be able to use those extra fund somewhere else"***. There are 8 numbers of references under these symptoms and the findings for these issues can be simplified in the following Table 17.

Table 17: Summary of symptom in failure to support improvement opportunities

(Note: orange colour: symptom identified in literature review and exploratory interview)

Type of Symptom	Symptoms	No. of Respondents	No. of References
Key Issue: Failure to Support Improvement Opportunities			
Existing	Cost data inherit waste	3	3
	Early commitments to design solutions can lead to making wrong decisions	4	5
	Focused more on direct labour time instead of overhead cost	0	0
Emerging	Pretty bound to honour the contract and not able to really innovate	3	8

3.6.2.4.3 Interruption by Business Cycle

Interruption by business cycle is a new key issue and only one participant did talk about it. The participant I2 mentioned that ***"The industry is caught up in a cycle of revenge reminiscent of the story told in Aeschylus' Oresteia. When buyers have the upper hand (supply exceeds demand), they gouge sellers. When sellers have the upper hand, they gouge buyers. The result is that the industry never gets better. All, or certainly most, performance improvement initiatives are interrupted by the business cycles".*** There is 1 number of references under this symptom and the findings for this issue can be simplified in the following Table 18.

Table 18: Summary of symptom in Interuption by business cycle

Type of Symptom	Symptoms	No. of Respondents	No. of References
Key Issue: Interruption by Business Cycle			
Emerging	Interruption by business cycle	1	1

3.6.2.4.4 Relative Neglect of Value Consideration

The participants are next asked on their experience dealing with key issue on relative neglect of value consideration. There are 3 responses for this key issue that support one emerging symptom, i.e. transaction of value. There is no participant mentioning about existing symptoms identified in literature review. All their responses indicate their personal opinion on the failure of transaction of value during project delivery. I1 and I2 sequentially commented; ***"From the perspective of delivering value you have another issue which is that we define our scope of work and make bids and write contract based on the scope of work and testify the amount either lump sum or not to exceed most contract and those are there can be gaps and scope between what actually required to construct and what was define and bid or estimated and bid"*** and ***"Many projects cost more than they should, and many of those same projects do not result in satisfied customers; so waste is greater than necessary and value is less".*** These gave the researcher the impression that to some degree, the value is not well implemented in the current construction cost management. There are 5 numbers of references under these symptoms and the findings for these issues can be simplified in the following Table 19.

Table 19: Summary of symptoms in relative neglect of value consideration

Type of Symptom	Symptoms	No. of Respondents	No. of References
Key Issue: Relative Neglect of Value Consideration			
Emerging	Transaction of value	3	5

3.6.2.4.5 Poor Support for Inter-organizational Cost Management

For the fifth key issue, the participants are asked to describe on their experience related to key issue poor support for inter-organizational cost management as shown in Table 20. Overall, there is only one participant that had experienced on this issue and the symptom mentioned is many-tiered supplier networks create a major addition in transaction cost until it reach the final customer. The rest of the participants did not describe anything on this key issue. I1 described the situation to this symptom as ***"There are transaction cost now and the supply chain, is not that they don't exist, there isn't visibility into the supply chain.....and there probably too many level in supply chain. Interoperability issues between different supply management system used at different level by different companies and therefore the issues of interoperability effecting the accuracy of information and timeliness of information".*** These two comments are clearly shown that the participant experiences are similar with the findings from the literature review. They indicated that the problem of many level of supplier networks created a major transaction in construction project cost.

Table 20: Summary of symptom in poor support for inter-organizational cost management
(Note: orange colour: symptom identified in literature review and exploratory interview)

Type of Symptom	Symptoms	No. of Respondents	No. of References
Key Issue: Poor Support for Inter-Organizational Cost Management			
Emerging	Many-tiered supplier networks create a major addition in transaction cost until it reach the final customer	1	2

3.6.2.4.6 Negative Influence on Behaviour

The researcher seeks to determine the previous involvement of the participants in the issue of negative influence on behaviour. Based on Table 21 there are 3 participants that have experienced with the same symptoms identified from the literature review, which is poor estimate and the contractors trying to look for opportunity to claim. It seems that there is no difference among the responses of the participants and they seem to be in agreement that the contractors are keen to look for opportunity to claim instead of improving the construction process that can save the overall construction cost as mentioned by I6 ***"Cost is a lagging indicator, costs are not well understood as contracts are all mostly based on price, costs are managed by the use of budget buckets containing as much contingency as the market allows, claims are a standard contract item as are defects/snags, the final account is never the same as the tender price".*** There are no emerging symptoms identified from any participants.

Table 21: Summary of symptom in negative influence on behaviour
(Note: orange colour: symptom identified in literature review and exploratory interview)

Type of Symptom	Symptoms	No. of Respondents	No. of References
Key Issue: Negative Influence on Behaviour			
Existing	Poor estimate and the contractors try to look for opportunity to claim.	3	3

3.6.2.4.7 Constraint Created by Budgeting

In this section, the researcher seeks to determine the previous involvement of the participants in the issue of constraint created by budgeting. Based on Table 22 there are 5 participants that have experienced with the same symptoms identified from the literature review, which included each and every activity involved in the product delivery process will be bench marked with a budget.

There is only 1 emerging symptoms identified from 4 participants. These 4 participants relate constraint created by budgeting with incompatible with project optimization. In general it can be said that most of the participants are in agreement that budget has restricted project optimization in a construction project, as described by I2***, "Costs are managed against budgets, as if the work being funded by those budgets was independent, one from another. This is a form of local optimization, incompatible with project optimization"***. There are 5 numbers of references under this symptoms and the findings for this issues can be simplified in the following Table 22.

Table 22: Summary of symptom in constraint created by budgeting
(Note: orange colour: symptom identified in literature review and exploratory interview)

Type of Symptom	Symptoms	No. of Respondents	No. of References
Key Issue: Constraint Created by Budgeting			
Existing	Each and every activity involved in the product delivery process will be bench marked with a budget	5	6
Emerging	Incompatible with project optimization	4	5

3.6.3 Design of the Interview Process for In-depth Interview

The interview questions are designed through the use of provisional key issues that were revealed through theory in categorizing all information received from the respondents. The interview sessions are conducted with the aid of a semi-structured interview questions attached in Appendix B of this thesis. In entirety, there are 2 sections within the interview questions as follows:

3.6.3.1 Section I – Interviewee's Background Information

The explanations in this section are similar with Section 3.6.2.1.

3.6.3.2 Section II – Understanding the Status of Current Construction Cost Management and the Need of Future Improvements

This section comprised of 14 questions aimed at investigating the understanding of the current status of the construction cost management and the need of future improvements. 2 questions are asked to determine the participant's awareness and feelings regarding the current status of the construction cost management. These were achieved by enquiring them to identify what is the changes/trends that they have seen in the construction cost management and their opinions on why it happens (if any). The following 7 questions are geared for investigating the participant's awareness and feelings regarding the provisional key issues that were revealed through theory. The remaining 4 questions are targeted at the opinions of the participants on improving the current cost management approaches.

3.6.3.3 Surveyed Sample for In-depth Interview

Respondents for in-depth interview exercise are selected from a group of professionals that are involved in traditional construction as the interviewees. There are three (3) interviewees selected from a group of professionals that is actively involved in the management of cost in a construction project. The objective of this data collection is to look into perspectives or opinions from another different group of professional which is practising traditional cost management on the key issues of cost management in construction industry. The main criteria for the respondents selected for in-depth interview are similar with survey sampled for exploratory interview which is described in detail in Chapter 3, Section 3.6.2.3. Table 23 shows the detail of sample in-depth interview. During interview session, the researcher has experienced some difficulties in conveying the findings from the theory to the participants due to the traditional mind-set that the participants have and therefore were unable to relate their experience with the outcome from the theory.

Table 23: Detail of sample for in-depth interview

Organization	No. of Participants	Participant Labels	Managerial Level
C1	1	I1	Quantity Surveyor
C2	1	I2	Director
C3	1	I3	Academician

3.6.3.4 In-depth Interview Findings

As for in-depth interview exercise, respondents are being selected from a group of professional that involve in traditional construction as the interviewee. The objective of this data collection is to look into perspectives or opinions from another different group of professional which is practising traditional cost management on the key issues of cost management in construction industry. This is to look at a range of similar and contrasting opinions from different group of people with different views with the exploratory interview done previously to strengthen the precision, the validity and the stability of the findings.

3.6.3.4.1 Failure to Forecast

The researcher seeks to determine the previous involvement of the participants in the issue of failure to forecast. Based on Table 24 only 1 participant has experienced the same matters identified from the literature review, which included cost is just understood to be there, early commitments to design solutions can lead to making wrong decisions and unethical practices. The results show that the experiences for construction professionals in construction cost management pertaining to issue of failure to forecast are variety. There are 7 emerging issues experienced by 3 participants which included improvement through new technologies, level of accuracy, limited information, the needs for improvement, theory vs. practical, time pressures and types of client/clients objectives. The participants had agreed that improvement through new technologies can increase the level of accuracy as mentioned by I2 ***"With the new technologies allow the client to visualize and run various simulations for the entire project to find what will be the impact on cost from beginning to the end to have a more realistic final contract sum at the very beginning"***.

3.6.3.4.2 Failure to Support Improvement Opportunities

The second key issue seeks to identify what lessons or problems that the participant had encountered during the process of construction cost management that related to failure to support improvement opportunity. These lessons and problems are the symptoms contributed to the key issue and based on Table 25, all participants have not had any experience with the same symptoms identified from the literature review, which included cost data inherit waste and early commitments to design solutions can lead to making wrong decisions

There are 12 emerging symptoms identified from 3 participants which are shown in Table 25. It should be highlighted that a significant amount of references are made on the problems faced with non-responsive to change as indicated by I3, ***".....so the construction professionals as well as the***

clients, they are reluctant and they are afraid of taking challenges and let the changes happen" and therefore, to motivate the parties in construction to move to the right direction I3 also did mentioned "***To make this link a bit stronger to initiate that change to let the client to be inform as educated as inform the client. "***.

Table 24: Summary of symptom in failure to forecast

(Note: orange colour: symptom identified in literature review and in-depth interview)

Type of Symptom	Symptoms	No. of Respondents	No. of References
Key Issue: Failure to Forecast			
Existing	Cost is just understood to be there	1	2
	Early commitments to design solutions can lead to making wrong decisions	1	1
	Unethical practices	1	1
	Cost data inherit waste	0	0
Emerging	Improvement through new technologies	2	2
	Level of accuracy	3	6
	Limited information	2	2
	The needs for improvement	1	4
	Theory vs. Practical	1	1
	Time pressures	1	1
	Types of client/client's objectives	2	2

Table 25: Summary of symptom in failure to support improvement opportunities

Type of Symptom	Symptoms	No. of Respondents	No. of References
Key Issue: Failure to Support Improvement Opportunities			
Emerging	Client expectation or needs	1	1
	Collaboration (Procurement)	1	2
	Conditions of contract	1	1
	Delivering value to the client	1	1
	Different in objective between client and contractor	1	3
	Involvement of contractor during design phase or	1	1
	Collaboration (procurement)	1	2
	Modern construction process	1	1
	Modern cost Management	1	1
	Non-responsive to change	2	9
	Resistant to change	1	1
	The initiator	1	2

3.6.3.4.3 Costs are Considered as Resulting from Action

In this third key issue, the researcher seeks to determine the previous involvements of the participants in the issue of costs are considered as resulting from action. In general, based on Table 26, all of the symptoms identified from the participants are emergent symptoms from all 3 participants.

There are 5 emerging symptoms identified which include communication and team work, different objectives to be achieved, new technologies, non-responsive nature and procurement. 2 participants agree that communication and team work are one of the indications to this issue that can influence the construction costs as mentioned by I1 ***"It is about communication between the architect and the quantity surveyor and the other professional team to talk to one another, to make sure that information flows are adequate and are timely so that the best cost can be applied as the design develops to ensure that it doesn't go above that cost target throughout the whole source, design and construction phase"***. In general, all the participants are in agreement that different objectives to be achieved can cause the key issue to occur in construction project which reach 7 numbers of references.

3.6.3.4.4 Relative Neglect of Value Consideration

For the forth key issue, the participants are asked to describe on their experience related to key issue relative neglect of value consideration as shown in Table 27. Overall, there are 2 participants that had experienced on the existing symptom, i.e. the client do not know where and how to do VM. One participant did not describe anything on this key issue.

Table 26: Summary of symptom in costs are considered as resulting from action

Type of Symptom	Symptoms	No. of Respondents	No. of References
Key Issue: Costs are Considered as Resulting from Action			
Emerging	Communication and team work	2	4
	Different objectives to be achieved	3	7
	New technologies	1	2
	Non-responsive nature	1	1
	Procurement	1	1

There are 8 emerging symptoms which include additional scope of work for QS, cannot 100% to rely on software, communication, integration support, modern system helps better, new technologies, promoting VM and willingness to spent additional money. Based on number of respondents, integration support and willingness to spent additional money in implementing VM in construction cost management shows the highest frequency in number of respondents. It should be highlighted that the implementation of VM does contribute to extra cost described by I3, ***".....value management practices would need the client to spend some money upfront in order to go through that process and that is not cheap actually you have to get a set of professional in a place where they can brainstorm"***. Therefore, to increase the implementation of VM in construction cost management, there should be an effort on promoting the benefit of VM to the parties involve in

construction as mentioned by I3, ***"One can't make value management compulsory. Well, one can make it desired by most of the client"….. "More and more success stories to convince clients to say that value management process is actually valuable. And the moment that they see that this is valuable practices they would go through value management processes voluntarily rather than making it compulsory"***.

Table 27: Summary of symptom in relative neglect of value consideration
(Note: orange colour: symptom identified in literature review and in-depth interview)

Type of Symptom	Symptoms	No. of Respondents	No. of References
Key Issue: Relative Neglect of Value Consideration			
Existing	The client do not know where and how to do VM	2	3
Emerging	Additional scope of work for QS	1	1
	Cannot 100% to rely on software	1	2
	Communication	1	1
	Integration support	2	2
	Modern system helps better	1	2
	New technologies	1	2
	Promoting VM	1	6
	Willingness to spent additional money	2	2

3.6.3.4.5 Poor Support for Inter-organizational Cost Management

The objective of questioning the participant experience related to his key issue is to determine the participant experience related to this key issue in construction cost management. For key issue poor support for inter-organizational cost management, only one participant has the same experienced with the existing symptom identified through theory, i.e. create a major addition in transaction cost until it reach the final customer as shown in Table 28. The rest of the symptoms are emerging symptoms identified from 2 participants.

Based on the findings, it seems that the long term relationship is one of the best solutions suggested to tackle the problem with poor support for inter-organizational cost management. This is based on the number of occurrence of the participant talking about it. Furthermore it has the highest number of references. Basically, most of the emerging symptoms include the suggestion on how to overcome the problem identified. Realization, supply chain management and Integration are few of the suggestions identified by the participants and in the researcher opinion are interrelated. The nature of the supply chain management as mentioned by I1, ***"In a traditional approach, I think what you got to consider is do contractor really examine their supply chain. Does it take some external consultant to come in or somebody from outside to look at the operation and saying are you really doing things as efficiently as you can be"*** should be integrated through a suitable procurement as described by I1, ***"how well are those sub-contractor are integrated and talk to one another within***

a traditional approach, you know, is open to debate compare to a more sort of collaborative approach in a partnering arrangement, we are slightly going off to being of management cost".

Table 28: Summary of symptom of poor support for inter-organizational cost management

(Note: orange colour: symptom identified in literature review and in-depth interview)

Type of Symptom	Symptoms	No. of Respondents	No. of References
Key Issue: Poor Support for Inter-Organizational Cost Management			
Existing	Create a major addition in transaction cost until it reach the final customer	1	1
Emerging	Awareness/education	1	1
	Integration	1	2
	Long term relationship	2	3
	Project manager scope of work	1	1
	Realization	1	1
	Supply chain management	1	1

3.6.3.4.6 Negative Influence on Behaviour

The researcher seeks to determine the previous involvement of the participants in the issue of negative influence on behaviour. Based on Table 29 there are 2 participants that have experienced with the same symptoms identified from the literature review, which is Contractor cash flow problems (cash flow problems) – expend more effort on generating profit through claim rather than improving the construction methods.

It should be highlighted that all of the participants seems to be in agreement that faulty in contract or tender document/design team weakness seems to be the important symptoms to the negative influence on behaviour. The participant I1 described that ***"If a contractor identifies there are design information and the document have gone to tender are a bit weak and it looks incomplete, he knows that there will be variation. He takes his commercial view to put in a lower price to win the job and then he covers his cost during the course of the construction contract on the variation"***. In addition, participant I2 mentioned that ***"If there are areas which are loosely define in a contract between a main contractor and sub-contractors or a contract between the client and the management contractor, in that case, there will be lots of claim coming in"***. Furthermore, participant I3 adds in that "***I think we should minimize our own mistake in our own practices and errors are evitable by going through a structured process where the measurement are getting re-check in any cost management technique. The level of errors we have to reduce".***

Table 29: Summary of symptom in negative influence on behaviour
(Note: orange colour: symptom identified in literature review and in-depth interview)

Type of Symptom	Symptoms	No. of Respondents	No. of References
Key Issue: Negative Influence on Behaviour			
Existing	Contractor cash flow problems (cash flow problems) – expend more effort on generating profit through claim rather than improving the construction methods	2	2
Emerging	Bad practice	1	2
	Estimate A but build B	1	1
	Faulty in contract or tender document / Design team weakness	3	4
	New technologies	1	1
	Procurement	1	1
	Time constraint	1	2

3.6.3.4.7 Constraint Created by Budgeting

The participants are next asked on their experience dealing with key issue on constraint created by budgeting. There are 6 responses from 3 participants for this key issue that support the existing symptom, i.e. each activity will be benchmarked with a budget. All three participants had experiences that contributed to the 6 emerging symptoms which include allocation of money from the government / the norm, conditions of contract, incorporating value management to help improving the budget, new technologies, readiness and suitability incompatible with project optimization. All of the participants expressed their concerned on the suitability of the construction industry without having fix budget at the early stage of the project as commented by I1, ***"Budget is essential. How else would you manage the cost over construction project from the point of view of design development?".*** However, it should be highlighted that one of the participant (I2) sees the potential of having no budget by mentioning ***"Do the cost management process in a way that it promotes innovation through visualization. It is not the cost and cost alone that helps innovation. The computer technology can help to enhance innovation at the early stage of the construction. Before budget is agreed, a visualization of the project can be run and budget can be agreed based on how you visualize the project. This will allow finding for innovation and can do some lean changes and value management to the project. The saving you can be invested somewhere else in the project".*** These gave the researcher the impression that to some degree, this could be realised to the construction cost management.

