Generating value in alliance contracts through the lean concept

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LIST OF ABBREVIATIONS

AIB	Australian Institute of Building
ALT	Alliance leadership team
BIM	Building information modelling
COV	Co-efficient of variation
CT	Cycle time
ECI	Early contractor involvement
ECRS	Eliminate, combine, rearrange, simplify
EOI	Expression of interest
FMEA	Failure mode and effect analysis
GDP	Gross domestic product
HR	Human resources
HRM	Human resource management
IPD	Integrated project delivery
JIT	Just in time
KPI	Key performance indicators
KRA	Key results area
LU	Labour utilisation
NZ	New Zealand
NVAN	Non value adding necessary
NVAU	Non value adding unnecessary
OEE	Overall equipment effectiveness
PAA	Project alliance agreement
PE	Process efficiency
PFI	Private finance initiative
PPP	Private public partnerships
RFP	Request for proposal
RII	Relative important index
SPSS	Statistical Package for Social Sciences
TFV	Transformation- flow- value
TOC	Theory of Constraints
TPM	Total Productive Maintenance
TQM	Total Quality Management

VA	Value adding
VFM	Value for money
VSM	Value stream map
WIP	Work in progress

Attestation of Authorship

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which, to a substantial extent, has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

Nimesha Vilasini

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The writing of this thesis has been a difficult, but a rewarding task. This thesis work gave me a greater understanding of the way of performing empirical research as well as a deeper understanding of the construction industry. Many people have supported me and contributed to completing this research.

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Auckland, March 2014 Nimesha Vilasini

DEDICATION

To my dear parents, Shrimathi Fernando (Mother) and P.P.G. Sunil (Father),

my husband Sumudu Nishantha,

my lovely daughters Dihini Thasanga and Dinuli Yasanga

and to all those who have contributed to the enrichment of my life.

ABSTRACT

The construction industry has recognised alliancing as a means to increase construction efficiency. Despite the potential benefits attributed to alliancing, the true performance enhancements have not been fully gained in existing alliances. The main focus of the alliance framework is on contractual and organisational domains but less on the operational domain. Even though the operational domain is vital, there has been little research conducted to investigate the integration of operational systems into alliances. Therefore, the current research investigates existing operational practices within projects executed using alliance procurement methodology. It goes on to determine the potential application of lean concepts to improve operations on alliance projects.

A number of research questions are posed with a view to increasing the available knowledge about the interferences in alliance projects and ways of applying Lean in an alliance. Due to the contemporary nature of the research problem, a case study research approach was adopted. The selected case study was a viaduct replacement project in Auckland, New Zealand. This study used participant observations, document reviews, interviews and questionnaires as data collection methods. The participant observation covered five processes in an alliance project to identify process waste.

Initial process studies were conducted at the southbound construction phase of the viaduct. After completion of each process study, the process study findings were validated through process study reports and presentations at follow-up meetings. The participants of the follow-up meetings were the construction manager, project engineers, site engineers and supervisors. After initial process studies, separate study visits were conducted to study the improvements achieved, the problems faced during implementation and the reasons for precluded improvements. In order to identify behavioural waste in an alliance project, interviews and a questionnaire survey were conducted. Consequently, depending on the data forms, quantitative or qualitative data analysis was performed. The empirical data were analysed by iterating between observed evidence and the literature, also using experts' comments and suggestions.

The study confirms that the construction work in an alliance project can be improved considerably by eliminating waste factors. Moreover, the study showed that the savings are substantial as the processes studied were cyclic and repetitive. This study yields a methodology for process waste detection and improvements at site level. It is evident from the process study observations that the non-integration of site workers and sub-contractors within an alliance can create process waste. The study proposes best practices to eliminate that behavioural waste in alliances by using lean principles.

Even though previous researchers stated that there are resistances to lean implementations and process changes in construction, alliance project members were interested in making changes and willing to extend their joint effort. The percentages of process waste in the current study are consistent with recent productivity studies conducted under different procurement methods. Therefore, the study confirms that there is no significant difference in the volume of process waste for the various procurement models. In conclusion, it is not sufficient to change only contractual and organisational practices to achieve a game breaking level of performance with alliances, but it requires a robust operating system for an optimised delivery of a project.

This research contributes to existing knowledge in the area of Lean and alliances. In particular, the study makes contributions to the lean theory applied to construction and provides advice to professional practice.

Keywords - alliance contracts, case study, construction industry, lean concept, New Zealand

SUMMARY OF THE PUBLISHED PAPERS

Aspects of this study have been published in peer reviewed conferences and scientific journals. In the following sub-section, a summary of the published papers is provided.

Paper 1: Vilasini, N., Neitzert, T. R., & Rotimi, J. O. (2011). Correlation between construction procurement methods and Lean principles. The International Journal of Construction Management, 11(4), 65-78.

The objective of this paper is to identify an appropriate procurement method that accommodates Lean principles. It reviews related literature on Lean principles and construction procurement methods. The study found that relational procurement arrangements have a higher correlation with Lean.