Table 30: Summary of symptom in constraint created by budgeting
(Note: orange colour: symptom identified in literature review and in-depth interview)

Type of Symptom	Symptoms	No. of Respondents	No. of References
Key Issue: Constraint Created by Budgeting			
Existing	Each activity will be benchmarked with a budget	3	6
Emerging	Allocation of money from the government / The norm	1	2
	Conditions of contract	1	1
	Incorporating Value Management to help improving the budget	1	2
	New technologies	1	1
	Readiness	2	3
	Suitability	2	3

3.7 Discussion

The findings from the main seven (7) that included existing and emerging symptoms have been thoroughly discussed. Table 31 presented the summary of the symptom identified in both empirical investigations (highlighted in orange colour), symptom identified only in exploratory interview (highlighted only in blue colour) and symptom identified only in 'in-depth' interview (highlighted in purple colour). In addition, the relationship between each symptom in exploratory interview can be visualised in Figure 21 and Figure 22, whereas for in-depth interview, it can be visualised in Figure 23. The research could summaries that those seven key issues identified earlier through theory are also confirmed with empirical investigation.

In addition, the findings from the empirical investigation are also used during the development of the conceptual solutions because it also includes the solution to the cause. This is also important to help in identifying the key issue by investigating what are the problems that can be solved by those solutions given. Another finding that has been identified is at which stages of the construction process that the problems occur which is shown in Figure 22. Some suggestions to the problem and some views that does not support from the earlier findings (literature review) have also being identified for further investigation. Taking from here, as the continuation of the process highlighted in green as shown in Figure 20, the creation of the conceptual solutions is carried out based on the discussion in Chapter 2, Section 2.4.3.2.

Table 31: Summary of cross reference of list of symptoms and causes

(Note: orange colour: symptom identified in both empirical investigation, blue: symptom identified in exploratory interview and purple: symptom identified in 'in-depth' interview)

Type of Symptom	Symptoms	
	Findings from Exploratory Interview	Findings from In-Depth Interview
Key Issue: Failure to Forecast		
Existing	Cost is just understood to be there	Cost is just understood to be there
	Early commitments to design solutions can lead to making wrong decisions	Early commitments to design solutions can lead to making wrong decisions
	Cost data inherit waste	Unethical practices
Emerging	Estimate in detail is not a problem because it is forecasting – ACCEPTABLE SITUATION	Improvement through new technologies
	GAP-between what required to construct and specification and estimated and bid.	Level of accuracy
	No similarity between estimate and cost to manage production.	Limited information
	People by future - return on investment	The needs for improvement
	Price volatility – uncertainty	Theory vs. Practical
	Problem with project management	Time pressures
		Types of client/client's objectives
Key Issue: Failure to Support Improvement Opportunities		
Existing	Cost data inherit waste	
	Early commitments to design solutions can lead to making wrong decisions	
Emerging	Pretty bound to honour the contract and not able to really innovate	Client expectation or needs
		Collaboration (Procurement)
		Conditions of contract
		Delivering value to the client
		Different in objective between client and contractor
		Involvement of contractor during design phase or Collaboration (procurement)
		Modern construction process
		Modern cost Management
		Non-responsive to change
		Resistant to change
		The initiator
Key Issue: Interruption by Business Cycle		
Emerging	Interruption by business cycle	
Key Issue: Costs are Considered as Resulting from Action		
Emerging		Communication and team work
		Different objectives to be achieved
		New technologies
		Non-responsive nature
		Procurement
Key Issue: Relative Neglect of Value Consideration		
Existing		The client do not know where and how to do VM
Emerging	Transaction of value	Additional scope of work for QS
		Cannot 100% to rely on software
		Communication
		Integration support
		Modern system helps better

Type of Symptom	Symptoms	
	Findings from Exploratory Interview	Findings from In-Depth Interview
		New technologies
		Promoting VM
		Willingness to spent additional money
Key Issue: Poor Support for Inter-Organizational Cost Management		
Existing		Create a major addition in transaction cost until it reach the final customer
Emerging	Many-tiered supplier networks create a major addition in transaction cost until it reach the final customer	Awareness/education
		Integration
		Long term relationship
		Project manager scope of work
		Realization
		Supply chain management
Key Issue: Negative Influence on Behaviour		
Existing		Contractor cash flow problems (cash flow problems) – expend more effort on generating profit through claim rather than improving the construction methods
Emerging	Poor estimate and the contractors try to look for opportunity to claim.	Bad practice
		Estimate A but build B
		Faulty in contract or tender document / Design team weakness
		New technologies
		Procurement
		Time constraint
Key Issue: Constraint Created by Budgeting		
Existing	Each and every activity involved in the product delivery process will be bench marked with a budget	Each activity will be benchmarked with a budget
Emerging	Incompatible with project optimization	Allocation of money from the government / The norm
		Conditions of contract
		Incorporating Value Management to help improving the budget
		New technologies
		Readiness
		Suitability
		Incompatible with project optimization

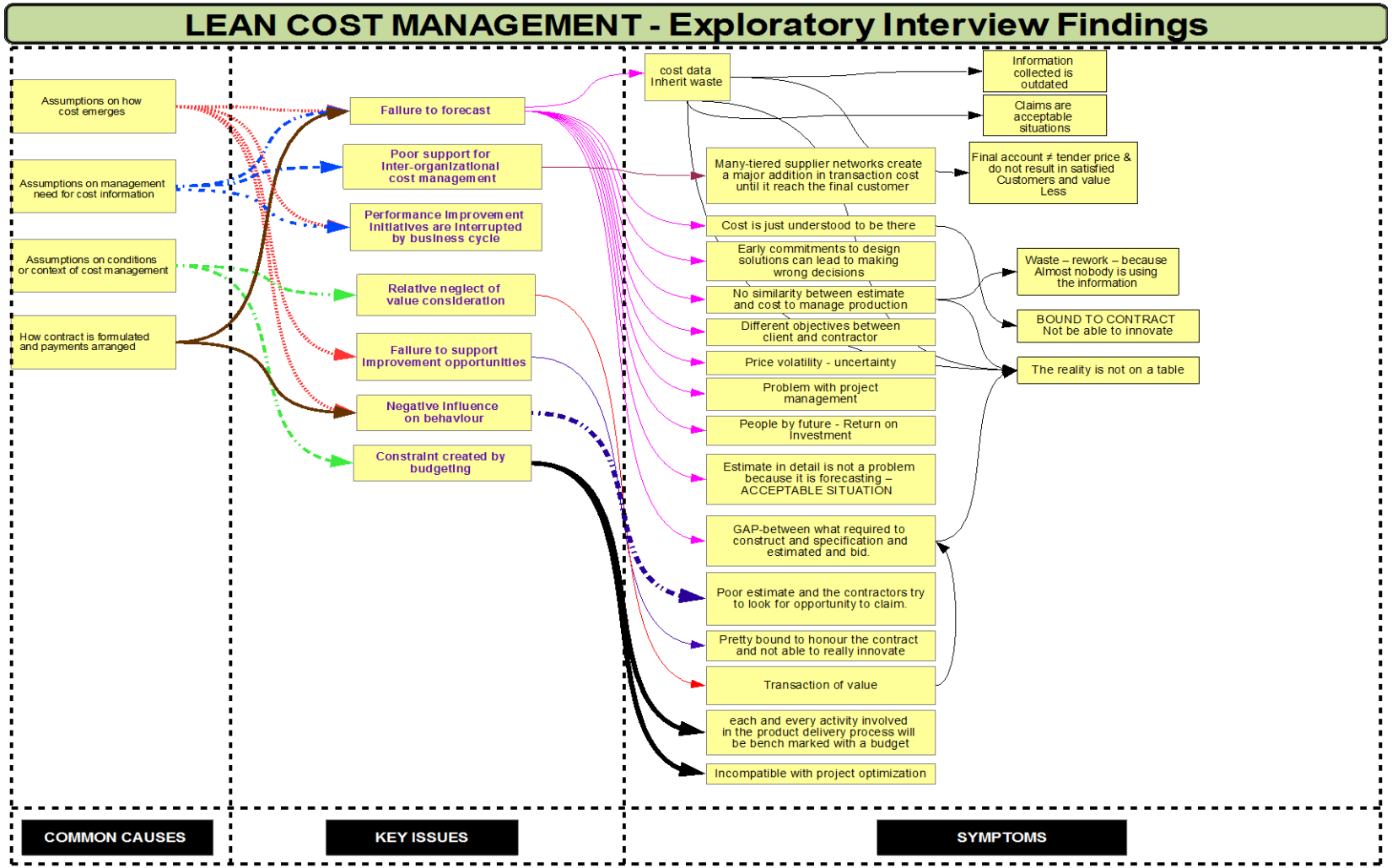


Figure 21: The relationship among common causes, key issues and symptoms for exploratory findings

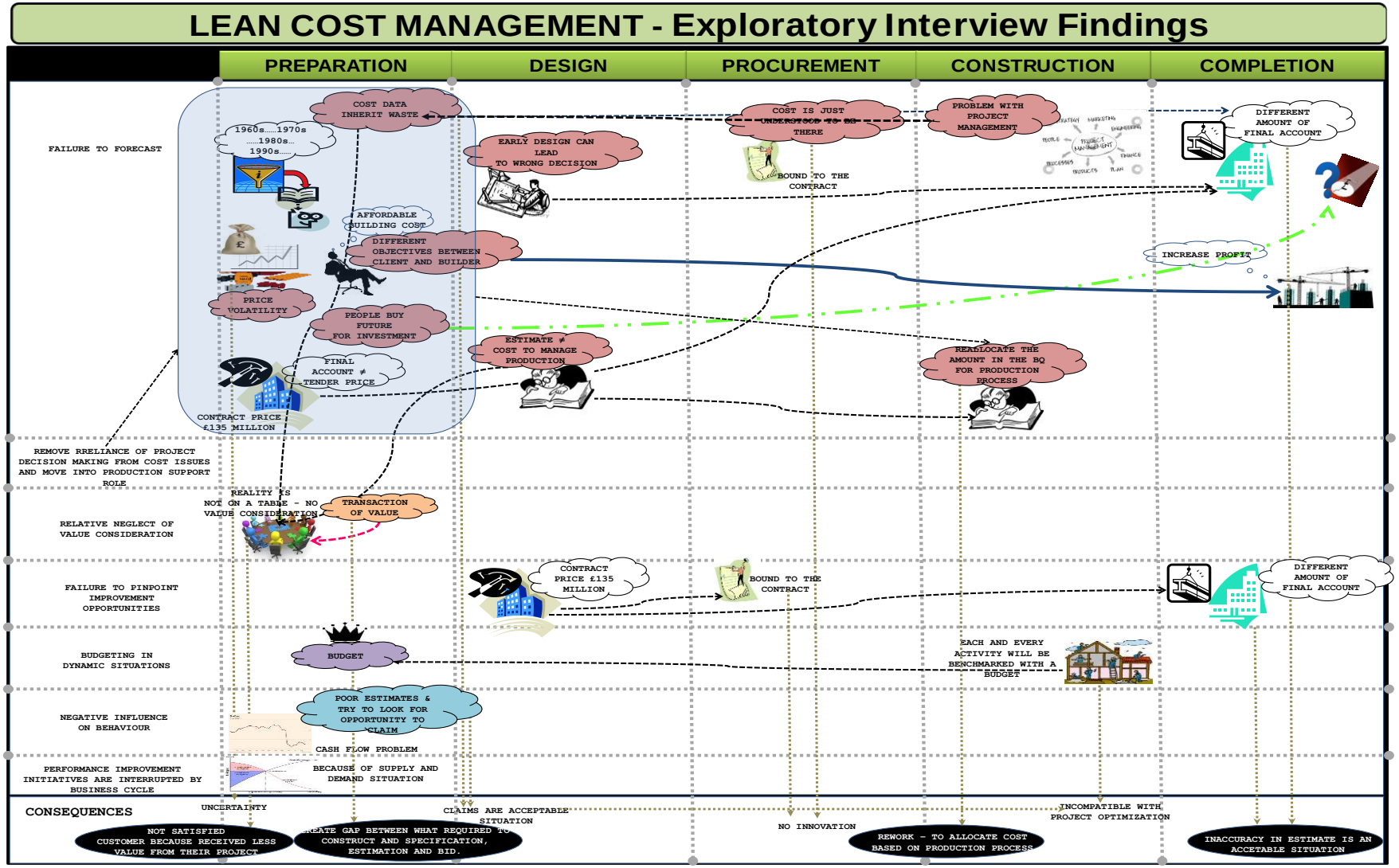


Figure 22: Rich picture diagram for exploratory findings

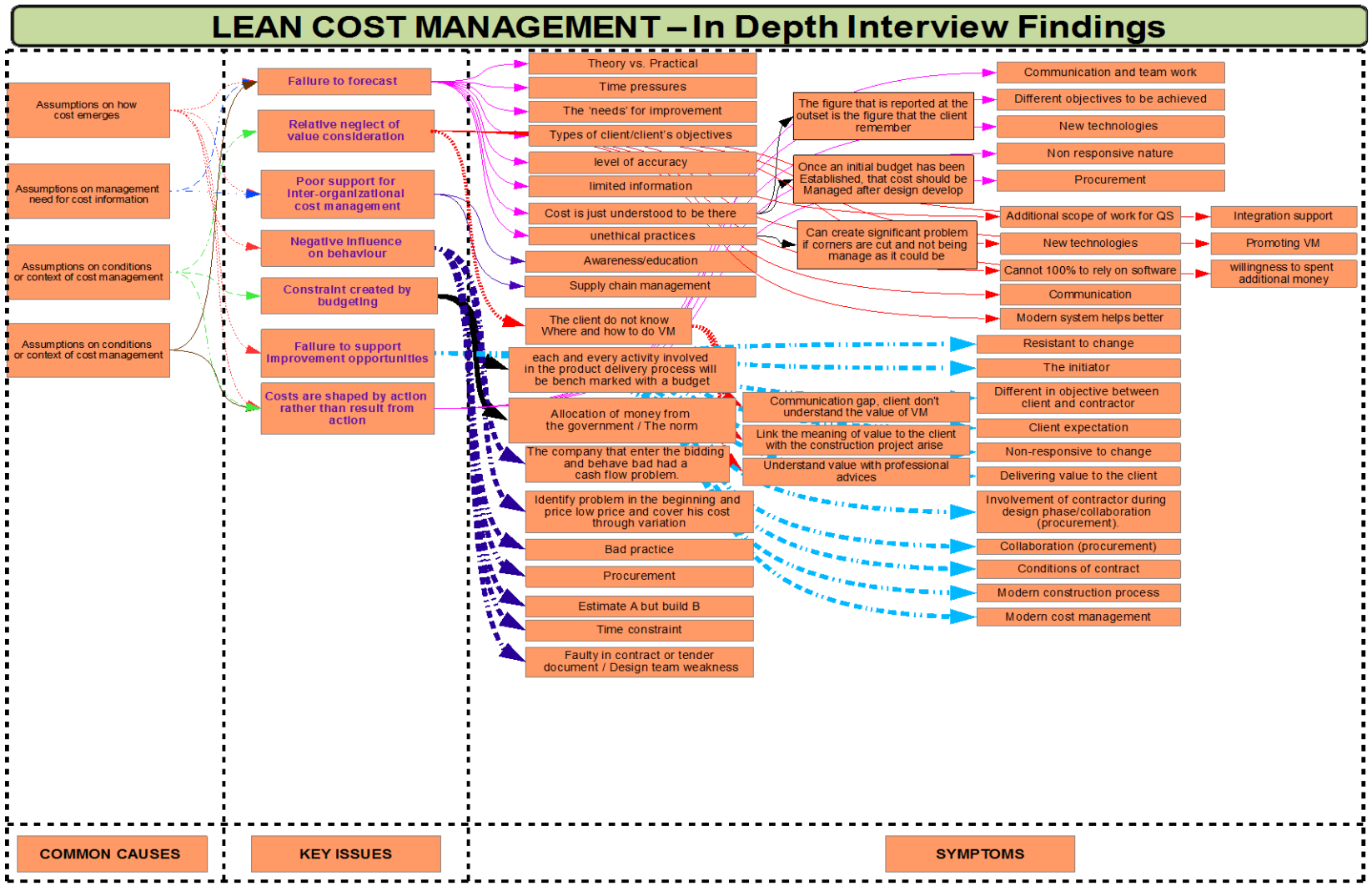


Figure 23: The relationship among common causes, key issues and symptoms for in-depth interview findings

3.8 Summary

This chapter has explored the key issues and could summaries the number of key issues and it symptoms through literature review, workshop and interviews for establishing awareness to the current problem in the area of the construction cost management.