Paper 2: Vilasini, N., & Neitzert, T. R. (2012, July 4 - 6). Lean methodology to remove interferences existing in an alliance environment. Paper presented at the meeting of the Australasian Universities Building Education Association, Sydney, Australia.

By taking inputs from 'Paper 1' and reviewers' feedback, this paper analysed the real and ideal alliance project characteristics. This leads to the idea of how Lean can provide an operational framework to an alliance. This paper was selected by the Australian Building Institute (ABI) for further development.

Paper 3: Vilasini, N., Neitzert, T. R., & Gamage, J. R. (2011, July 22 - 27). Lean methodology to reduce waste in a construction environment. Paper presented at the 15th Pacific Association of Quantity Surveyors Congress, Colombo, Sri Lanka.

This paper discusses how process waste in an alliance project should be identified and measured. The selected construction process consisted of up to 55% of waste activities. It is expected that organisational conditions exist in alliance projects which help to disseminate and sustain Lean principles.

Paper 4: Vilasini, N., Neitzert, T. R., & Jayathilake, P. (2012, 28 – 30 June). Appropriateness of Lean Production System for the Construction Industry. Paper

presented at the World Construction Conference – Global Challenges in Construction Industry, Colombo, Sri Lanka

This paper is built on the hypothesis that construction is a Lean resistant industry because it differs from manufacturing. To test the hypothesis, this paper tries to find different characteristics of construction processes and how Lean techniques can be adopted to them. It has been identified that the construction process is a combination of fabrication and assembly processes.

Paper 5: Vilasini, N., Neitzert, T. R., Rotimi, J. O., & Windapo, A. (2012, 23-25 January). Towards a reorganisation of sub-contractor management practices in alliance contracts. Paper presented at the International Conference on facilities management, procurement system and public private partnership, Capetown, South Africa.

This paper explains the behavioural waste arising due to disintegration of sub-contractors in an alliance. Literature is used to identify current sub-contractor management practices and best practices for sub-contractor integration in alliances. The study proposes a framework to improve sub-contractor management practices in alliances by using Lean supply principles.

Paper 6: Vilasini, N., Neitzert, T. R., Rotimi, J. O., & Windapo, A. O. (2012). A framework for sub-contractor integration in alliance contracts. International Journal of Construction Supply Chain Management, 2(1), 17-33.

The starting point of this paper is views from the reviewers and presentation audience of 'Paper 5'. The purpose of this paper is to propose a sub-contractor integration mechanism to an alliance project and establish the feasibility of the process. This paper added interview findings on the sub-contractor integration framework and modified the model presented in 'Paper 5'.

Paper 7: Vilasini, N., & Neitzert, T. R. (2012). Improving project performance through worker participation in alliance projects. In S. D. Smith (Ed.), 28th Annual ARCOM conference (pp. 621-630). Edinburgh, UK: Association of researchers in Construction Management.

This paper explains the behavioural waste arising due to disintegration of site workers. The study reveals the importance of worker participation practices in an alliance project. The way project teams are acknowledged and rewarded to increase participation appears to be an area that can be developed further.

Paper 8: Vilasini, N., Neitzert, T. R., & Rotimi, J. O. (2013). Towards a framework for process improvement in site operations: an action research approach [Accepted]. Construction Management and Economics (Special Issue on productivity improvement in the construction process).

The objective of this paper is to propose a framework for process improvements. Participant observations, project documentation and action research meetings were used to collect data on the waste identification and elimination process. The findings indicate that the construction work in a project alliance can be improved considerably by eliminating or reducing waste. It was found that the implementation of a process improvement methodology was projected to process efficiency and there is need for training for effective use of Lean tools and behavioural changes.

Paper 9: Vilasini, N., Neitzert, T. R., & Rotimi, J. O. (2013). Barriers to a Continuous Improvement Culture in an Alliance. [Extended abstract was accepted]. The Built & Human Environment Review, (6).

The past studies showed that there have been improvements in alliances, yet these seem not to have been continuous due to various factors. The research reported in this paper looks at the barriers for continuous improvement programmes in alliancing projects via a case study methodology. This study will eventually provide more confidence in continuous improvement initiatives in future alliances and will encourage future alliance projects to apply continuous improvement initiatives upon reviewing the barriers.

Paper 10: Vilasini, N., Neitzert, T. R., & Rotimi, J. O. (2013). Critical Review of Relational Project Delivery Systems. [Under review].The International Journal of Construction Management.

In this study the literature on partnering, early contractor involvement, alliancing and integrated project delivery was reviewed. The findings show all four contracting methods have a common theme of long term relationship development among participants.

1 INTRODUCTION OF THE RESEARCH

1.1 INTRODUCTION

The construction industry plays a vital role in many economies (Enshassi, Mohamed, Mustafa, & Mayer, 2007). However, the industry performance in terms of productivity has been low in comparison to other industries (Forbes, Ahmed, & Barcala, 2004). The New Zealand Department of Building and Housing (2009) has reported that the New Zealand (NZ) construction industry has also been suffering productivity losses mainly due to its fragmented nature of the industry. Consequently, innovative procurement methods have evolved, developing more effective working for the project environments. Alliancing for example was developed as a procurement methodology to improve productivity in complex construction projects. Since its development, project executed using have had proven reward of accomplishment (Sweeney, 2009). Revisiting these potential benefits, more infrastructure projects have been commissioned using alliancing in the past decade in NZ (Ross & PCI Alliance services, 2009).

Despite the benefits attributed to alliancing, the opportunities for considerable performance enhancements have not been noticed in some existing alliances (Ross, 2007). It is implicit that the alliance principles mainly focus on commercial and organisational integration little focus on process management strategies. Although extensive research has been carried out on alliancing, comparatively, there exists little research that has been set out to study the benefits and limitations of process management practices in alliancing. Therefore, this study was designed to improve the operational performance in projects executed using alliancing procurement methodology by modifying the extant process management practices.

In the recent past, researchers and practitioners have attempted to improve construction projects by applying process management practices, for example Lean, Value Engineering and Total Quality Management (TQM). From a review of these methodologies, it is noted that all methodologies have a common core aim which is to eliminate waste (Koskela, 2000). The lean concept has offered significant improvements in manufacturing and it might also help construction firms to lift their performance. In this study, it is proposed to improve the operational performance of alliance projects by showing how the lean concept can be implemented.

It was evident from the preliminary review of literature and initial discussions with subject matter experts and academics that the alliance and lean concepts are relatively new to the NZ construction industry. Therefore, a case study projects executed using alliancing procurement methodology was used in this study so that contemporary set of events during the introduction of Lean in an alliance environment can be explored.

This chapter consists of 11 sections including this introduction section. The next two sections (1.2 and 1.3) explain the background and the purpose of the study. Section 1.4 presents briefly the current state of knowledge and the existing gaps. The next section (1.5) outlines the research focus by explaining the study aim, objectives and questions. Section 1.6 contains an overview of the research approach. The next two sections provide details of delimitations (1.7) and assumptions (1.8) of the research. The delimitations and assumptions of the study lead to some limitations which are explained in section 1.9. The chapter closes with a description of the thesis structure (1.10) and a summary of the first chapter (1.11).

1.2 BACKGROUND

Productivity improvement studies in construction have received a surge of interest over the last two decades due to the industry's significance and its peculiarities. In the context of NZ, the construction sector has a significant impact on NZ's economic performance as the sector contributes 4.3% of the gross domestic product (GDP) and currently about 176,000 people are employed in the sector representing roughly 8% of the NZ workforce (Department of Building and Housing, 2010). Productivity improvements would therefore have a direct benefit to the NZ economy through an increase in GDP (Miller, 2008) .

A report prepared by the NZ Construction Industry Council (2004) has revealed a number of key issues that the NZ construction sector is facing, namely a focus on costs over value, constrained innovation and inappropriate risk allocation.

More recent studies have reported that one of the root causes of the aforementioned issues is the procurement method of projects (Department of Building and Housing, 2008, 2009).

In many current procurement methods, particularly traditional contracts, 'value' is achieved through price competition which could lead to adversarial relations (Egan, 1998). Very often traditional procurement methods are fraught with time and cost overruns and overall poor performance (Enshassi, Al-Najjar, & Kumaraswamy, 2009). Traditional contracts do not encourage contractors to propose innovations (Blayse & Manley, 2004) due to high price competition and lack of early collaboration (Mathews & Howell, 2005). However, traditional contracts dominate in NZ construction (Zuo, Wilkinson, Masurier, & Zon, 2006).

Traditional contracts have been found to be inadequate for complex and high risk projects (Sakal, 2005). In such projects, contracts need to be aligned with the interest of project participants to reduce fragmentation while generating value (Ballard, 2008). Therefore, alliancing is widely used in complex construction projects with scope changes, unpredictable risks, complex stakeholder issues and tight schedules. Alliancing improves working relationships among all participants thus conferring significant benefits over traditional contracts (Colledge, 2005). Alliancing has been widely used in Australia for public sector projects (Clifton & Duffield, 2006). NZ has been influenced by Australia in adopting the alliance concept (Sweeney, 2009). NZ is the second highest alliance user in the South Pacific region with projects worth $4.25 billion progressed between 2001- 2010 (Figure 1.1).