In the following chapter, the research study will present the solution to the research problems identified which is an innovation to construction solution for solving to the domain problem identified. The process of constructing the conceptual solutions is being presented too in this chapter.

4 DEVELOPMENT OF CONCEPTUAL SOLUTIONS

4.1 Introduction to the chapter

This chapter presents the solution to the research problems identified. The process of constructing the solution is by obtaining a general and comprehensive understanding of the problem identified and followed by a root cause analysis. Next, the countermeasures are then proposed – these are the conceptual solutions. In terms of evaluating the validity of them, they are synthesized into existing practical solutions. The chapter also discusses the outline criteria required for developing new cost management framework and identifies the rubrics and mechanics of the development phase of the conceptual solution framework within the context of 5 - 'Why' Analysis. Accordingly, it is structured as follows:

- Firstly, it discusses the method used to develop the conceptual solutions by linking the method used to DSR for justification. It also discusses the outline criteria required for developing the conceptual solutions and identifies the rubrics and mechanics of the development phase of the conceptual solution framework within the context of 5 - 'Why' Analysis.
- Secondly, it explores and justifies on how the root cause is being selected after going through the process of 5-Why Analysis in getting to the deepest level of problem.
- Thirdly, the conceptual solutions are presented through the process of grasping the problem, analysis to the root cause, inference of countermeasure to the root cause, synthesis of the solution.

4.2 The Method used to Develop Conceptual Solutions

The development of the conceptual solutions to the research problems is tackled using one of the categories under The Toyota Way (Liker, 2004). There are 14 management principles that constitute the "Toyota Way" and from these key principles the techniques and tools of the Toyota Production System and the management of Toyota in general derive. All these principles have been categorised under 4 categories (Liker, 2004) shown in

Figure 24. These categories include problem solving, people and partners, process and philosophy. The method used for the development of the solution to the research problems comes from the 'Problem Solving' category. Only this category was chosen from those four because it is parallel with the objective of DSR, which is centered toward practical problem solving in a particular field.

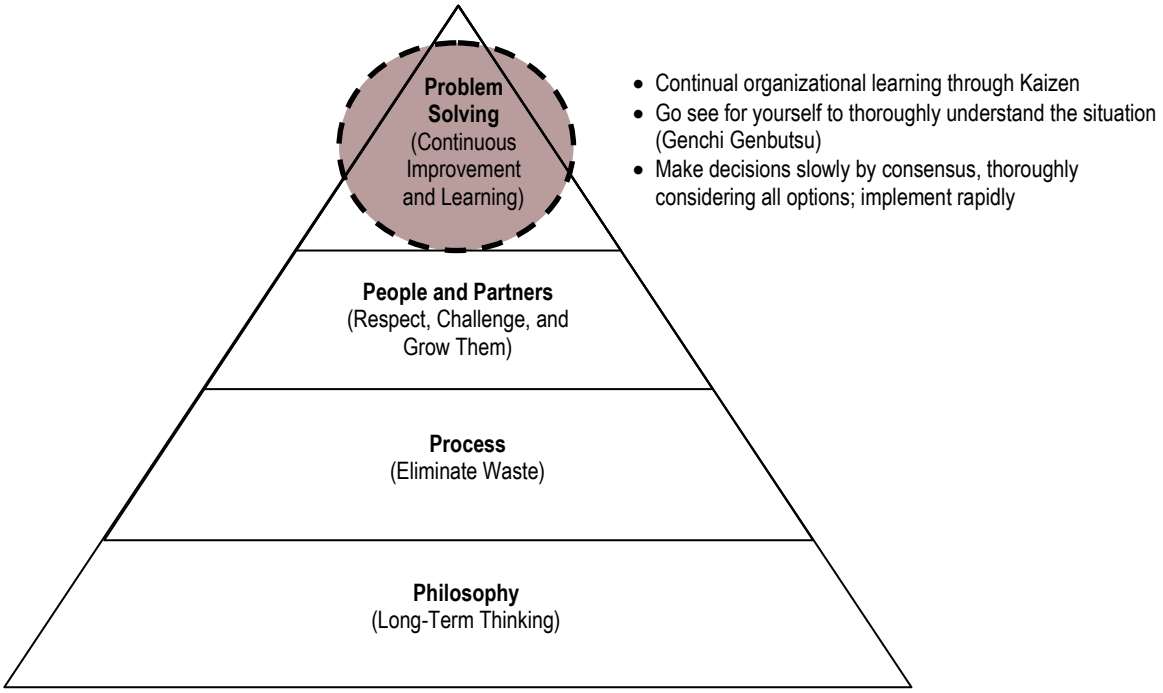


Figure 24: A "4 P" model of the Toyota way.
(Source: Liker (2004))

The method used for the development of the solution to the research problems under 'Problem Solving' category involves determining the root causes of problems and providing effective countermeasures. Getting to the root cause of the problems is determined using an integral part of kaizen, the 5 - 'Why' analysis. The 5 - 'Why' is a method to pursue the deeper, systematic causes of a problem in order to find correspondingly the right countermeasures. The uniqueness of this technique is that it makes us realise that the countermeasure at the initial level of problem is completely different from that at the deepest level.

The countermeasures targeted – that is, conceptual solutions - are the countermeasures at the deepest level of cause that is feasible and at the level that will prevent reoccurrence of the problem. This is done by asking 'Why' five times, which requires a high level of detailed thinking and analysis. The process of doing it is described by Taiichi Ohno in a book written by Liker (2004) as a process that requires identifying "….'root cause' rather than 'source'; the root cause lies hidden beyond the source". The process of asking 'Why' starts with asking the first 'Why' and then asking 'Why' again from the answer/answers that occur. It is mentioned in Liker (2004) that this process of asking ''Why'' leads upstream in the process. The questioning could be taken further to a sixth, seventh, or higher level and the "five" in 5 Whys is not an unquestionable truth, but five iterations of asking why is generally sufficient to get to a root cause (Wikipedia, 2013a).

It has been proposed that a Fault Tree Analysis needs to be prepared before starting the 5 - 'Why' analysis (Sondalini, 2013). Fault Tree Analysis is a process of building a cause and effect tree that is known as a Why Tree. This is needed so that the interactions of causes can be seen because sometimes only one cause sets off an event and other times multiple causes are necessary to produce an effect. The Why Tree for even a simple problem can grow huge, with numerous cause-effect branches. Next, every cause needs to go through a Why Table to sequential list the questions and their answers.

Subsequently, a countermeasure should be proposed to the identified root cause. The process of proposing a countermeasure is related to Toyota's practical problem-solving process model shown in Figure 20 and Figure 25. By referring to Toyota's practical problem-solving process model, the researcher needs to bear in mind that before the 5 - 'Why' analysis was carried out, the identification of the 'practical problem solving' needs to be carried out first for clarifying the problem and grasping the real situation of the problems. This was described in detail in Chapter 3 and Chapter 4. Figure 20 and Figure 25 show at which stage in Toyota's practical problem-solving process this process belongs to. For developing the conceptual solutions, the next step in Toyota's practical problem-solving process needs to be carried out which is called 'Cause Investigation' stage which is shown in Figure 25. This is where the process of determining the root causes of the problems started and followed by the process of proposing the countermeasures.

4.3 Justification of Countermeasure at the Root Level.

One of the ultimate results from using 5-Why Analysis is getting to the root cause of each problem identified by peeling away every layer of the symptom. Right and effective countermeasures will then be determined to each of the root causes. Problem-solving is a mental process that involves discovering, analyzing and finding solutions to problems. The ultimate goal of problem-solving is to overcome obstacles and find a solution that best resolves the issue (Cherry, 2013). There are many kinds of problem-solving strategies available at present. However, the traditional mental process does not go to the deepest level of problem and it is believed that the mind-set of the problem-solver only reaches level of problem No. 1, which proposes a different kind of countermeasure comparing with the countermeasure proposed using 5-Why Analysis. The difference in terms of the countermeasure proposed happen because of the different approach taken to interact with the problem.

There have been useful discussions on the selection of the root cause resulting with the summary of important aspects. These important aspects have come to the surface from several sources. The suggestions to those aspects highlighted are tabulated in Table 32.

Table 32: Determination of the root cause

Suggestion	Occurrences in Literature Review
For identification of root cause, Wikipedia (2013a) suggests that answers that related to a process is the real root cause. It is also suggested that instead of asking the question **Why?,** ask **Why did the process fail?**	(Wikipedia, 2013a)
For identification of root cause, Bank (2009) suggests that while asking the question of **Why?,** on-the-spot verification of the answer to the current "why" question before proceeding to the next is recommended .	(Bank, 2009)
In determining the root cause, more than one "cause" is allowed and more than one corrective action is not forbidden.In proposing the countermeasure, it is suggested that the simplest or the lowest cost approach is preferred especially if there are alternatives that are equally effective. In addition, the process of asking 'Why'should establish a sequence of events or timeline.	(Wikipedia, 2013c)
Good judgment and common sense are needed to determine how far to go in the investigation of the root cause. Theoretically, root causes can be traced back to the Stone Age but the effort would serve no useful purpose and this is deal by identifying a significant cause that can, in fact, be changed. There are three basic types of causes that can be used as a guideline in identifying the root cause: 1. **Physical causes** – Tangible, material items failed in some way (for example, a car's brakes stopped working). 2. **Human causes** – People did something wrong, or did not doing something that was needed. Human causes typically lead to physical causes (for example, no one filled the brake fluid, which led to the brakes failing). 3. **Organizational causes** – A system, process, or policy that people use to make decisions or do their work is faulty (for example, no one person was responsible for vehicle maintenance, and everyone assumed someone else had filled the brake fluid).	(Tools, 2013)
The process of asking 'Why' need to be done one level at a time to find the real failure path through that 'level of problem'. At each level the true failure path should be identified by ***true evidence***and logic to prove which one(s) brought about the incident. Once the first level cause(s) are confirmed then only the process of asking 'Why' in the following level can be continued and so on. The ***latent causes*** are the most critical ones to find, but they are usually the hardestto deal with and often an embarrassing one for all involved. There are many incidents and events that can cause the problemand these causes and effectsare branches to the root cause(s).	(Sondalini, 2013)

The 5-Why Analysis allows the deepest level of problem to be dug out in order to look for the right countermeasure to the root cause. The researcher has identified that there are differences between Toyota's practical problem-solving process (Figure 20 and Figure 25) and the 5-'Why' Analysis as shown in Table 33in terms of at which stage to propose the countermeasure. Based on 5-'Why' Analysis, countermeasure is proposed at every level of problem whereas Toyota's practical problem-solving process proposes countermeasure after the root cause has been identified. However, the researcher has decided to follow the Toyota's practical problem-solving process where the countermeasure will only be proposed after the root cause has been identified. The researcher choice is supported by Liker (2004) who mentions that the countermeasures taken are the countermeasures at the deepest level of cause that is feasible and at the level that will prevent reoccurrence of the problem.

Furthermore, the researcher believes that the root cause is actually the real cause to the problem and therefore the researcher has the opinion that the countermeasure needs to be given attention only at the root cause identified and not at every level of problem as shown in Table 33. Once the root cause is being tackled, the rest of the problems will be resolved straight away. This is because the root cause is actually the root problem that needs rectification or mitigation.

Table 33: The 5-Why analysis process: an example

	Level of Problem	Corresponding Level of Countermeasure
Why?	Inaccuracy between the forecast cost and the final cost emerges.	To implement reference project cost method.
Why?	Changes in the scope during the project because of uncertainty in the scope and ambition level is not detected at the moment of forecast and the scope widens during the project.	To capture the naturral tendencies to cost increase during the projects, through accumulation of new knowledge and insight.
Why?	The accumulation of new knowledge and insight during construction is not taken into account during cost forecast.	
	The standard method being used during cost forecast is static in nature of the theory of cost management.	To develop cost management approaches, which account for the emergent nature of the total construction process as suggested by the dynamic, processual view.

While going through the process proposed in the 5-Why Analysis, the researcher experienced another situation, which is divergence in terms of the answers given when asking 'Why'. Either several answers or only one answer emerge while going through the process of asking 'Why' until to the root cause. This scenario can be seen in Figure 26. When more than one answer emerges, this creates divergences. This situation has been realised by Liker (2004) who mentions that the process of asking 'Why' starts by asking the first 'Why' and then asking 'Why' again from the answer/answers that occur. However, he does not mention how to deal with this scenario. The researcher recognized that there are two types of answer given in this process, i.e. systemic answers or incidental answers. In order to select the root cause of the problem, the researcher has decided to focus just on the systemic answers because it is the fundamental/root cause of the problem.

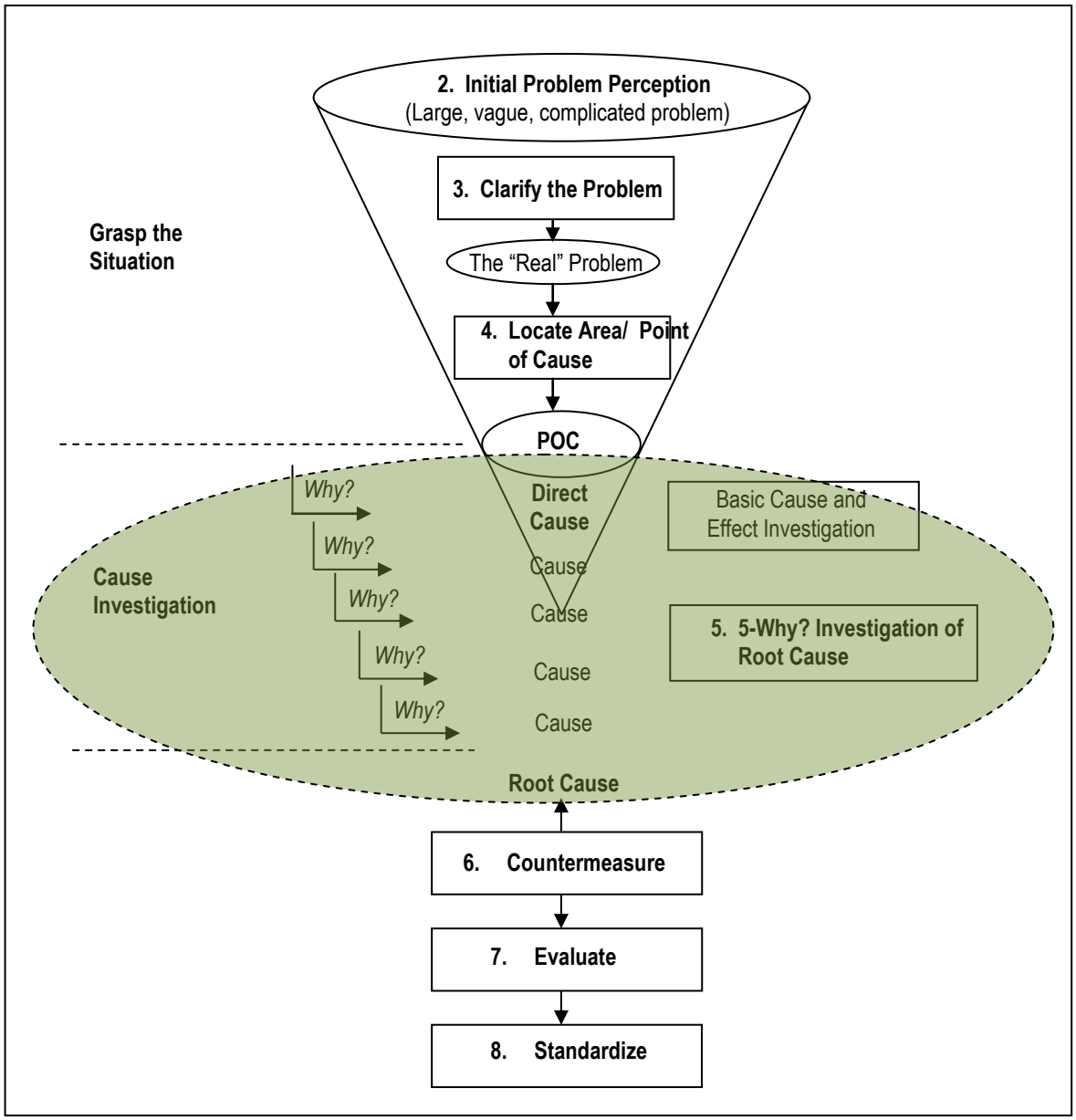


Figure 25: Toyota's practical problem-solving process – cause investigation
(Source: adapted from Liker (2004))
(Note: The green colour shows the stage of the process in Chapter 5)