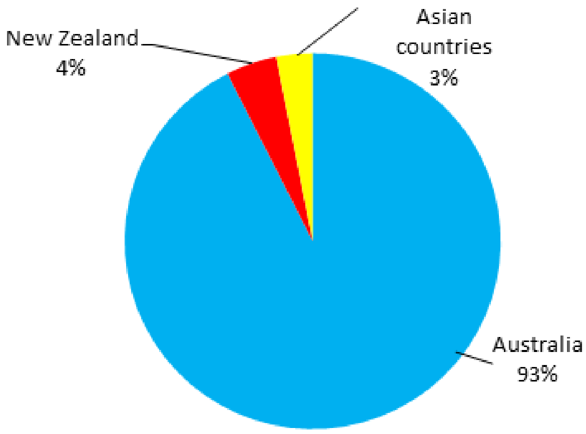


Figure 1.1: Alliancing by countries in Australasian region 1996 - 2010

Source: (Alliancing Association of Australasia, 2011b), compiled by the author

The studies led by Sweeney (2009) and Regan (2009) compared the success of project delivery methods in large projects (Table 1.1). This analysis shows that the traditional methods are not effective in delivering large projects. Evidence suggests that alliances were delivering procurement cost savings in the range of 2-4% and for complex projects such as the new terminal of London Heathrow airport it was 24% (Regan, 2009).

Table 1.1 : Variation of project performance with procurement type

Procurement type	Sweeney (2009)		Regan (2009)	
	% of projects			
	On cost	On time	On cost	On time
Traditional	16.7%	39%	25-55%	34-63%
PPP*/PFI**	79.0%	82%	79%	82%
Alliance	82.5%	100%	77%	78%

* PPP- public private partnerships ** PFI- private finance initiative

1.3 RESEARCH MOTIVATION

NZ invests heavily in infrastructure development to stimulate its economic growth (National Infrastructure Unit, 2011) and the use of alliancing as a strategic option has slightly increased from 2006 to 2009 (Alliancing Association of Australasia, 2011b). During the period 2001-2010, road construction was the largest sector in NZ to use alliancing as a procurement method, representing 43% of all alliance projects (Figure 1.2).

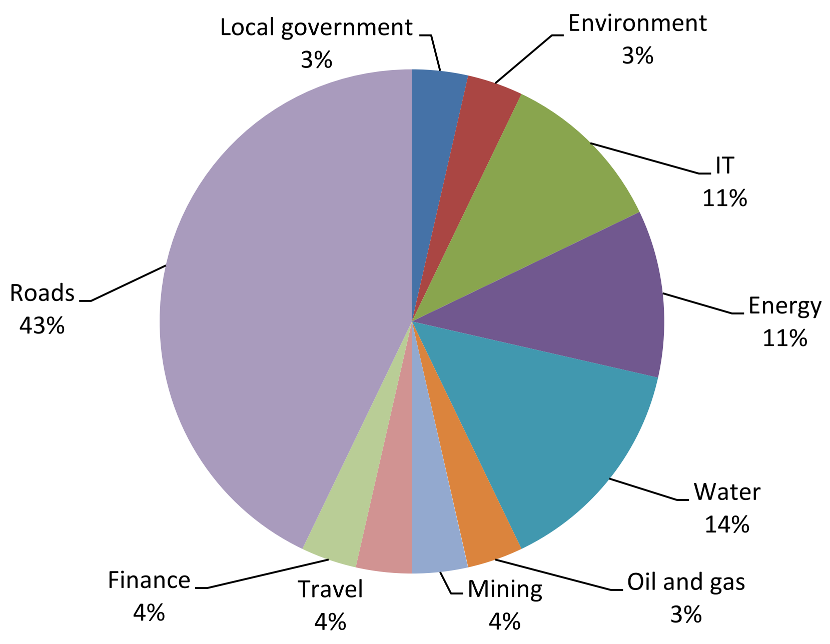


Figure 1.2: Alliancing by industry sector 2001-2010 in NZ
Source: (Alliancing Association of Australasia, 2011b), compiled by the author

Alliancing has confirmed its significance in major projects across NZ with its framework focusing on aligned goals, mutual trust and risk sharing. Most of the alliancing projects executed in NZ have been related to the public sector (Figure 1.3).

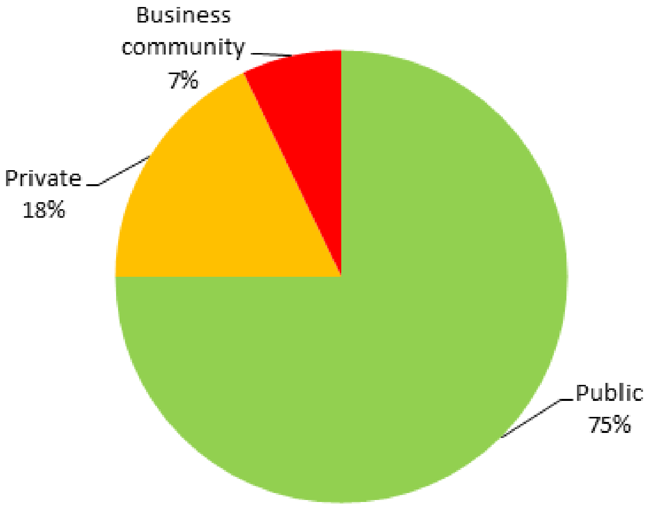
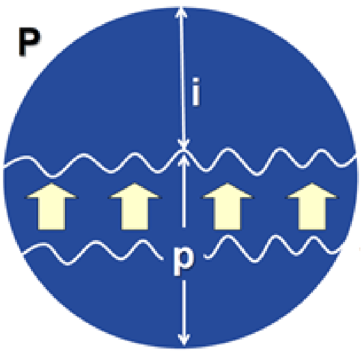


Figure 1.3: Alliancing by organisation sector 2001-2010 in NZ
Source: (Alliancing Association of Australasia, 2011b), compiled by the author

There is a large number of attempted alliances in construction but only a small number is genuinely high performing and producing significant added benefits for the participants (Buffet, 2010). For example in Australia, alliancing was successfully utilised on only nine out of approximately 50 projects in 2001 (Clifton & Duffield, 2006). Similar figures are reported by Blismas and Harley (2008) who conducted a survey of alliances project and the study shows that around 33% and 39% respectively of 18 alliance projects studied have experienced time and cost overruns. A PhD study of project delivery methodologies by Sweeney (2009) showed that seven out of 40 alliances have experienced cost overruns, 13 projects had no change to the budget and the rest were below the budget. Sweeney (2009) also reported that eight out of 27 alliances were delivered on time and the rest have been completed ahead of the planned date.

According to Gallwey's formula, the full potential of a project performance cannot be achieved due to interferences (Figure 1.4). These interferences could be reduced by alliancing which predominantly removes commercial misalignments (Ross, 2007). However, a significant portion of interferences still exists (Ross, 2007). Alliances eliminate causes for low productivity by creating a relational environment. Past studies of alliance project performance (Table 2.5) showed that opportunities for a 'game breaking' level of performance have not been detected (Buffet, 2010).



p= P- I where,
Actual performance - (p)
True potential - (P)
Interferences - (I)

Figure 1.4: Gallwey's formula for project performance
Source: (Ross, 2007)

Despite the proven benefits of alliancing, there is a trend to reduce the number of alliance infrastructure projects in Australia (Ross, 2007). Yet, there is scope for performance improvements in alliancing and the benefits of alliancing are such that interferences are worth exploring.

1.4 RESEARCH JUSTIFICATION

Alliancing, as a project delivery model, has come a long way since its beginnings in the North Sea oil & gas industry in the UK and its subsequent uptake in Australia in the mid-1990s. There is an increase in project alliances in Australia as a means to effectively delivering infrastructure in the public sector (MacDonald, Walker, & Moussa, 2013). The increasing consideration of alliance projects has led to a number of research studies in recent years. Most of these studies have been based in Australia and a few in NZ (Figure 2.4).

Past studies have confirmed that collaborative approaches like alliancing can provide real benefits to project participants in terms of project outcomes (Bresnen & Marshall, 2000a), added value in cost, time, safety, relationship and innovations (Hauck, Walker, Hampson, & Peters, 2004) and high performance work systems lead to improved employees' work life balance (Lingard, Brown, Bradley, Bailey, & Townsend, 2007). Furthermore, Table 1.1 showed that alliancing is more effective in delivering large projects compared with traditional procurement methods.

Previous studies of alliance projects (e.g.: Sweeney, 2009 and Blismas & Harley, 2008) also showed that only a small number of alliance projects are genuinely high performing and producing benefits for the participants. Several studies highlight existing issues and reasons for sub-optimal results in alliances. Some of the issues include:

- Few incentive drivers to achieve innovation (Buffet, 2010)
- Clients have had a poor business case, poor demonstration of value for money and increased commercial focus among participants (Marosszeky & Ward, 2011)
- A self-sustaining attitude instead of a win-win attitude and lack of open communication among project participants (Ng & Skitmore, 2002)
- Participating organisations focus more on short-term profit sharing due to a project based nature (Ingirige & Sexton, 2006) and
- Insufficient understanding or commitment to alliance principles by project participants (Ross, 2007)

Mitropoulos and Tatum (2000) suggests that projects should adopt integration mechanisms in terms of the contractual, organisational and operational domains. Similarly, Alarcon, Christian, and Tommelein (2011) are of the opinion that to generate more optimal results, attempts for performance improvements must be considered in all three areas, while retaining the balance between them. From the comparison of relational contracts (section 2.4), it was found that the focus of alliances is more on contractual and organisational domains through collaboration. These two domains mainly affect the strategic level of projects and are likely to cause a reduction of disputes and claims (Jefferies, 2006), reduction of uncertainties (Grynbaum, 2004) and improved working relations between all parties (Colledge, 2005). Substantial improvements in projects cannot be achieved only through organisational and contractual integration. Therefore it is important to change how work is done at the project level to improve the efficient use of labour, equipment and materials (Singleton & Hamzeh, 2011).