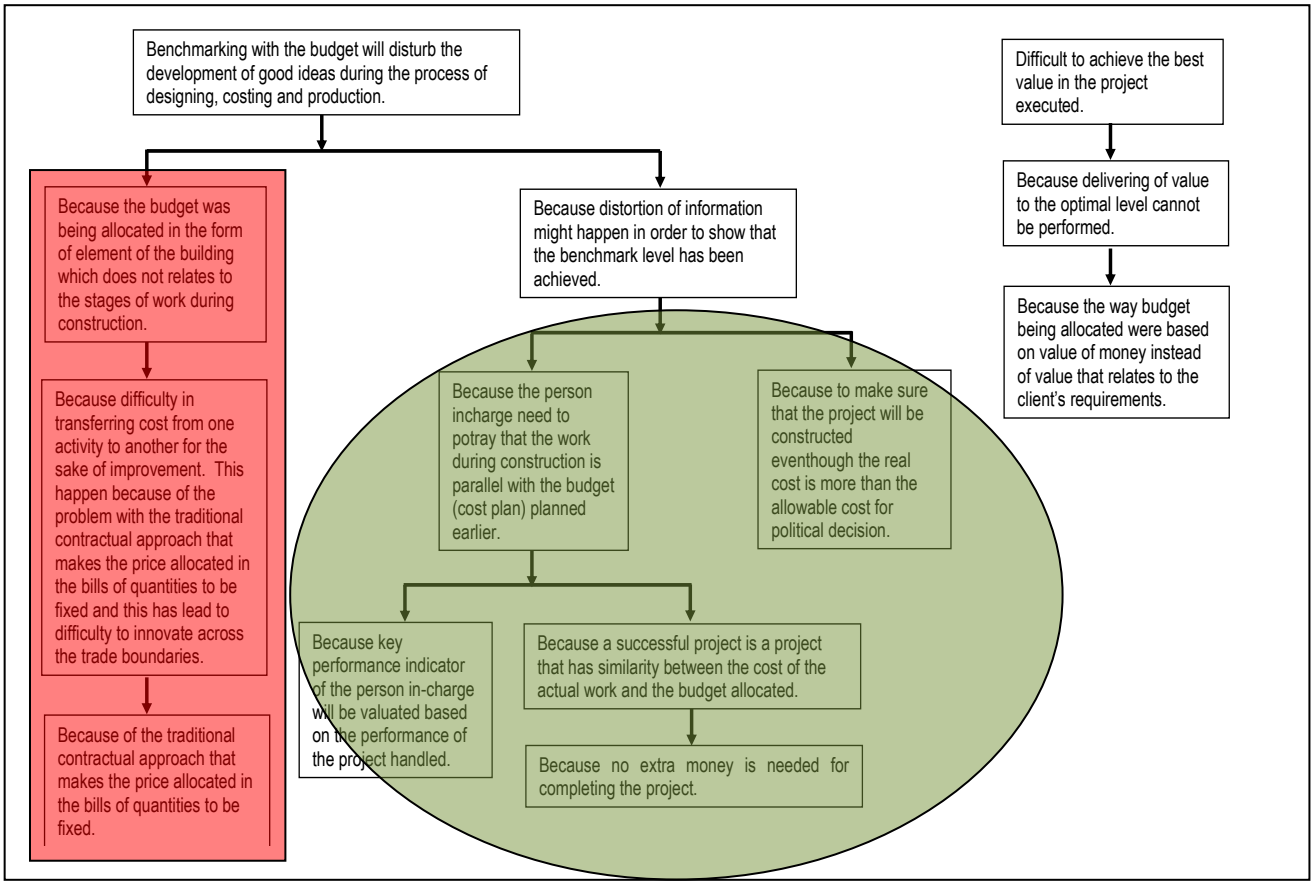


Figure 26: Several scenarios emerge while going through the process of5-'Why'analysis
(Note: The green colour shows the divergence in terms of the answers given and the red colour shows linear sequential flow in terms of the answers given)

4.4 The Development of the Conceptual Solution

4.4.1 Key Issue No. 1 - Failure to forecast

4.4.1.1 Grasping the Problem Situation

The failure to forecast happens when there is a discrepancy between cost forecast and final cost that will lead to cost escalation which is seen as a sign of inefficiency (Flyvbjerg et al., 2004). However, the level of accuracy accepted by different individual (the client) is different among them because of different objectives that they have to get the project started. In the research literature this situation are often correlated with public sector projects (Flyvbjerg et al., 2004). In public projects, the level of discrepancy between cost forecast and final cost is so important especially in Mega-Projects because cost overrun can even collapse the governments when it happens (Flyvbjerg et al., 2003). Due to this problem, it can results in cost overruns, benefit shortfalls, and the mismanagement of risk to a degree that often jeopardizes project viability (Flyvbjerg, 2007).

4.4.1.2 Analysis to the root cause

Barring bad management, the discrepancy between the forecast cost and the final cost emerges through two main reasons: All work related to the scope is not detected at the moment of forecast or the scope widens during the project.

These reasons emerge because projects occur over time, and there is an intrinsic process of accumulation of new knowledge and insight during this time, causing these reasons.

Why are these reasons not taken into account in cost forecasts? The reason to this is the way cost forecasts are done, costing a preliminary design as it is. This method is static, not taking the processual character of a project into account.

Thus, the root cause seems to be the static nature of the theory of cost management. Please refer to Table 20 for the regressive analysis.

4.4.1.3 Inference of countermeasure to the root cause

It is suggested that a dynamic, processual view on costs would provide a countermeasure to the found root cause. This is the conceptual solution sought.

4.4.1.4 Synthesis of the solution

As discussed above, although the aim in this research is to develop conceptual solutions, the procedure is extended to developing the practical, embodied solution for evaluating the validity of the found conceptual solution. If a practical, existing solution can be reached through synthesis, this shows that the conceptual solution has initial validity.

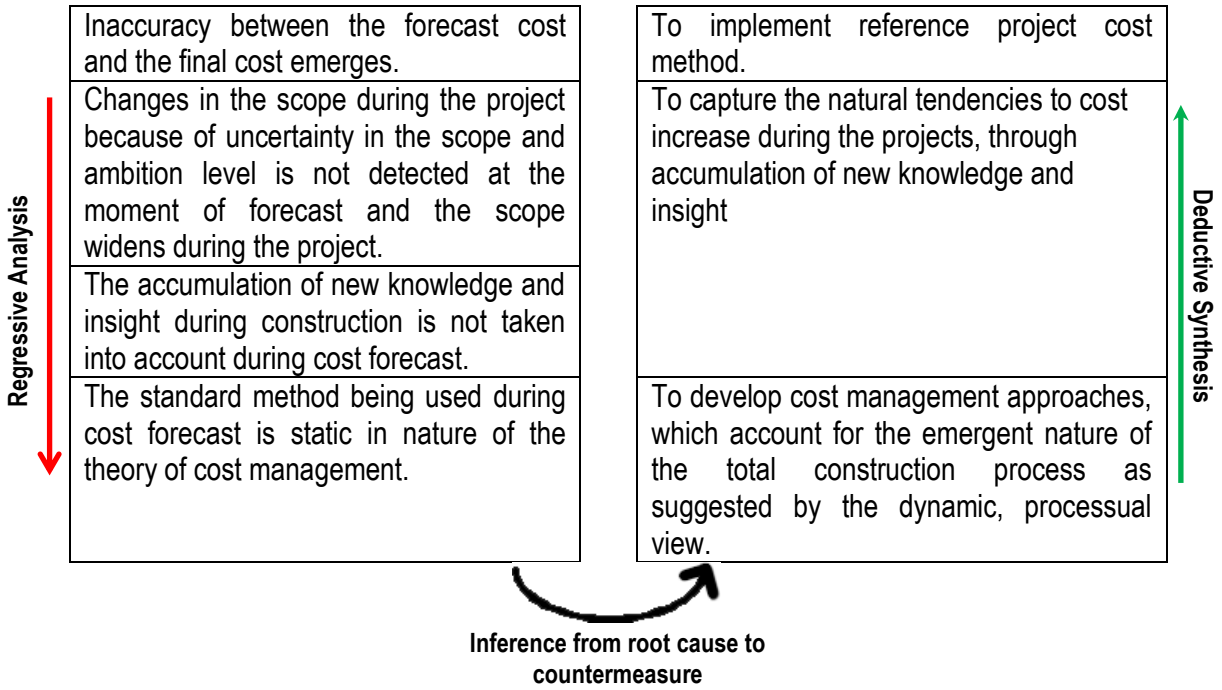
Therefore, as practical countermeasure, the task is to develop cost management approaches, which account for the emergent nature of the total construction process as suggested by the dynamic, processual view. For forecasting the final cost, it is thus necessary to capture the natural tendencies to cost increase during the projects, through accumulation of new knowledge and insight.

An easy and practical way of doing this is to use the reference class approach method, which is a comparative (top–down) method and contrasts to an engineering (bottom–up) approach. In an engineering approach, a model is developed that includes cost estimates for each component of the system, which when summed, yields an estimate of the capital costs. The engineering approach is useful in estimating the costs of a particular project, but requires site-specific information and is subject to optimism bias. It is static in nature and can thus not take processual aspects into consideration. In

the comparative approach, cost data from existing projects are used as a basis for analogy. If the physical infrastructure in two regions is similar, then the project characteristics maybe similar even if other characteristics of development–installation strategies, government regulation, etc., vary. A reference class is a set of existing projects for which cost information is available and is used to improve the accuracy of comparative cost estimation by limiting the sample to those projects that are similar to a proposed project. A reference class approach can be used to estimate the costs of a specific project, the final cost is forecast taking the realized cost of recent corresponding projects into account (Flyvbjerg et al., 2004, Kaiser and Snyder, 2012). As the prior projects, on which the reference class method is based, have already traversed through all their process stages, the resulting cost information can be characterized as processual.

Thus, the conceptual solution found can be evaluated as valid.

Table 34: Root cause analysis and solution synthesis for key issue 1



4.4.2 Key Issue No. 2 - Failure to Support Improvement Opportunities

4.4.2.1 Grasping the Problem Situation

Construction cost management fails to support improvement opportunities by failing to provide a responsive approach to improve the design (during design stage) and construction (during production stage). For example, early commitments to design solutions lock the design and the cost. The prevailing thinking is that the design that is established during the initial stage, accounts for 70%-80%

of product costs (Rush and Roy, 2000), making people to downplay the potential of improvement along the later stages.

4.4.2.2 Analysis to the root cause

As presented in Table 35, the immediate reasons to the problem are suggested to be in the situation where in this setting, the relevant processes could not provide integration among themselves. This is suggested to be caused by the lack of a felt need to improve continuously. The cause for this, and indeed the root cause, is that in conventional cost management, decisions are considered as optimal, thus not needing any continuous improvement. Please refer to Table 35 for the regressive analysis.

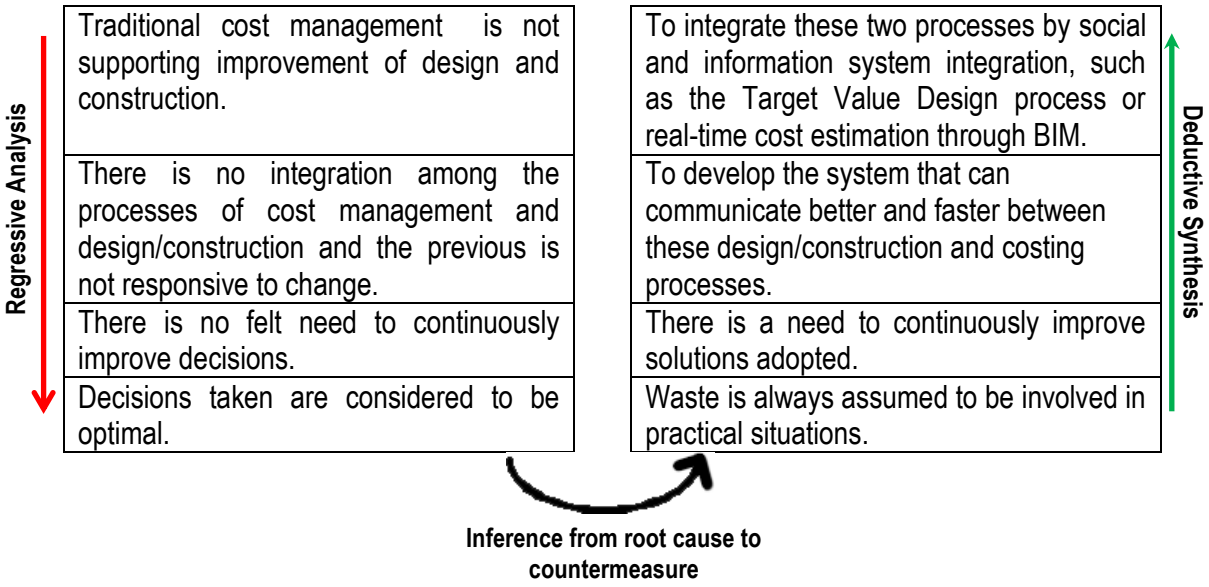
4.4.2.3 Inference of countermeasure to the root cause

The problem started during the evolution of the management science, where the changes in the dominant conceptualization of the classical management and organizational science happen. The switch from a production-centric view of management to a social science-oriented view in 1959 does not address the productive context and making it being outside management and followed by the rejection of the concept of waste. In addition, through this, the subscription is solely to the view in economics assuming decision-making to be optimal. It is suggested that the production-centric view of management would provide a countermeasure to the problem and root cause at hand, as it deals with issues that are directly related to waste issues. This is suggested to solve, at the conceptual level, the problem addressed at the outset.

4.4.2.4 Synthesis of the solution

If we accept the flow theory of production-centric view, and indeed the existence of waste as the starting point, we assume that there is room for continuous improvement. Costs can be influenced by integrating the process of designing and construction with the process of costing in order to reduce generation of waste. As practical solutions, methods like Target Value Design and real-time, BIM based cost estimation can be pinpointed.

Table 35: Root cause analysis and solution synthesis for key issue 2



4.4.3 Key Issue No. 3 – Costs are Considered as Resulting from Action.

4.4.3.1 Grasping the Problem Situation

In principle, the construction cost management process embraces costing to be either costing the design or designing to cost. As revealed by the literature, it can be said that the traditional cost management is oriented towards costing the design. That is, costs are considered as resulting from action, rather than as being shaped by action. Unfortunately, this promotes (Zimina et al., 2012) the natural tendency towards the emergency of non-value added activities and contributes to cost increases.

4.4.3.2 Analysis to the root cause

The reason to the problem is suggested to be in the situation that the designing of the project will usually lead the costing process. This is related to the nature of the traditional construction cost management process, which has a division of work and big batches within the design team. Looking into the history of construction, these two processes were combined still during the Napoleonic War, between the years of 1803–1815 (Cartlidge, 2006). The separation of cost management process and design process has created a communication barrier and lacking in teamwork between designers and cost persons that created a non-responsive system of the mainstream cost management. The cause for this, and indeed the root cause, is that conventional cost management has subscribed to the modern management of science that has hindered the consciousness of this issue as a problem. In conventional cost management the segregation of work is the result of a paradigm shift from the

classical management science to a modern management science, where connections of management science and organization theory to production have been cut off, leading also to the separation between cost management (as part of management) and design (as part of production). Please refer to Table 36 for the regressive analysis.

4.4.3.3 Inference of countermeasure to the root cause

By subscribing to the idea of neglect of production as the cause of irrelevancy of management science, a possible countermeasure can be achieved through the connection of organization theory back to production conceptually and by combining or integrating these two processes, i.e. cost management (management) and design (production) by organizational and computational means.

4.4.3.4 Synthesis of the solution

Therefore, a possible countermeasure is to develop cost management approaches, which account for the connections of management science and organization theory to production as suggested by the classical management. A practical way of doing this is by subscribing to target value design (Ballard, 2011) or target costing that defines the life cycles cost basing on spaces needed and workplace planning which links spaces to business operations (Pennanen et al., 2005).

Table 36: Root cause analysis and solution synthesis for key issue 3

The designing of the project will lead the process instead of costing of the project.	To adopt efficient method of cost management to steer and reduce cost towards client targets, through target costing that defines the life cycles cost basing on spaces needed and workplace planning or Target Value Design.
The division of work and big batches that are practiced in the mainstream cost management isolate the process of designing and costing from each other.	To reduce the lapse between these two processes throughorganizational and computer integration.
Subscription to modern management of science that cut off the connections of management science and organization theory to production (with design as one part of it).	Connecting management and organization theory back to production.

Regressive Analysis

Deductive Synthesis

Inference from root cause to countermeasure

4.4.4 Key Issue No. 4 – Relative Neglect of Value Consideration

4.4.4.1 Grasping the Problem Situation

The challenge of relating customer value to price and cost has been addressed by many attempts in the literature and practice that have led to a 'new' cost management techniques (McNair et al., 2001). It was understood that people do not know where and how to do it (McNair et al., 2001). These techniques do not enable an identification of which activities should be emphasized and provide no assessment of specific linkages between internal cost structure and externally defined value and each tool fails to fully explain the complex relationship between cost and value (McNair et al., 2001). The same situation also occurs in construction cost management as cost management does not provide enough encouragement and supportive environment towards the implementation of value management in it.

4.4.4.2 Analysis to the root cause

As presented in Table 37, the immediate reason for this problem is suggested to be in the situation where cost management does not provide enough encouragement and support towards the implementation of value management (VM). One of the negative aspects coming out from neglecting value is the ignorance of VM implementation in cost management practice. The processes of value management are isolated from other processes in construction cost management because it is not conceptualized in the quantity surveying roles. Therefore, value creation cannot be advanced because of the process of value consideration is not being recognized in cost management and thus is being neglected. The cause for this, and indeed the root cause, is that in conventional cost management, the transformation theory of production (Koskela, 2000) is subscribed to. That theory leads to an emphasis on internal production rather than on satisfying the customer needs which determine the value of the product.

4.4.4.3 Inference of countermeasure to the root cause

It is suggested that the TFV theory of production (Koskela, 2000) would provide a countermeasure to the problem and root cause at hand, as it deals with issues that are directly related to value. Through this theory, the concept of value generation is achieved through fulfilment of customer needs by translating these needs accurately into a design solution, which then can be used to produce products that conform to the specified design.

4.4.4.4 Synthesis of the solution

It is suggested that the adoption of the TFV theory in the construction cost management should be implemented. Through the adoption of the TFV theory, the missing link between cost and value could be created. This theory enables the continuous improvement of value as well as monitoring of loss of value by creating a better alignment between cost and value for helping the firm target areas where costs can best be leveraged to improve its overall profit potential (McNair et al., 2001). The practical solutions that can be pointed are Target Value Design and Benefits Realization.

Table 37: Root cause analysis and solution synthesis for key issue 4

Regressive Analysis	Cost management does not provide enough encouragement and support towards the implementation of value management		Utilization and further development of methods where value generation is integrated: Target Value Design, Benefits Realization
	Value management is an isolated process and detachedfrom other processes in construction cost management.		Considering value management in the standard process of construction cost management.
	Value is not conceptualized in the conceptual framework of quantity surveying roles		Adding value to the conceptul framework of quantity surveying
	Transformation theory of production is in use as a foundational theory.		Value generation theory of production to be used, too.

Deductive Synthesis

Inference from root cause to countermeasure

4.4.5 Key Issue No. 5 – Poor Support for Inter-organizational Cost Management.

4.4.5.1 Grasping the Problem Situation

The organization of construction projects have moved to be based on a multi-layered supply chain model, motivated by the idea of finding the cheapest suppliers from the market. However, in cost management, costs and their causes become non-transparent in this setting, effectively preventing cost improvement. This is problematic as there are grounds to argue that multi-layered supply model leads to added transaction costs until it reaches the final customer, where it is unnecessary cost in the entire value chain (Kulmala et al., 2002). Cost becomes invisible in this organizational setting and that creates wastages as well as inaccuracy to the final project cost.

4.4.5.2 Analysis to the Root Cause

As presented in Table 38, the immediate reason for this problem is suggested to be in the situation where the costs are known only at the level of bids and contracts (that is, about chunks of work to be contracted). This, in turn, is based on the assumption in conventional cost management of costs being caused by sub-transformations of the total transformation (Cherry, 2013). Thus, it is enough to minimize the cost of each mutually independent sub-transformation. The cause for this, and indeed the root cause, is that in conventional cost management, construction is seeing as transaction.

4.4.5.3 Inference of Countermeasure to the Root Cause

It started with the diffusion of classical management science where the concept has pushed production and waste aside resulting in improper conceptualization of production and waste in economic theorizing and has contributed to seeing construction as transaction. This has led to not addressing production costs into account at all in the economic theorizing and economic organization only aims at minimizing transaction cost. With this, production costs are assumed to be constant. However, in reality production costs cannot be held constant because they contain waste to a varying extent which caused by variability (roughly, unpredictability) in the production flows (Rooke et al., 1997, Koskela and Ballard, 2012). It is suggested that taking into account the production costs would provide a countermeasure to the problem and root cause at hand, as it deals with issues that are directly related to cost issues that relates to waste and non-waste activities in production costs which was assumed to be constant before.

4.4.5.4 Synthesis of the Solution

If we accept the construction as production as the starting point, we assume that costs are caused both by value adding transformations and non-value adding activities, waste (Koskela, 2000). Waste reduction should be handled besides transaction cost minimization and also through production costs minimization because there are myriad different causes of waste. A practical way of doing this is by subscribing to Open Book accounting where it strategies towards co-operation between firms situated in a supply chain and information is used to influence the flow of products and services between the firms in question (Mouritsen et al., 2001).

4.4.6 Key Issue No. 6 – Negative Influence on Behaviour.

4.4.6.1 Grasping the Problem Situation

Negative influence on behaviour comes from both sides, i.e. the contractor side and the client side. Every party has their own agenda for achieving individual benefit rather than contributing to the whole

project/client benefit. Based on the literature review there are several negative behaviours by different parties in the construction industry for many different reasons.

Table 38: Root cause analysis and solution synthesis for key issue 5

Causes of cost are not transparent in inter-organisational settings	Cost transparency through Open book accounting
Knowledge on costs is based on bids on different parts of the project.	Knowledge on costs must be system wide
Costs are assumed to be caused by mutually independent transformations.	Costs are assumed to be caused by transformations and waste (including transaction costs): waste is caused by pointwise issues and system wide characteristics.
Construction is seeing as transaction.	To see construction as production.

Regressive Analysis

Deductive Synthesis

Inference from root cause to countermeasure

From the contractor side, there are situations where the contractors might expend more effort on generating profit from claims rather than improving the construction methods and also overpricing elements that is going to be constructed earlier to receive money in advance which is called unbalancing bid. The faulty tender document produced by design team that has some weaknesses and also contractor cash flow problem contributed to this situation and created poor estimate by contractor. From the decision maker side, there are situations where a project, which has higher cost than the money allocated, is being launched for political decisions.

4.4.6.2 Analysis to the Root Cause

Obviously, the project parties are keen to improve their financial gains through the means available to them. In the traditional way of contracting, those means are connected to each sub-project rather than the whole project.. Initiatives taken for improving to the benefit of the whole project are not rewarded.

4.4.6.3 Inference of Countermeasure to the Root Cause

Incentive is a motivator that can be used to drive the progress of the work in a particular project. Therefore, this can be seen as the stepping stone towards a better project with the involvement of all the parties in the project. The use of incentives is to alter motivation and behaviour has been researched for more than half a century (Lewin, 1938). Pritchard et al. (1988) reported that financial and nonfinancial incentives can indeed increase performance when the incentive system is properly

designed and incentives can have positive effects on individual performance. Please refer to Table 39 for the regressive analysis.

4.4.6.4 Synthesis of the Solution

Introducing incentive as a motivator for project success and reducing non-value added activities, have to be supported with shared risk between the owner and the builder. As a practical solution, the concept of gainsharing and painsharing introduced by Ballard (2012) can be used as guidance in introducing incentive in construction of a project. Gainsharing is used to spur innovation and hence reduce the actual cost within the allowable cost, whereas, painsharing; reflecting the contradictory through the usage of relational contract or alliance contract.

Table 39: Root cause analysis and solution synthesis for key issue 5

Regressive Analysis	Project parties adopt negative behaviour that works against the targets of the whole project..	To include gainsharing and painsharing as incentives
	Project parties endeavour to improve their financial gains using available opportunities.	
	Available incentives do not support improving and contributing to the whole project.	Using incentives that reward behaviour contributing to the whole project.
		Deductive Synthesis

Inference from root cause to countermeasure

4.4.7 Key Issue No. 7 – Constraint Created by Budgeting

4.4.7.1 Grasping the Problem Situation

In conventional cost management, budget is used as an establishment of desirable totals for expenditure and revenue, coupled with plans to ensure that the actual operations are kept within these bounds (Willsmore, 1939). However, benchmarking with the budget will disturb the development of good ideas during the process of designing, costing and production because each and every activity involved will be benchmarked with a budget (Elfving et al., 2005). This has led to difficulty in transferring cost from one activity to another to innovate across the trade boundaries for the sake of improvement. In addition, lacking in terms of incentive given to improve beyond the budget figures also discourage innovation on site. Budgeting will leads to negative aspects such as distortion of information because of stress to achieve the budget success that have led to a breakdown in corporate ethics where information is only funnelled to those with a “need to know” and not the rest of the team

(Hope and Fraser, 2003b) and to support political decisions, where unethical practices such as project champions / person in-charge (planner & the politicians) proceeding with projects even when inaccuracy in estimating (budgeting) is detected at the outset (Flyvbjerg, 2008). Furthermore, the damage done by using budget is that it rejects flexible planning where it prohibits innovation and stop improvement opportunities that can encourage project optimization.

4.4.7.2 Analysis to the root cause

The cause to this problem is suggested to be in the situation that the information shown in budget displayed the costs of functions and departments instead of the costs of the activities people perform and this is not helping to see the real cost drivers of their business. In construction industry this was displayed in the form of elements of the building, which does not relate to the stages of work during construction. The traditional contractual approach makes the price allocated in the bills of quantities to be fixed after contract has been signed and the consequence to this is that the transferring of cost from one activity to another activity makes it difficult to innovate across the trade boundaries for the sake of improvement. The cause for this, and indeed the root cause, is that in conventional cost management, the functions (which are explained in the following section) of construction project budgets have been combined and therefore difficult to monitor.

4.4.7.3 Inference of countermeasure to the root cause

It has been argued that construction project budgets have traditionally served two functions (Ballard, 2012) that are in tension with one another; namely, to provide sufficient funds to achieve the purpose of the project and also to minimize the project cost and it is not shown in the budget displayed. It is suggested that the separation of the functions of construction project budget should be subscribed to provide a countermeasure to the problem and root cause at hand, as it deals with issues that are directly related to cost issues for project achievement. Please refer to Table 40 for the regressive analysis

4.4.7.4 Synthesis of the solution

Budget should be decomposed to segregate its functions for encouraging project improvement. In one of the functions, which is to minimize the project cost, budgets should be seen in a flexible manner and priority should be given to whole project improvement rather than to the goal of keeping the actual operations within the pre-conceived plans. As a practical solution, budget that has two different financial elements, i.e. provide sufficient funds to achieve the purpose of the project and to minimize the project cost can be pinpointed.

Table 40: Root cause analysis and solution synthesis for key issue 7

Difficulty in transferring cost from one activity to another to innovate across the trade boundaries for the sake of improvement.	The implementation of Integrated Project Delivery
Budget was being allocated in the form of element of the building which does not relates to the stages of work during construction.	
The traditional contractual approach makes the price allocated in the bills of quantities to be fixed.	To adopt a more flexible contractual approach that allow transferring of cost from one activity to another that can encourage project improvement and reject inflexible planning.
The function of construction project budgets has been combined.	The separation of the functions of construction project budget should be subscribed.

Regressive Analysis

Deductive Synthesis

Inference from root cause to countermeasure

4.5 Evaluation

For evaluating the conceptual solutions, a corresponding practical working method has been pinpointed. Through this, the aim has been to demonstrate that the conceptual solution works by indicating that the original problems have been solved through practical solutions where the conceptual solution is embodied.

4.6 Summary

This chapter presents the solution to the research problems identified which is an innovation to construction solution for solving a domain problem identified. The processes involved in the development of the conceptual solutions are described in detail for justifying the validity of the findings because every stage of the processes involved in the development of the conceptual solutions has its own characteristic that need to be explained for justifying why the method has been chosen in getting to the deepest level of the problem for exploring the root cause.

In the following chapter, a summary of this research will be presented by presenting an overview of the conceptual solutions and theoretical contribution of the research findings.

5 THE CONCEPTUAL SOLUTIONS

5.1 Introduction to the chapter

This chapter presents the summary of this research and is divided into two sections. In the first section, an overview of the conceptual solutions is presented and followed with a discussion concerning the theoretical contribution of the research findings. It comes from a holistic perspective by presenting the main findings and outcomes of this research study.

5.2 The Conceptual Solutions

5.2.1 Overview of the Conceptual Solutions

Table 41 depicts the seven key issues related to the cost management process in the construction industry. The seven key issues in construction cost management presented here are the ultimate discoveries based on the literature review discussed previously. The indication that can be interpreted from the literature review is that the researches in this area are very fragmented where there are multiple separate categories of research that has been carried out. In view of this, the researcher has filtered the information gathered from literature review with her analytical lens using anomaly detection concept for making meaningful synthesis. The awareness of anomaly has led to regrouping of those multiple separate categories into a more manageable order which has marked the discovery of those seven key issues which include the followings:

- Failure to forecast,
- Failure to support improvement opportunities,
- Costs are considered as resulting from action,
- Relative neglect of value consideration,
- Poor support for inter-organizational cost management,
- Negative influence on behaviour and
- Constraint created by budgeting.

These are contended to be the key issues contributing to the current drawback of construction cost management. These key issues establish awareness with the actual problem in this area. These seven key issues are the core categories that need to be initially considered, since they are the new

categories that have been regrouping from those multiple separate categories into a more manageable order. The seven key issues are the starting point towards the exploration of the root cause of the problem in construction cost management and also the starting point towards the development of the conceptual solutions.

The development of conceptual solutions took place for mitigating the current drawbacks of construction cost management and the development of the conceptual solutions continued with an inference of countermeasure (conceptual solution) to the each root cause and synthesising of the (practical) solutions.

The following are the inferences of countermeasure, that is, conceptual solutions to the key issues:

- Adoption of the dynamic approach to managing costs.
- To accept the flow theory of production-centric view to reduce generation of waste.
- Integrating costs to design.
- The adoption of the TFV theory that is achieved through fulfilment of customer needs.
- By taking into account the production costs.
- Incentives aligned to improvement.
- Separating the different functions of budgeting.

Table 41 presents the summary of the findings from this research study, which includes the key issues, the anomaly, grasping the problem, the root cause and inference of countermeasure.

Table 41: A summary of the development of conceptual solutions for construction cost management problems

Key Issue	Anomaly	Grasping the Problem	Root Cause	Inference of Countermeasure (Conceptual solution)
Failure to Forecast	Forecasting is the main function of mainstream cost management and not being delivered. The anomaly is that this function has	The discrepancy between the forecast cost and the final cost.	The static nature of the theory of cost management.	Adoption of the dynamic approach to managing costs

Key Issue	Anomaly	Grasping the Problem	Root Cause	Inference of Countermeasure (Conceptual solution)
	failed.			
Failure to Support Improvement Opportunities	Lean has forwarded a new way for improvement which is not supported by the current mainstream cost management although economizing is at the heart of cost management.	The construction cost management fails to support improvement opportunities by failing to provide a responsive approach to improve the design (during design stage) and construction (during production stage).	Decisions are considered as optimal, thus not needing any continuous improvement.	To accept the flow theory of production-centric view to reduce generation of waste.
Costs are Considered as Resulting from Action	The separation of cost management process and design process has created failure to the mainstream cost management. The anomaly is that it does not make cost and value to drive the design process.	The traditional cost management is oriented towards costing the design.	Paradigm shift from the classical management science to a modern management science, where connections of management science and organization theory to production have been cut off , leading also to the separation between cost management (as part of management) and design (as part of production).	To develop cost management approaches, which account for the connections of management science and organization theory to production conceptually and by combining or integrating costs to design.

Key Issue	Anomaly	Grasping the Problem	Root Cause	Inference of Countermeasure (Conceptual solution)
Relative Neglect of Value Consideration	Value is as important as cost in mainstream cost management and the anomaly is that yet value remains as lip service and it is not being developed.	Cost management does not provide enough encouragement and supportive environment towards the implementation of value management in it.	The transformation theory of production is subscribed to which leads to an emphasis on internal production rather than on satisfying the customer needs which determine the value of the product.	The adoption of the TFV theory that is achieved through fulfilment of customer needs by translating these needs accurately into a design solution.
Poor Support for Inter-organizational Cost Management	The business environment of mainstream cost management has changed from being focusing on internal operation to inter-organizational operation. The anomaly is that the current mainstream cost management is not responding to this change.	The organization of construction projects have moved to be based on a multi-layered supply chain model, motivated by the idea of finding the cheapest suppliers from the market.	Construction is seen as consisting of transactions.	By taking into account the production costs, as it deals with issues that are directly related to cost issues that relates to waste and non-waste activities in production costs which was assumed to be constant before.

Key Issue	Anomaly	Grasping the Problem	Root Cause	Inference of Countermeasure (Conceptual solution)
Negative Influence on Behaviour	The use of mainstream cost management theory, which is commonly accepted, leads to negative behavioural outcomes that are widely believed to be common. The anomaly is that principles and methods of cost management, which are expected to ameliorate the situation, factually create problems to the field.	The project parties are keen to improve their financial gains through the means available to them	Initiatives taken for improving to the benefit of the whole project are not rewarded.	Introducing incentive as a motivator for driving the progress of the work in a particular project.
Constraint Created by Budgeting	Budgeting is a core role in the mainstream cost management and the anomaly is that yet it creates problem to cost management.	The damage done by using budget is that it rejects flexible planning and prohibits innovation and hinders improvement opportunities that can encourage project improvement.	The functions of construction project budgets have been merged and therefore difficult to monitor.	Budget should be decomposed to segregate its function for encouraging project improvement.

5.3 The Theoretical Contribution of the Conceptual Solutions

The conceptual solutions developed provide new theoretical ingredients for construction cost management, which is a field with scarce theoretical underpinnings. Each conceptual solution gives direction for the development of new practical solutions for the underlying problem (key issue).

5.4 Summary

An overview of the conceptual solutions is presented here, followed with a discussion concerning the theoretical contribution of the research findings. In the following chapter, the gist of the findings found in each of the objectives will be briefly presented for the fulfilment of the research objectives. A discussion on the contribution to knowledge will be articulated and followed with a discussion on the limitations of the research, final note, and recommendations for further research.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction to the chapter

This chapter presents the discussion on the fulfilment of each of the research objectives. Next, a discussion on the contribution to knowledge that can be found from this research study was presented and it includes a contribution to knowledge in the aspect of research process in DSR, the key issues, the root cause and inferences of countermeasure. The limitations and constraints of this research, as well as final note are articulated, along with recommendations for further research.

6.2 Overall summary of the thesis

This research was undertaken based on the landscape of construction cost management that reveals problems existed since long time ago in this research area and still remain the same even though there are so many research studies have been carried out to deal with these problems. Design science research has been selected as the research methodology for this research study where at the beginning stage, the establishment of awareness towards the problems has been identified by using anomaly detection technique. The seven (7) key issues have been discovered and therefore this is believed as the main problem in this research area. The conceptual solutions have been formed to deal with the problems identified by using The 5 - 'Why' analysis.

6.3 Fulfilment of the Research Objectives

The overall aim of the research was expected to be addressed through a number of objectives as stated below. The following sections reflect on how they have been achieved.