In 2012, an editorial note in a special issue of the Construction Management Economics Journal explained that more research effort has focused on procurement systems (collaborative project delivery) and the “soft” issues of communication and relationships. However, there is an emerging interest in blended approaches to improve performance such as combining collaborative project delivery systems with process management techniques (Kenley, 2012). The aim of this study, therefore, is to improve performance of alliance projects through a suitable process management technique.

With the development of the Transformation, Flow and Value (TFV) theory by Koskela, the construction industry was inspired by new process management techniques (Elfving, 2008). Different methodologies were introduced to the industry and the best known of them are Lean, Six Sigma, Total Quality Management (TQM), Total Productive Maintenance (TPM), Business Process Re-engineering (BPR) and Theory of Constraints (TOC) (Sullivan, 2010). All these methodologies focus on similar basic issues and they have many common features in terms of results, tools and techniques. Therefore, a suitable process management technique needs to be selected which complements alliance doctrines, especially in regards to team collaboration. The analysis in section 3.3 identified Lean as a potential process management technique for alliances.

The lean concept continuously improves safety, quality and productivity while reducing waste. The lean approach was originally used as a tool to improve operational performance (Joosten, Bongers, & Janssen, 2009) and has now become a management approach for improving operational and socio-technical performance (Anvari, Ismail, & Hojjati, 2011). In alliancing, most of the benefits realised at the initial value management workshops are passed on to the owner and most of the savings realised during the development of the final design are not passed on to the non-owner project participants. Therefore, process efficiency improvements at site level should be considered to increase gain: pain share for the non-owner alliance participants. Accordingly, the use of lean construction techniques is a natural fit for alliance projects by taking the value stream viewpoint. That is by focusing on maximising value adding (VA) activities, minimising non-value added necessary (NVAN) activities and eliminating non-value added unnecessary (NVAU) activities. Therefore, this study is designed to improve alliance project performance through lean thinking.

In summary, the background study identified the following issues in alliance practices and the current study was designed to address those issues.

- only a small number of alliance projects have been genuinely high performing
- focus of alliance framework is mainly on organisational and contractual systems while little concern on operational system, and
- lack of studies of process management techniques in alliancing projects

1.5 RESEARCH FOCUS

Forming a clear research focus to which the researcher can refer to during the study is an important step of research. The research focus is developed mainly by defining the research aim, objectives and research questions.

1.5.1 Research aim

The research of construction productivity improvements had a surge of interest over the last two decades due to industry significance and its peculiarities. Much of this interest has been devoted to contractual and organisational aspects. There has also been emerging interest in the technical and operational aspects such as design data communication (e.g. building information modelling (BIM)) and production management techniques (e.g. lean construction). More recently there is a growing interest in integrated approaches to improve performance, where initiatives that address different aspects are integrated to solve productivity issues in the industry. Due to a growing interest in blended approaches, the research aim was established to explore how lean thinking can be utilised in alliance projects to improve the alliance project performance.

1.5.2 Research objectives

The alliance and the lean concepts are recognised as primary research areas in this study and the following two research objectives were formulated based on preliminary literature review findings.

1. To explore reasons for operational deficiencies that exist in alliance projects

Walker and Hampson (2008a) identified financial, technological, management and strategic motives in collaborative projects in UK and Australia. The findings of their study showed that outstanding results were gained in technical, managerial and strategic areas but little similar evidence was seen in financial areas. The financial motive covers cost and time performance measurements. In most of the alliances, innovation was applied to all activities particularly where it could reduce cost and time for completion and improve quality (Wood & Duffield, 2009). A key to overcoming inefficiency in financial terms is first to determine existing deficiencies in alliance projects.

From the review of relational contracts (section 2.4), it was found that the focus of alliances is more on contractual and organisational domains through collaboration. Project performance cannot be achieved only through organisational and contractual integration. So, it is important to change how work is done at the project level to improve the efficient use of labour, equipment and materials. This research was carried out to explore how operational management techniques can be utilised in alliance projects to improve the alliance project performance. For that, existing operational management techniques were reviewed (section 3.3). The lean concept was selected as a potential technique for improving performance in alliance. Therefore, it is one objective of this study to analyse the existing deficiencies in alliance projects from the lean perspective.

2. To examine the applicability of lean thinking in alliance projects

As mentioned before, the non-owner participants' intellectual capital is provided in value management workshops at the early stage of an alliance with no reward. Consequently, at this stage of early alliancing, the owner has reaped the rewards of the non-owner participants' intellectual capital for only the cost of conducting a value management workshop. The only incentive for the non-owner participants is that they get the project for a reduced target operating cost. Therefore, process efficiency improvements at the site level are an incentive for the non-owner alliance participants. This signifies the importance of process management techniques at alliance projects.

Nevertheless, the preliminary findings from literature showed that alliancing is more focused on contractual and organisational aspects and leaves alliance management to find the best process management techniques to attain the project objectives. As a result, the applications of individual principles and methods in an ad-hoc and fragmented manner would gain only partial success.