6.3.1 To understand the evolution of and to identify the shortcomings (key issues) in cost management.

Cost management has gone through a great amount of changes through a process of evolution from medieval era throughout the 20th century. From the mid of the 20th century, changes in management thinking, where connections of management science and organization theory to production have been cut off, have influenced cost management. Even though cost management has evolved, the progress in this area has produced results that are not relevant with the current needs in cost management due the followings reasons:

- Despite the environmental, managerial and technologies changes that have occurred in the last few decades, existing cost management systems tend to be very similar to the ones that have been used since the mid-twenties. .
- Today's competitive environment, where competitiveness is no longer promoted by the efficiency of mass production enterprises.
- Today's manufacturing operations consider quality, inventory, productivity, innovation and work force in their performance management systems.
- Today's global competition requires that nonfinancial measures such as mentioned before to be used in the evaluation of a company are manufacturing performance.
- The needs of accurate product cost information have increased.
- Innovations in manufacturing and innovations in management accounting have not run in parallel.

In this research, seven key issues are the ultimately discovered, based on indications interpreted from the literature, to contribute to the current drawback of construction cost management. The seven key issues include the following:

- Failure to forecast,
- Failure to support improvement opportunities,
- Costs are considered as resulting from action,
- Relative neglect of value consideration,
- Poor support for inter-organizational cost management,
- Negative influence on behaviour and
- Constraint created by budgeting.

6.3.2 To Analyse the Root Causes of the Key Issues in Construction Cost Management

The process of finding the root causes started with the establishment of awareness to each of the seven key issues. Then the key issues will be analysed with the 5-Why Analysis technique in order to

go to the deepest level of problem for identifying the root cause. The root causes identified are as follows, presented in the same order as the key issues above:

- The static nature of the theory of cost management
- Decisions are considered as optimal, thus not needing any continuous improvement.
- Paradigm shift from the classical management science to a modern management science.
- Use of the transformation theory of production.
- Construction is seen as consisting of transactions.
- Initiatives taken for improving to the benefit of the whole project are not rewarded.
- The functions of construction project budgets have been merged.

6.3.3 To Develop and Evaluate Conceptual Solutions for Improved Cost Management.

The developing of conceptual solutions was taking place for mitigating the current drawbacks of construction cost management. There are four stages in the process involved for the development of the conceptual solutions which are listed below:

- Grasping the problem situation – literature review and anomaly.
- Analysis to the root cause – using The 5-Why Analysis.
- Inference of countermeasure to the root cause.
- Synthesis of the solution.

The ultimate discoveries of this research study after going through the four (4) stages of process are the inferences of countermeasure to each root cause which have listed below:

- Adoption of the dynamic approach to managing costs.
- To accept the flow theory of production-centric view to reduce generation of waste.
- Integrating costs to design.
- The adoption of the TFV theory that is achieved through fulfilment of customer needs.
- By taking into account the production costs.

- Incentives aligned to improvement.
- Separating the different functions of budgeting.

For evaluating these conceptual solutions, a corresponding practical existing method was pinpointed through synthesis. These practical methods are as follows (in the same order as the conceptual solutions):

- Reference class approach method.
- Target Value Design and real-time, BIM based cost estimation
- Target Value Design or target costing that defines the life cycles cost basing on spaces needed and workplace planning which links spaces to business operations.
- Target Value Design and Benefits Realization
- Open Book Management.
- Implementation of relational contract or alliance contract.
- Introducing budget that has 2 functions, i.e. provide sufficient funds to achieve the purpose of the project and to minimize the project cost.

6.4 Contribution to Knowledge

The conceptual solutions are something that has been missing in research of this area, which arguably has led to the irrelevance of research results. The conceptual solutions are the responses to the seven (7) key issues identified during the establishment of awareness to the problems.

In addition, the researcher has identified that the research in this area is by its character too fragmented and therefore has rearranged the multiple separate categories in construction cost management to a more manageable order and has discovered the seven (7) key issues. The identification was based on the anomalies shown in the area of study and has led to the regrouping of the existing categories in this area.

From the point of view of research methodology, the researcher has adapted the existing DSR process to deliver a better quality of research findings in the particular context of the research. The revised DSR process facilitates the development of conceptual solutions, in contrast to the mainstream case where embodied solutions are developed.

6.5 Limitations of the Study

The limitations to this research include the following:

- DSR introduced in this thesis has not been fully tested yet in relation to construction cost management research, although it is a promising philosophy, as suggested by Kasanen et al. (1993). This is a good reason for using it since the character of DSR is suitable for mode 2 knowledge production (the character of construction management and economics knowledge) where in DSR's philosophy the result from scientific justification can be used in designing solutions to complex and relevant field problems (Aken, 2004).

- Six (6) interviewees were involved in each exploratory interview and three (3) interviewees were participated in-depth interview. Kvale (1996) suggests this is adequate, the common number of interviews lying between five and twenty-five. Nevertheless, it would be useful to conduct similar research with more interviewees, perhaps of different kinds. This study focuses on managerial level staffs that are in-charge for decision making purposes. However, if the participants were lower-level staffs, who is using techniques available in the construction cost management, the issues uncovered might be different.

- The literature review did not give the clear outcomes regarding shortcomings of the current cost management as the current literature is based on the traditional mind set and therefore anomaly detection concept had to be adopted to detect the patterns in the given data set that do not conform to an established normal behaviour (outliers, change, deviation, surprise, aberrant, peculiarity, intrusion, etc.). In this way the data was translated to critical and actionable information and that also helped the researcher to perceive and interpret the data and facilitated having the perception that something had gone wrong to the current researches in construction cost management.

- A similar situation also happened when interviewing people during the empirical investigation.

- It is recommended that the conceptual solutions established in this study to be further tested in the future, i.e. to have more empirical evaluation like focus group for evaluating the conceptual solutions.

6.6 Recommendations for Future Research

The conceptual solutions are recommended to be used as guidance in developing new practical solutions in the future.

The process of inferring and synthesising the solution was done on each of the seven key issues and was not combined with the rest. This provides the possibility of the unification of theory of cost management in future research.

A further area of research, not just to overcome the limitations discussed above is to use the DSR approach in other research areas in construction projects, such as tools that are related to management of project. Based on the outcome of this study, DSR approaches show very promising ways of doing research, therefore it is not only useful in the research of construction cost management but also it could be used in other areas. A final future research activity is to get DSR approach more widely known to the research communities. The researcher intends to write and publish a number of papers and present during conferences and seminars. This will help more discussion or critique made on those approaches not only within academia but also to practitioners.

6.7 Final Note

This chapter concluded the main findings by summarising the overall research process through four main stages of research process which were: establishment of awareness of problem, exploration of key issues of construction cost management, development of conceptual solutions and evaluation, which was the final stage of the research process.

This study has taken many views by filtering information gathered through lean construction lens which is part of construction's new paradigm that has offered a new way of delivering construction project. This was addressed through this study in order to provide a better understanding of the potential use of lean construction applications in construction cost management setting and for identifying the key issues which contribute to such drawbacks, and developing conceptual solutions to mitigate them. This embodies a contribution to both theory and practice within the construction cost management area in general.

Appendix A

EXPLORATORY INTERVIEW QUESTIONS

SECTION A: INTERVIEWEE'S BACKGROUND INFORMATION

INTERVIEW GUIDELINE

This interview is aimed at identifying and gaining an understanding of the key issues in construction cost management. The findings will direct the development of requirements and conceptual solutions to enhance the cost management in construction industry. Please feel free to state any important point(s), as you is think appropriate, without limiting to the questions stated here. Thank you for agreeing to participate in this study.

Interview number:

General Information on the Interviewee

Designation:

Job Description:

Years of Employment/Appointment:

Qualification / Background:

Date of Interview:

Contact Details:

SECTION B: INTERVIEW

Status of current construction cost management and the need of future improvements

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1. The current problems facing the traditional construction cost management.
2. How do you describe Lean Cost Management?
3. How Lean Cost Management can be used as solutions to the shortcomings in the traditional construction cost management (if any)?

Appendix B

IN-DEPTH INTERVIEW QUESTIONS

SECTION A: INTERVIEWEE'S BACKGROUND INFORMATION

INTERVIEW GUIDELINE

This interview is aimed at identifying and gaining an understanding of the key issues in construction cost management. The findings will direct the development of requirements and conceptual solutions to enhance the cost management in construction industry. Please feel free to state any important point(s), as you is think appropriate, without limiting to the questions stated here. Thank you for agreeing to participate in this study.

Interview number:

General Information on the Interviewee

Designation:

Job Description:

Years of Employment/Appointment:

Qualification / Background:

Date of Interview:

Contact Details:

SECTION B: INTERVIEW

(*Phase 1*) – General information on the Interviewee professional experience.

Please describe your professional experience in construction cost management?

(*Phase 2*) – Status of current construction cost management and the need of future improvements

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1. Which current changes / trends you have seen in construction cost management?

2. What are your views on the problems / issues facing construction cost management nowadays? (*Do you think the current construction cost management is successful?)*

3. The important function of cost management is to forecast the project price. Do you think that the current construction cost management approaches help to forecast in a satisfactory manner?

4. Are the current construction cost management approaches helping various stakeholder to pinpoint improvement opportunities in construction project / product / production / process?

5. Do you think the current construction cost management system allows active steering of the design to an acceptable overall project cost rather than the cost reflecting the design?

6. Do you think the current construction cost management provides enough support or hinder the implementation of value management in delivering value to the customer / client?

7. Currently, many-tiered supplier networks exist in traditional supply chains where the connections between key supplier's suppliers exist. These many-tiered supplier networks create a major addition in transaction cost and create varying amount of wastes that are embedded in the construction costs. Do you think the situation that this waste is not acknowledged, results in failure to the current construction cost management approaches/system?

8. Currently, the opportunity of one party to manipulate design and production to its own advantage create incentives for negative behaviour ranging from claims culture to manipulation of bids and performance measures. Do you think this contributes to the failure of the current construction cost management approaches/system?

9. Currently, a number of non-construction companies have recognized the extent of the damage done by budgeting. They believe that having a budget in a business unit will create negative scenarios among employees in an organization due to the fact that each activity will be benchmarked with a budget. This will disempower the front line, discourage information sharing, and slow down the response to market development. Do you think a more flexible and a responsive approach to budgeting in construction cost management are needed to enhance construction project management?

10. Do you think that eliminating waste (as advocated in lean production) is sufficiently accounted for in the current approaches to construction cost management?

11. Are there any other aspects / approaches that need to be taken into account in improving the current construction cost management approaches / or developing future construction cost management methods?

12. What are the critical factors that need to be considered in developing alternative approach(es) / improvement to managing construction cost management?

13. Do you think the use of lean principles / perspective can result in generating different and improved approaches to construction cost management? Please explain.

14. Any other comments?

Thank you.

Letter of Invitation

Mahanim binti Hanid, PhD Candidate
Room 413,
School of the Built Environment
4th Floor, Maxwell Building,
University of Salford,
M5 4WT

Tel: +44 (0) 7508 787324
E-mail: m.b.hanid@edu.salford.ac.uk

Dear Sir/Madam,

Invitation to participate in research study

My name is Mahanim binti Hanid and currently doing my PhD in the area of Lean Cost Management at the School of the Built Environment, The University of Salford, Manchester.

I am conducting a research study in the area of construction cost management. The research focuses on developing solutions to improve construction cost management as a response to the shortcomings in the current approaches.

I would like to invite you to participate in this research study by being one of the interviewees. The interview will last for approximately 1 hour. Ethical approval has been granted for this study by the Ethics Committee of University of Salford.

If you decide to participate, please see the attached Participant Information Sheet. If you have any questions or concerns about the study, please contact me (Mahanim binti Hanid, PhD Candidate, Phone 07508 787324; Email: M.B.Hanid@edu.salford.ac.uk) or one of my supervisors (Professor Lauri Koskela, +44 161 295 7960; Email: L.J.Koskela@salford.ac.uk or Mohan Siriwardena, Phone +44 161 295 7052; Email: M.L.Siriwardena@salford.ac.uk).

Your participation is highly appreciated.

With kind regards,

Mahanim binti Hanid

PhD Candidate

E-mail Invitation

Dear Sir/Madam,

Invitation to participate in research study

My name is Mahanim binti Hanid and currently doing my PhD in the area of Lean Cost Management at the School of the Built Environment, The University of Salford, Manchester.

I am conducting a research study in the area of construction cost management. The research focuses on developing solutions to improve construction cost management as a response to the shortcomings in the current approaches.

I would like to invite you to participate in this research study by being one of the interviewees. The interview will last for approximately 1 hour. Ethical approval has been granted for this study by the Ethics Committee of University of Salford.

If you decide to participate, please see the attached Participant Information Sheet. If you have any questions or concerns about the study, please contact me (Mahanim binti Hanid, PhD Candidate, Phone 07508 787324; Email: M.B.Hanid@edu.salford.ac.uk) or one of my supervisors (Professor Lauri Koskela, +44 161 295 7960; Email: L.J.Koskela@salford.ac.uk or Mohan Siriwardena, Phone +44 161 295 7052; Email: M.L.Siriwardena@salford.ac.uk).

Your participation is highly appreciated.

With kind regards,

Mahanim binti Hanid
PhD Candidate

Participant Information Sheet

Title of Study: Lean Cost Management

Study Subjects

You are being invited to participate in this research which study on the situation of the current construction cost management approaches. Before you decide to take part, it is important for you to understand why the research is being done and what it will involve. Please take your time to read the following information carefully. You may also wish to talk to others about the study. Please ask if there is anything that is not clear or if you would like to have more information and please take time to decide whether or not you wish to take part in this study. Thank you for reading this.

What is the purpose of this study?

The aim of this study is to establish and consolidate the key issues in construction cost management, especially when analyzed from lean production perspectives. The findings will direct the development of requirements and conceptual solutions by developing ways for enhancement to the costmanagement approaches in construction industry.

Do I have to take part in the study?

Participating in this study is completely voluntary and you may withdraw at any time. Also, even after agreeing to participate in our study, you are still free to withdraw at any time and without giving a reason.

What will happen to me if I take part?

You will be interviewed at a location of your preference. The whole interview will take approximately 60 minutes to complete. The transcribed data will be sent to you for confirmation.
With your permission, the interview will be recorded. The recorded interview and information will only be used anonymously and for academic purposes. It will not be possible for any participants be personally identified. Information on individuals (such as name, gender, age, ethnicity, religion and so on) will not be revealed under any circumstances.
Meanwhile, we would like to indicate to you the following points for which your consent is needed. This is completely up to you. We will only use the records in ways that you agree to:

1. In any use of these records, your personal information will not be identified.
2. The anonymized records can be studied, transcribed and analysed by the interviewer only according to the research aims.
3. The anonymized records can be used for scientific publications and/or meetings.
4. The anonymized records can be shown in presentations to scientific or non-scientific groups.

Please be assured that confidentiality is highly protected for this survey. The transcribed interviews will be kept with no identifying information. The personal information collected about you in the beginning of the interview is only for discerning patterns in the data collected and could never be used to identify you personally. All data collected will be kept and accessed only by the researcher and the supervisor of this research and will never be made available for other parties or be made public.

What do I need to do?

If you decide that you would like to take part in the study, please contact the researcher (Mahanim binti Hanid, e-mail: m.b.hanid@edu.salford.ac.uk), who will arrange a convenient appointment time for you to participate and for us to answer any questions you may have. If you consent to the information on this sheet, you need to sign a consent form. Please be ensured that you can withdraw at any time even after signing the consent form.

What are the potential benefits from taking part?

Whilst there are no immediate benefits, i.e. monetary benefit, for those people participating in the project, it is hoped that this work will help to provide first hand evidence of the current situation. The study will also give us an opportunity to deepen our knowledge related to shortcomings in current cost management approaches in the construction industry in order to enhance the current cost management approaches.

What are the potential risks, discomforts and inconveniences from taking part?

There will be no possible disadvantages and risks of whatsoever for participating in this study. There are no risks of severe injury or discomforts that might occur. This is because the research study only deals with respondents at the managerial level and deals with the technical issues. As participation is voluntary, you may wish to discontinue the interview at any time or choose not to answer any particular question or not to participate at all.

Will I be paid for taking part?

You will not be paid for your participation in this research.

What will happen if I don't want to carry on with the study

You are free to withdraw from the study at any time without giving a reason.

What if there is a problem?

If you have any concerns about any aspect of this study, you may want to speak with the main researcher (see contact details below), who will answer your questions. If you remain unhappy and wish to complain formally, you can do this by either contacting the main supervisor (Professor Lauri Koskela, Tel: **0161 295** 6378; Email: L.J.Koskela@salford.ac.uk).

What if something goes wrong?

It is unlikely that you will be harmed during our study, but should an accident occur, there will be no special compensation arrangements. However, you have the right to take legal action in case of negligence on our behalf, but you may have to pay your legal costs.

Will my participation in this study be kept confidential?

All information obtained in connection with this study will be treated as privileged and confidential. All information will be anonymous so that you cannot be identified, except by a single Participant Identification Form, which will be saved electronically on a password protected computer. The results

obtained from this study will be kept for possible use in future studies, whereby all personal data will be deleted in three year from the time completion of the research.

What will happen to the results of the study?

The findings will be published in the form of a report, which will be included in a thesis that forms part of a post-graduate student's Doctorate degree. Furthermore, it is also likely that the researcher will write a scientific paper based on the findings of this study, and this paper will be published in professional journals or at conferences.

Who is organising and funding the study?

This is a post-graduate research in fulfilling the requirements of PhD in Lean Cost Management at The University of Salford. The research is organised by the School of the Built Environment at The University of Salford and funded by the The University of Malaya, Malaysia. It is being led by Mahanim binti Hanid (a PhD Candidate at The University of Salford) and supervised by Professor Lauri Koskela and Mohan Siriwardena at The University of Salford.

Who has reviewed the study?

The researcher's supervisors and The University of Salford Ethics Committee have reviewed all aspects of this study.

Contact for further information

For further information, please contact:

Name: Mahanim binti Hanid, PhD Candidate
Address: Room 413, School of the Built Environment, 4th Floor, Maxwell Building, The University of Salford, M5 4WT, Manchester, United Kingdom
Tel: +44 (0) 7508787324
E-mail: m.b.hanid@edu.salford.ac.uk

Supervisors contact details:

1. Name: Professor Lauri Koskela
   Address: Room 412a, School of the Built Environment, 4th Floor, Maxwell Building, The University of Salford, M5 4WT, Manchester, United Kingdom
   Tel: +44 161 295 6378
   E-mail: L.J.Koskela@salford.ac.uk

2. Name: Mohan Siriwardena
   Address: Room 402, School of the Built Environment, 4th Floor, Maxwell Building, The University of Salford, M5 4WT, Manchester, United Kingdom
   Tel: +44 161 295 7052
   E-mail: M.L.Siriwardena@salford.ac.uk

Yours sincerely,
Mahanim binti Hanid
PhD Candidate

PARTICIPANT CONSENT FORM

Title of Study: Lean Cost Management

Name of Researcher : Mahanim binti Hanid

Please read and tick the boxes below

1. I confirm that I have read and understand the Participant Information Sheet explaining the above research study and I have had the opportunity to ask questions about the project. ☐

2. I understand that my anonymity is assured as onlyThe University of Salford researchers involved in this study will use the data, and I give permission for these individuals to do so. ☐

3. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason and without there being any negative consequences. In addition, should I not wish to answer any particular question or questions. I am free to decline. ☐

4. I understand that, if I decide to withdraw from this study, or if the researchers withdraw me from this study, then any collected data would be retained and used in this study only if I give my permission. ☐

5. I understand that, if I decide to participate in this study, then the results obtained from this study, will be kept for possible use in future studies. ☐

6. I agree to take part in the above research study. ☐

_____	_____	_____
Participant's Name	Date	Signature

_____	_____	_____
Researcher's Name	Date	Signature

ACADEMIC AUDIT AND GOVERNANCE COMMITTEE

College of Science and Technology Research Ethics Panel (CST)

To **Mahanim Hanid and Prof Lauri Koskela**

cc: **Prof Mike Kagioglou, Head of School SOBE**

From **Nathalie Audren Howarth, College Research Support Officer**

Date **4th July 2012**

MEMORANDUM

Subject: **Approval of your Project by CST**

Project Title: **Lean Cost Management**

REP Reference: **CST 12/02**

Following your responses to the Panel's queries, based on the information you provided, I can confirm that they have no objections on ethical grounds to your project.

If there are any changes to the project and/or its methodology, please inform the Panel as soon as possible.

Regards,

6.7.1.1 Nathalie Audren Howarth

College Research Support Officer

For enquiries please contact:
College of Science and Technology
College Research Support Officer
The University of Salford
Maxwell building, (7th floor, room 721)
Telephone: 0161 295 5278
Email: n.audren@salford.ac.uk

Exploratory interview

Key Issue No.1 – Failure to Forecast

SUB-ISSUES	CODING
Cost is just understood to be there	Is almost impossible to move money across this contractual boundary. (I1)
	The innovations that we can't take advantage of are the ones that involve multiple contract moving money across those contracts after the contract are executed and agreed upon. (I1)
	They are looking at the amount that they bid to you and to optimize the cost against its total. (I3)
	We are going have a difficult time permitting that sub-contractor that their approach to work differently and reduce their profit for the benefit of the contract. (I3)
	Then I have been talking about moving money across boundary and the challenges you may find is that something is less expensive and then from the thing is less expensive you want to be able to use those extra fund somewhere else. (I4)
Early commitments to design solutions can lead to making wrong decisions	They are pretty bound to honour them so it is often difficult to take advantage of innovation and opportunity to safe money that we realize. (I1)
	Often client changes their mind during construction and that is the result of not understanding the design. (I1)
	So the question is really in terms of return on investment are people prepare to invest more in during that sort of production planning and conjunction with the preparation of estimate where they may or may not get the work. (I3)
	I think the uncertainty aspects of it are very important. (I4)
	The final account is never the same as the tender price. (I6)
Cost data inherit waste	Many projects cost more than they should, and many of those same projects do not result in satisfied customers; so waste is greater than necessary and value is less. (I2)
	I think the uncertainty aspects of it are very important. (I4)
	The final account is never the same as the tender price. (I6)
Estimate in detail is not a problem because it is forecasting.	We simply don't know the cost so we have to estimate the cost but we estimate in detail is not a question that you can't estimate in detail just the question that you are forecasting. (I1)
Gap between what required to construct and specification and estimated and bid.	There can be gaps and scope between what actually required to construct and what was define and bid or estimated and bid. (I1)
	The problem we always have is knowing and anticipating how much productivity we can't expect and how much the actual condition on the job site affect the cost. (I1)
	I think the uncertainty aspects of it are very important. (I4)
	The final account is never the same as the tender price. (I6)

SUB-ISSUES	CODING
No similarity between estimate and cost to manage production.	The received of good, the deliveries and signing the material tag is almost completely manual system and those are operational problem and simply tracking and managing cost so it is difficult to compare back to the original budget on which decision are based because of the setup of the cost management system and the actual functioning of the cost management system down to the field level. (I1)
	Often time see similarity of the estimate is not the same as the similarity that you want to manage production. (I3)
	So one of the thing that we try to do is before we simply load the estimating data in as our control budget, is actually to prepare a resource loaded production plan and to use the resource loaded production plan as a, we call it a back checker to double check on the validity of the estimate. (I3)
	Almost nobody was actually using the information. (I5)
People buy future - return on investment	Forecasting the cost based on our experience when we estimate and obviously when we are building we actually tracking the cost so we are looking forward and then when we are building we are actually looking backward in a certain sense so the time differences what account for the difficulty we simply don't know the cost so we have to estimate the cost but we estimate in detail is not a question that you can't estimate in detail just the question that you are forecasting. (I1)
	The problem we always have is knowing and anticipating how much productivity we can't expect and how much the actual condition on the job site affect the cost. (I1)
	So the question is really in terms of return on investment are people prepare to invest more in during that sort of production planning and conjunction with the preparation of estimate where they may or may not get the work. (I3)
	I think what people do is they put in future they lock in prices or they buy future. I mean they spent some money now to have the privilege at some latter point later to buy material at the given price. (I4)
Price volatility – uncertainty	Forecasting the cost based on our experience when we estimate and obviously when we are building we actually tracking the cost so we are looking forward and then when we are building we are actually looking backward in a certain sense so the time differences what account for the difficulty we simply don't know the cost so we have to estimate the cost but we estimate in detail is not a question that you can't estimate in detail just the question that you are forecasting. (I1)
	I think the uncertainty aspects of it are very important. Uncertainty on the material price volatility. (I4)
	The final account is never the same as the tender price. (I6)
Problem with project management	You collect information in 30 days in one long chunk. In often time that information doesn't become available to management per se 15 to 30 days after it is actually collected. In so by the time you receive the information as a manager is reporting information that may be 60 days old. About cost which is already being incurred and so it doesn't really do anything to help you manage production at the work phase. (I3)
	Often time see similarity of the estimate is not the same as the similarity that you want to manage production. (I3)
	So one of the thing that we try to do is before we simply load the estimating data in as our control budget, is actually to prepare a resource loaded production plan

SUB-ISSUES	CODING
	and to use the resource loaded production plan as a, we call it a back checker to double check on the validity of the estimate. (I3)
	Is almost impossible to move money across this contractual boundary. (I1)
	Then I have been talking about moving money across boundary and the challenges you may find is that something is less expensive and then from the thing is less expensive you want to be able to use those extra fund somewhere else. (I4)
	The variation that you expecting cost to occur I think is very much tie to how you manage your design process. (I4)

Key Issue No.2 – Failure to Support Improvement Opportunities

SUB-ISSUES	CODING
Cost data inherit waste	Many projects cost more than what they should be, and many of those same projects do not result in satisfied customers; so waste is greater than necessary and value is less. (I2)
	I think the uncertainty aspects of it are very important. (I4)
	The final account is never the same as the tender price. (I6)
Early commitments to design solutions can lead to making wrong decisions	They are pretty bound to honour them so it is often difficult to take advantage of innovation and opportunity to safe money that we realize. (I1)
	Often client changes their mind during construction and that is the result of not understanding the design. (I1)
	So the question is really in terms of return on investment are people prepare to invest more in during that sort of production planning and conjunction with the preparation of estimate where they may or may not get the work. (I3)
	I think the uncertainty aspects of it are very important. (I4)
	The final account is never the same as the tender price. (I6)
Pretty bound to honour the contract and not able to really innovate	From the perspective of delivering value you have another issue which is that we define our scope of work and make bids and write contract based on the scope of work and testify the amount either lump sum or not to exceed most contract and those are there can be gaps between what actually required to construct and what was define and bid or estimated and bid. (I1)
	Is almost impossible to move money across this contractual boundary. (I1)
	The contract are exactly there and they are pretty bound to honour them so is often difficult at this point to take advantage of innovation and opportunity to safe money that we realize. (I1)
	The innovations that we can't take advantage of are the ones that involve multiple contract moving money across those contracts after the contract are executed and agreed upon. (I1)
	That is exactly what would happen on a firm fix price sub-contract. It would be much more difficult after some form save and discipline on that project due having a commercial enticement for that sub-contractor who is making a lot of money

SUB-ISSUES	CODING
	could do something that might benefit the overall project. (I3)
	There are other commercial mechanisms you can put in place even though they are lump sum contract where they will allow you to reward people for superior then there may be some incentive plan that we share with the trade partner based on the way that we actually perform during construction. (I3)
	The way that our contract being structured on the project here would share with the owner in the benefit of this type of outcome. We can deliver the project faster and less expensively and there is opportunity for us to share any increase saving that are generated on the project. (I3)
	Then I have been talking about moving money across boundary and the challenges you may find is that something is less expensive and then from the thing is less expensive you want to be able to use those extra fund somewhere else. (I4)

Key Issue No.3 – Interruption by Business Cycle

SUB-ISSUES	CODING
Interruption by business cycle	The industry is caught up in a cycle of revenge reminiscent of the story told in Aeschylus' Oresteia. When buyers have the upper hand (supply exceeds demand), they gouge sellers. When sellers have the upper hand, they gouge buyers. The result is that the industry never gets better. All, or certainly most, performance improvement initiatives are interrupted by the business cycles. (I2)

Key Issue No.4 – Relative Neglect of Value Consideration

SUB-ISSUES	CODING
Transaction of value	From the perspective of delivering value you have another issue which is that we define our scope of work and make bids and write contract based on the scope of work and testify the amount either lump sum or not to exceed most contract and those are there can be gaps and scope between what actually required to construct and what was define and bid or estimated and bid. (I1)
	Many projects cost more than they should, and many of those same projects do not result in satisfied customers; so waste is greater than necessary and value is less. (I2)
	Part of cost is value issues and there is more than just cost, there might the function, there all kinds of other dimensions of the project. (I5)
	The mechanism and moment which value arises and to find what is the mechanism where it happens. (I5)
	Value is very subjective and can satisfied customer even though sometimes the actual cost burst the budget cost. (I5)

Key Issue No. 5 – Poor Support for Inter-organizational Cost Management

SUB-ISSUES	CODING
Many-tiered supplier networks create a major addition in transaction cost until it reach the final customer	Interoperability issues between different supply management system used at different level by different companies and therefore the issues of interoperability effecting the accuracy of information and timeliness of information. (I1)
	There are transaction cost now and the supply chain is not that they don't exist there isn't visibility into the supply chain and there is not invisibility the problem with interoperability exchange of information so and there is batch and que processes in supply chain and there probably too many level in supply chain. (I1)

Key Issue No. 6 – Negative Influence on Behaviour

SUB-ISSUES	CODING
Poor estimate and the contractors try to look for opportunity to claim.	The reality of people decision is not on the table. (I5)
	Do result from poor estimate by contractor and this contractor have approach of trying to look for every opportunity to make a claim and those projects become quite difficult to manage. (I1)
	Cost is a lagging indicator, costs are not well understood as contracts are all mostly based on price, costs are managed by the use of budget buckets containing as much contingency as the market allows, claims are a standard contract item as are defects/snags, the final account is never the same as the tender price. (I6)

Key Issue No. 7 – Constraint Created by Budgeting

SUB-ISSUES	CODING
Each and every activity involved in the product delivery process will be bench marked with a budget	Costs are managed against budgets, as if the work being funded by those budgets was independent, one from another. This is a form of local optimization, incompatible with project optimization. (I2)
	If you are working with the trade contractor on a long time basis with a firm fix price it will be extraordinary difficult because they are looking at the amount that they bid to you and saying my goal is to optimize my cost against its total. (I3)

SUB-ISSUES	CODING
	Then I have been talking about moving money across boundary and so that is I think the challenges you may find that something is less expensive and then from the thing is less expensive you want to be able to use those fund somewhere else. (I4)
	The reality of people decision is not on the table. (I5)
	Cost is a lagging indicator, costs are not well understood as contracts are all mostly based on price, costs are managed by the use of budget buckets containing as much contingency as the market allows. (I6)
	I am not sure this has been defined yet, but it should remove the reliance of project decision making on cost issues and move cost and cash flow into a production support role. (I6)
Incompatible with project optimization	The innovations that we can't take advantage of are the ones that involve multiple contract moving money across those contracts after the contract are executed and agreed upon. (I1)
	Costs are managed against budgets, as if the work being funded by those budgets was independent, one from another. This is a form of local optimization, incompatible with project optimization. (I2)
	the traditional approach to cost management is to look at each piece of the budget and try to grab the cost of each piece down without regard to how one equal case or impact the other and one of the thing that we try to do is to see whether our potential production trade-off and therefore financial compromises or financial trade-off. (I3)
	That is exactly what would happen on a firm fix price sub-contract. It would be much more difficult after some form save and discipline on that project due having a commercial enticement for that sub-contractor who is making a lot of money could do something that might benefit the overall project. (I3)
	Then I have been talking about moving money across boundary and so that is I think the challenges you may find that something is less expensive and then from the thing is less expensive you want to be able to use those fund somewhere else. (I4)

6.7.1.2 In-depth interview.

Key Issue No. 1 – Failureto Forecast

SUB-ISSUES	CODING
	The important issue in managing cost is crucial to ensure the right decision in the early stages was made. Procurement path is important too and where you go forward and the strategy that are going to be adopted and developing the design appropriately with cost reported properly at each stage of the design. (I1)
	The figure that is reported at the outset is the first figure that the client remembers. (I1)
	Once you establish an initial budget you should manage that cost after design develops based on the original budget. (I1)
	Cutting corners and resulting in the out of control situation. (I1)
Theory vs. Practical	In theory, the mainstream cost management is great, however in practice the situation is different because of the time pressures. (I1)
Improvement through new technologies	With the new technologies allow the client to visualize and run various simulations for the entire project to find what will be the impact on cost from beginning to the end to have a more realistic final contract sum at the very beginning. (I2)
	The techniques are working fine, but again there is room for improvement and with the future changes of new introduction of technologies and the new way of working, the new way of procurement. (I3)
level of accuracy	A building that was to be constructed has no resemblance with the building that was priced based on the initial budget. (I1)
	One of the things that affect the level of accuracy is the clients. (I2)
	Information availability and the level of accuracy that we can get from cost prediction. (I3)
	The more information that you have, the more that you can get from your cost prediction, the more accuracy that you can attain in your cost prediction. (I3)
	Producing cost plan based on historical cost data, which may not be accurate but still would give a guideline as to where to draw the line very broadly. (I3)
	As you move along you get, in the traditional sense you get more and more detail and the accuracy of cost estimate and cost prediction would become more and more with the time. (I3)
Limited information	.....reporting of creating cataract in the initial budget and cost of estimate based on very limited information and generally the figure that is reported at the outset is the first figure that the client remembers. (I1)
	There are two variables that we have to look into, information availability and the level of accuracy that we can get from cost prediction. (I3)
Time pressure	..... the problem that you have with the traditional approach in practice is the significant time pressures. Because traditional approach is very sequential and the nature of a client as with most applicable is that they won't think yesterday. So if you want it as soon as possible so is the time pressure on getting the design completed, getting the document out to tender and then getting the thing build. (I1)
Types of client/client's objective	In public sector project, the initial budget will create a cost ceiling. So the budget is based on standard or factors which result in a building with a certain size that cannot go above the certain price level and you have to manage that design

SUB-ISSUES	CODING
	within that ceiling. Whereas in private sector, the process is more flexible and they perceived the design as it has developed is the solution that they want or whether they can't afford that cause the appropriate cost check has been done and that is reported and communicated. (I1)
	I think, it depends on the particular context. There can be an acceptable situation or there can be unacceptable one. What causes the difference should be look into. One of the things that affect most of this, the clients. (I2)
The needs for improvement	When comparing the traditional way of thinking and the traditional way of working within the construction industry, the techniques are working fine, but again there is room for improvement and with the future changes of new introduction of technologies and the new way of working, the new way of procurement. (I3)
	Well, it works in the past isn't it, like again the problem comes, we have to draw the line, what is our expectation. Are we thinking in terms of improving further yes we can but if we are thinking about achieving what we are trying to achieve by delivering a project to the client specification, as they understand it right now, yes, the traditional methods are capable of delivering that. (I3)
	.....there are lots of ways within the processes that we can improve. By improving those processes I am sure we can improve quite a lot but that doesn't mean that current cost practices, current cost management practices are not usable or are failing. They are not failing, they are holding their ground, because those actually continue to deliver result, but the efficiency and the effectiveness of those results are the questions really. (I3)
	Can we improve those, yes we can. Well if you are trying to get at, justifying current, or the need for improvement in current cost management practices, I think those are delivering the output to a certain extend but certainly there are room for improvement and I think that is what we need to do that is what we have to understand. (I3)