Therefore, an integration of such process management techniques would create a framework in alliances for improving the performance at operational level. It was identified that all methodologies share common roots focusing on operations and on process improvements. However, Lean was identified as a suitable technique within an alliance environment. Hence both concepts are seen as complementary to each other, this study was designed to explore how the lean thinking can be utilised in alliance projects to eliminate identified deficiencies in alliance projects.

1.5.3 Research questions

From the stated research aim and objectives two main research questions are put forward. The research questions provide the framework for the research. Figure 1.5 illustrates the relationship between the research aim, research objectives and the research questions of this study.

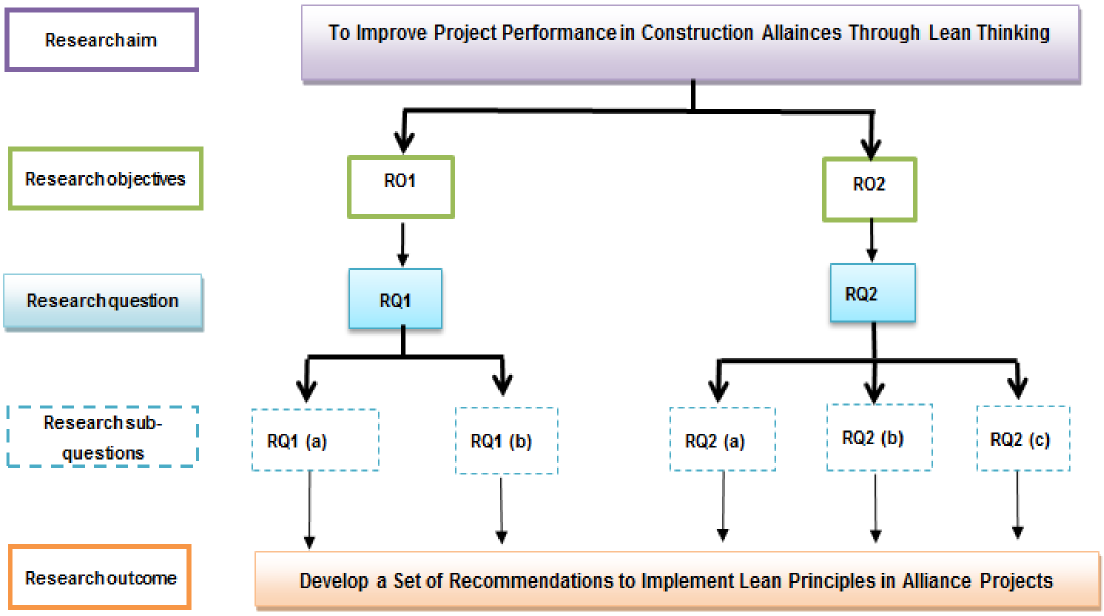


Figure 1.5: Relationship between the research aim, objectives and questions

RQ1: What are the operational deficiencies that exist in an alliance project from a lean perspective?

In order to improve the performance in alliancing, the researcher attempts to identify the improvement opportunities in an alliance project by using lean thinking. Within the context of lean principles there are seven types of process waste namely overproduction, waiting, transport, extra processing, inventory, motion and rework which will lead to inefficiencies. In addition to these seven types of process waste identified by Ohno (1988), Womack and Jones (1996) identified an eighth category - unused creativity of workers. This waste relates to the behavioural waste, in particular unused ideas of project participants for improving processes and practices. It is identified (and described and justified in more detail in section 3.7.3) that this eighth waste is inherent in the seven types of process waste previously defined. It is noted that the suggested eighth waste is much harder to quantify and requires a qualitative understanding. Therefore the main research question is sub-divided into two sub-questions.

RQ1-a): What are the types of process waste that exist in an alliance project from a lean perspective?

RQ1-b): What are the types of behavioural waste that exist in an alliance project from a lean perspective?

RQ2: How can lean thinking reduce the identified deficiencies in an alliance?

This question tries to generate strategies to overcome the identified deficiencies in (RQ1). Since the deficiencies arise due to two types of waste the following two sub-questions are formed:

RQ2-a): How can process waste be eliminated through lean thinking?

RQ2-b): How can behavioural waste be eliminated through lean thinking?

A critical step of this study is to investigate the applicability of lean thinking for improving the performance of an alliance. Therefore the next research sub-question mainly tries to identify the uptake of lean thinking in alliance projects.

RQ2-c): How does the alliance project environment facilitates a lean implementation?

1.6 THE NATURE OF THE STUDY

This section explains the study definitions and the research approach used for this research.

1.6.1 Study definitions

The purpose of this study is to explore how lean thinking can be utilised in alliance projects to eliminate identified deficiencies in alliance projects.