Key Issue No. 2 – Failure to Support Improvement Opportunities

SUB-ISSUES	CODING
Resistant to change	The most significant barrier would be the reluctant or the resistant to change. We all would like, sort of remain, who we are and what we do rather than going through the process of changes. (I3)
The initiator	It is the client who should drive this initiative because if there are no challenges coming your way why should you improve. If you are delivering what the client wants, and if the client is happy and if you are happy then why would you need to change. (I3)
	There are no incentives in the construction industry to initiate this change. (I3)
Different in objective between client and contractor	.....where that product might not necessary give the client best value because the contractor is simply competing on price at the point of tendering and he is not be in the position to provide advice during the design phase as to nature of the particular product on the till within the design from the point of view of build ability which impact on his resource cost. (I1)
	From the point of view product in the traditional approach he will be looking to use product that meet the specification. However he is got to compete on price and therefore he is looking to get the lowest price product. (I1)

SUB-ISSUES	CODING
	On production of process, he will be looking, because he is competing on price, to identify ways of constructing the project in the most efficient way to give him a competitive advantage on his fellow tenderers. So again looking to provide a reduction in the level of rising. (I1)
Client expectation/needs	Their expectations are certainly change from being very conservative to being very challenging. (I3)
Non-responsive to change	Sometimes it is difficult because in mainstream cost management system, it is not very responsive to change. (I2)
	.....so the construction professionals as well as the clients, they are reluctant and they are afraid of taking challenges and let the changes happen. (I3)
	Most of the time our research is not driven by the client initiative or the industry needs. But at the moment both the parties are doing well with two different things. We live in our own silos and do what we think would be helpful for the industry but that never goes back to the industry and the industry struggling with their own problem and they never come back to us for any solution. (I3)
	Their problem is they don't understand what to expect. They don't understand their limitation. It's our duty as researchers to show them what they can expect and what they can ask the design team or construction team to deliver the goods in this manner and to meet this target. (I3)
	To make this link a bit stronger to initiate that change to let the client to be inform as educated as inform the client. (I3)
	I think the moment that we get request from the client and the industry to do certain type of research then the loop will automatically get close. So whatever we do as part of our research we will go back to the industry. (I3)
	Conducting seminar and conduct client awareness programs... (I3)
	the other thing is the result of any research that we do itself will creates impact, if we do good research and if it create impact in one corner of the country then that will get sort of communicated to the rest of the world simply because its impact is high. (I3)
	.....and then we have to have a stronger link between the industry and academic research centers....(I3)
Delivering value to the client	.....where that product might not necessary give the client best value because the contractor is simply competing on price at the point of tendering and he is not be in the position to provide advice during the design phase as to nature of the particular product on the till within the design from the point of view of build ability which impact on his resource cost. (I1)
Involvement of contractor during design phase/Collaboration (procurement)	.....take more collaborative approach where the contractor working together in partnership so that he can actually look to get the best product, adopt the best production techniques and embed the best processes to deliver the best project on time. (I1)
Collaboration (procurement)	Partnering, there are advantages to working collaboratively which the partnering approach to procurement can bring. (I1)
	In open book accounting you probably need more people on site to do the proper check and balances because open book accounting isn't an open cheque book (I1)

SUB-ISSUES	CODING
Conditions of contract	There are incentives that you can embed into contractual arrangement under partnering situation which in generally paying gain sharing arrangement. There is also a partnership within a framework agreement that identifies ways of finding solution which results in savings below the initial target cost whereby you share and agreed a percentage split between the client and the contractor. (I1)
Modern construction process	With the use of prefabricated construction and the use of modern technologies for the construction process, still you can use the mainstream cost management system but sometimes through various challenges. So, it is always good to have new tools and techniques for cost management that will go hand in hand with the new technologies. (I2)
	If you are using modern cost control techniques, they are very responsive. If you do something very quickly you know what impact it brings. So, to use the mainstream cost management system and to get very fast response is sometimes difficult. So, you need modern cost management system with little use of IT, to be used as a fast response system. (I2)

Key Issue No. 3 – Costs are Considered as Resulting from Action

SUB-ISSUES	CODING
Communication and team work	It is about communication between the architect and the quantity surveyor and the other professional team to talk to one another, to make sure that information flows are adequate and are timely so that the best cost can be applied as the design develops to ensure that it doesn't go above that cost target throughout the whole source, design and construction phase. (I1)
	Again it is about communication and size of facilities because it is the important thing at the outset is the gross floor area is one of the main things that generate cost. (I1)
	The designer tends to practice cost to design instead of design to cost, without knowing who is doing what. (I2)
	It is the non-responsive nature of the system. The previous manual method was ok, but in order to get the response it was very difficult. (I2)
Different objective to be achieved	It does depend on the client power. (I1)
	...and again it links to the procurement method. The contractor is looking at management of cost from a completely different perspective then the clients' point of view. You are looking at pqs advice for a client, he is looking at measurement around finish work. Looking it from a completely different perspective. (I1)
	There are a lot of restriction on government funding and the use of various technologies can to help the cost ceiling establish very quickly and so that the designers don't exceed those limit. So the client can be kept notify it as to what extend can the design meet the client requirement. So, as, if the client wants something over and above that, then the client will get to know about it at very early stage rather than waiting till the end to find it is a different building. (I2)
	So we do use both this approaches in the industry traditionally. (I3)
	Depends on, perhaps sometimes individually approaches for that particular project. Individual is refers to the client or the design team. So time would be a critical factor in analyzing or in determining which approach to go ahead with...(I3)

SUB-ISSUES	CODING
	There is a lot of guidance and direction process and procedure that need to be follow through in the public sector to ensure that it is within the budget. (I1)
	The standard of finishing were result in it being in particularly high and we just have to adjust the standard finishing. (I1)
New technologies	Cost to design, that is a kind of very traditional system I would say. Again, with new techniques, it will be, it is very easy to know price first and then design according to that price. With a new technique, such as BIM and visualization, it will be possible for both the designer and the estimator to work hand in hand and have a fast flow of information among them at the same time.(I2)
	I think value management process cannot be automated. I don't think it can be automated fully. It will need a person to interpret certain thing. So, value management is a kind of a compromise that you have within that system. (I2)
Non-responsive nature	The non-responsive nature of the system that affected. The previous manual method was ok, but in order to get the response it was very difficult. (I2)
Procurement	The fundamental flaw of the traditional procurement method is that one of the main players, i.e. the contractor, is not involved during the design process. (I1)

Key Issue No. 4 – Relative Neglect of Value Consideration

SUB-ISSUES	CODING
	One of the issues is value fully understood and does the client fully understand out of particular project what does value means to him and what he wants out of the project. Not necessarily what is the lowest cost of the project but what are the outcomes the client actually wants from the project, and how does it actually link that to value of particular construction project arise. (I1)
	The client needs to understand what value means to him and he actually needs to be help with that by professional advises...(I1)
Additional scope of work for QS	There is no fix term of reference for quantity surveyors to say that these are your tasks, this is outside your task. I think value management is part and partial of their task anyway, part and partial of their duty anyway. (I3)
New technologies	It would allow 3D model and a prototype to be built. If the designers have had design parameters and if they have adopted value management into a design, the client can have an early version how the design look like and sees other aspects that can be improve. For example in terms of spaces and all that. (I2)
	Whereas, now with the modern technology, you can have a, kind of a, different types of views of the same building, you know, you can view it 3D on the screen and so many views and you can watch, view the physical prototype. The ability of all that has allowed the client to take a step back and kind of advises at a very early stage. (I2)
Cannot 100% to rely on software	I think value management process cannot be automated. I don't think it can be automated fully. It will need a person to interpret certain thing. (I2)
	You can't have 100% value engineered design because it won't suit the aesthetic requirements of the client. (I2)
Communication	There is a communication gap I believe. Most of the client still doesn't understand the value of value management. (I3)

modern system helps better	If it is a modern system it helps value management better than an old system. The old system does not hinder the use of value management but the new system helps better I would say. (I2)
	As for the modern cost management it does provide enough support to the value management by allowing the client to visualize the project using computer software...(I2)
integration support	The current cost management practices do not encourage or do not facilitate the value management practices. (I3)
	If it is a modern system it helps value management better than an old system. The old system does not hinder the use of value management but the new system helps better I would say. (I2)
promoting VM	One can't make value management compulsory. Well, one can make it desired by most of the client. (I3)
	More and more success stories to convince clients to say that value management process is actually valuable. And the moment that they see that this is valuable practices they would go through value management processes voluntarily rather than making it compulsory. (I3)
	If there is a need from the client, it will happen automatically. You don't have to push the quantity surveyor. It is not like the quantity surveyor is not willing to take the value management challenge....(I3)
	Need to create the needs for that then it will take care of itself. (I3)
	Quantity surveyor is very much geared towards doing the value management. They want to do the value management. But it is just that they don't have the encouragement or the requirement from the client or from the industry to perform that task. (I3)
Willingness to spent additional money	.....value management practices would need the client to spend some money upfront in order to go through that process and that is not cheap actually you have to get a set of professional in a place where they can brainstorm. (I3)
	.....if he prepares to pay for value management services over and above the traditional services that provided in a traditional approach. Can he see the value in that additional fees, how strongly are this value management services marketed, how they actually sold to the client....(I1)

Key Issue No. 5 – Poor Support for Inter-organizational Cost Management

SUB-ISSUES	CODING
	You can't use the word wastage, there is additional cost in taking on board that particular structure but in my opinion, it is a way of adding value to the client. (I2)
Long term relationship	Using a smaller number of suppliers on project after project after project. And working together with those suppliers, to improve the way that the supplier chain is actually operates. (I1)
	Using a wider number of suppliers, going out for tender to the various suppliers on each case for each individual project. You prepare to work together with the suppliers to reduce the actual cost of the final product then there is potential advantage in that, rather than just sit going out to change supplier, and say, right, can you give me best price. (I1)
	This is a long term relationship between management contractor and sub-

SUB-ISSUES	CODING
	contractor. (I2)
Awareness/education	If you feel look at nature of the construction industry and the type of contractor that we have is very fragmented industry, a lot of small and medium size contractors, perhaps don't have the best management school within their organization or they could not be to actually review this. (I1)
PM scope of work	...It has less links with the cost management aspect then the project management aspect. So I think dealing with suppliers and dealing with the wastage due to supplier arrangement would be something that the project manager can look into, rather than the costing professional or the quantity surveyors...(I3)
Realization	.....how they can be realized is through a more collaborative and partnering approach. Where you got people coming in to look at the operation and monitor them. (I1)
Supply chain management	In a traditional approach, I think what you got to consider is do contractor really examine their supply chain. Does it take some external consultant to come in or somebody from outside to look at the operation and saying are you really doing things as efficiently as you can be. (I1)
Integration	how well are those sub-contractor are integrated and talk to one another within a traditional approach, you know, is open to debate compare to a more sort of collaborative approach in a partnering arrangement, we are slightly going off to being of management cost.(I1)
	Using a smaller number of suppliers on project after project and working together with those suppliers to improve the way that the supplier chain is actually operates. (I1)

Key Issue No. 6 – Negative Influence on Behaviour

SUB-ISSUES	CODING
	If a contractor identifies there are design information and the document have gone to tender are a bit weak and it looks incomplete, he knows that there will be variation. He takes his commercial view to put in a lower price to win the job and then he covers his cost during the course of the construction contract on the variation. (I1)
	If a contractor did a front load to a particular bid, the reason is basically the cash flow for that particular company may not be that good. It is not the problem of the cost management techniques itself and it is the problem of the management of that particular organization or the company or the construction industry....(I3)
Faulty in contract or tender document / design team weakness	If a contractor identifies there are design information and the document have gone to tender are a bit weak and it looks incomplete, he knows that there will be variation. He takes his commercial view to put in a lower price to win the job and then he covers his cost during the course of the construction contract on the variation. (I1)
	But if they are not specific of various conditions under which they work, that will have an effect on the project because the contracting team might find a loop hole and try to exploit that loop hole and as a result there can be claims and all that. So that is based on the contract that the parties have agreed to. (I2)

SUB-ISSUES	CODING
	If there are areas which are loosely define in a contract between a main contractor and sub-contractors or a contract between the client and the management contractor, in that case, there will be lots of claim coming in. (I2)
	I think we should minimize our own mistake in our own practices and errors are evitable by going through a structured process where the measurement are getting re-check in any cost management technique. The level of errors we have to reduce. (I3)
Time constraint	We need this document going out by that night. It may be that it is not being possible for him to get the design to that level or the client hasn't make decision to finalise the design. And the client, looking for ways to actually get a document together and the tender price, to be submitted and then take it from there. (I1)
	For most organization, they did things fairly quickly, in all cases where time generally is an issue for people. (I1)
Estimate A but build B	A lot of tender but ultimately the price that need to pay at the end of the day is going to be higher. Anybody can submit a price and win a job. It doesn't mean that you are actually got to pay that price at the end of the contract. (I1)
Procurement	If you want something completing earlier then you look to choose a different route essentially, but the risk is associated with that as well. If you want to adopt a different procurement route, and get your building quicker but you do run a potential risk on how much you are actually need to pay for that, because where the traditional approach is favor by client, on paper is a fair price. (I1)
New technologies	One way or the other we will continue to take measurement on certain aspect of building, but with the introduction of new technology like BIM, I think it will lead to less and less mistakes in the future. To improve the mainstream cost management and measurement practices I think one of the missing links is that it bridge against the process. (I3)
Bad practice	At the moment, we are using the contingencies sum to cover up our own mistake that has to be avoided. So, it is not avoiding using the contingencies sum in BQ, but rather it is using the contingency sum appropriately in the construction industry...(I3)
	Using the contingency sum appropriately in the construction industry by updating the conditions of contract to reflect that the appropriate use of contingencies sum in a contract. (I3)

Key Issue No. 7 – Constraint Created by Budgeting

SUB-ISSUES	
Allocation of money from the government/The norm	There has to be series of correspondence to ensure that the project doesn't lose that money and carry forward that money next year. (I2)
	Overall completion they might achieve, but milestone completion, if they don't achieve, it might affect the cash flow. (12)
	Once you set something, it is difficult to change. (I2)
	It is important to empower the people on the front line, who are delivering that product and the service. It is supposed to be in the most effective way, budget is still needed to control the cost. It is about having the quality people working for you. (I1)

SUB-ISSUES	
	Ultimately, you need to control cost and have a figure at the outset as to the prediction of that cost and then monitor and manage that from the start to the completion" (I1)
	The client gives us the budget. If there is an open cheque book, then you can build anything that you need but eventually that will be problematic too. (I3)
	If there is no budget then people will start spending the way that they want. Say for an example, getting tiling to the client expectation. If there is no budget allocated and no figure in mind, the most luxurious tile will be selected. Therefore, the reference point is the budget and it doesn't say that you have to stick with this. (I3)
	The moment that you open up the things, be the budget, the quality and the time, people tend to go wild rather than thinking sensibly. So, I think by allocating a figure or by establishing a budget level, you are asking the professional who involves in the process to act sensibly and to get the maximum functional. The basic concept of value management is to make sure that you avoid unnecessary functionality at unnecessary cost" (I3)
Readiness	They should, just because you don't have a budget, doesn't mean to say that you are going to get the best solution. I don't quite see how it will work. I think it is essential that you have budget, it is just how they viewed. (I1)
	I can't say our commercial organization could deliver that. (I1)
	Because a budget most of the time satisfies the financing institution. (I2)
New Technologies	Do the cost management process in a way that it promotes innovation through visualization. It is not the cost and cost alone that helps innovation. The computer technology can help to enhance innovation at the early stage of the construction. Before budget is agreed, a visualization of the project can be ran and budget can be agreed based on how you visualize the project. This will allow finding for innovation and can do some lean changes and value management to the project. The saving you can be invested somewhere else in the project. (I2)
Incorporating Value Management to help improving the budget	I think the value management should come at the design stage if the design and construction is not separated. Then perhaps at the very early stages, when the design concept is being developed you have to look into to find out whether we can save money for that particular element while going through the functional requirement list and studying where you can save money and at the same time achieve the same value same functionality. The moment value management practice has completed, set a stone saying that this is the budget and that budget should reflect whatever the outcome from your value management practices. (I3)
	Value management should be started first before costing the design. (I3)
Conditions of contract	Profit sharing and negotiations can be made to incorporate this as part of the contract condition which is not there at the moment.(I3)
Suitability	Budget is essential. How else would you manage the cost over construction project from the point of view of design development? (I1)
	Client is always want to know how much is going to cost it and the only way that you can monitor that cost is to have initial budget. It doesn't mean just because we have got this budget set at design phase that we have to design a building to that budget. (I1)

SUB-ISSUES	
	I think the budgeting, the definition or the explanation of budgeting in banking sector and that particular segment is quite different to how we see budgeting in construction. Budgeting in construction is actually setting a realistic target for the client. Budgeting here would be, ok, you are given some money to do your task. That sort of thing, so, those are two different scenarios if you know what I mean. In banking the budgeting means, say if you are working for supply department of the bank let say, you have an annual budget, so you have to, your activities are constraint by that budget. But in construction, the budget is there to set realistic target for the client. The client gives us the budget. If there is an open cheque book, then you can build anything that you need but eventually that will be problematic so. I don't think that you can quite compare this two together. (I3)

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