Therefore, this research mainly deals with two main concepts namely alliancing and lean construction. The study used the following definitions for alliancing and lean construction respectively:

> "Alliancing is a*n agreement between two or more entities, which undertake to work cooperatively, on the basis of a sharing of project risk and reward, for achieving agreed outcomes based on principles of good faith and an open-book approach towards costs (Queensland Government Chief Procurement Office, 2008)"*

> *"Lean construction is the continuous process of eliminating waste, meeting or exceeding all customer requirements, focusing on the entire value stream and pursuing perfection in the execution of a constructed project" (Diekmann, Krewedl, Balonick, Stewart, & Wonis, 2004)*

A separate glossary of terms used in this study is provided in (Appendix A).

1.6.2 Research approach

This section provides an overview of the research approach used in this study and chapter four describes and justifies this approach in more detail. The research aim and literature review of alliancing (chapter two) and lean construction (chapter three) are used as the foundation for this investigation. The research aim of this study is to explore how lean thinking can be utilised in alliance projects to improve the alliance project performance. Because the intention of this study is not to describe but rather to explore improvement opportunities in an alliance, the interpretivist approach was used. Section 4.4.3 explains in more detail this paradigm selection.

From the initial literature review and initial discussions with subject matter experts and academics, it is understood that the alliance and lean concepts are relatively new to the NZ construction industry. The analysis of past alliances in NZ found that road construction was the largest sector which used alliance as a project delivery method (Figure 1.2). The analysis shows that there is a limited number of alliance project participants in NZ and most of them consistently worked together (Alliancing Association of Australasia, 2011b). These conditions led to a limited number of potential participants for the study. Therefore due to the nature of the research problem the case study methodology was selected. Section 4.5.2 justifies this selection in more detail.

The first research question sought to detect and measure operational deficiencies in alliance projects. In the initial stage of the research, the study looked for suitable on-going alliance projects in NZ. The selected project was chosen because it was formed by a majority of companies, which had just successfully completed an alliance project and were well conversant with the concept. The second research question sought to explore how lean thinking improves performance of an alliance. The study was designed in such a way that deficiencies identified in the south bound construction phase of the selected case study could be monitored with regards to improvements during the north bound construction phase (Figure 5.1). This is another reason for the choice of project and of a longitudinal case study approach.

Due to a lack of alliance contracts in NZ particularly in the Auckland region, the researcher selected a longitudinal study of a single project. When the project was commenced, four alliance projects were under development or execution in NZ. Each of these projects was evaluated by the researcher for its suitability for conducting research. The only alliance project under development within the window of opportunity for the conduct of this research project was the Newmarket Viaduct project that started in 2009. Since it consisted of many repeated process steps, the idea was generated to investigate the applicability of lean principles in an alliance environment. After a couple of meetings with alliance board members of the Newmarket viaduct project the cooperation was assured to conduct a research study.

Participant observation was used to identify operational deficiencies in the selected case study. Five processes of the south bound construction were observed. The processes were selected based on process characteristics (process complexity, repetitive nature, procurement method and project participants) and process performance (high variation in time, cost and quality). Certain processes were excluded due to project programme restrictions (e.g: the pier construction process overlaps with the pre-cast segment production process) and safety restrictions (e.g: gantry operation was excluded because no safety permission was provided for visitors). Section 5.4 justifies this selection in more detail.

After completion of each process study, the process study findings were validated through process study reports and presentations with the project management. The participants of the process study meetings were the construction manager, project engineers, site engineers and supervisors of the selected alliance project. Follow up process studies were conducted in the north bound construction phase to measure the effect of the suggested lean strategies to the alliance project. The method and lessons learnt registers were used as secondary data sources.

Semi-structured interviews were conducted with the alliance top management to identify causes for identified operational deficiencies and to find applicability of lean thinking in an alliance. The nine participants were selected based on their experience in construction and alliances and relevant expertise in the subject matter. A pre-tested questionnaire was used to collect middle management views to establish causes for identified operational deficiencies and to gauge applicability of lean thinking in an alliance. All 31 middle level managers of the case study organisation (project engineers, site engineers and supervisors) were selected as questionnaire participants. Revalidation of findings has been achieved through interviews with five subject matter experts. Section 4.6.3 and section 4.6.4 describe detailed data collection and analysis methods used in this study. Table 1.2 encapsulates the research questions and data collection methods used in this study.

Table 1.2: Research questions, data collection and analysis methods

Research question		Data collection method					
		Literature review	**Participant observation**	**Follow up meeting**	**Document analysis**	**Interview**	**Questionnaire**
RQ1: What are the operational deficiencies that exist in an alliance project from lean perspective?							
RQ1(a)	What process waste exists in an alliance project from a lean perspective?	√	√	√	√	×	×
RQ1(b)	What behavioural waste exists in an alliance project from a lean perspective?	√	√	×	×	√	×
RQ2: How can Lean thinking reduce the identified deficiencies in an alliance?							
RQ2(a)	How can process waste be eliminated through lean thinking?	√	√	√	√	×	×
RQ2(b)	How can behavioural waste be eliminated through lean thinking?	√	×	×	×	√	√
RQ2(c)	How does the alliance project environment facilitate a lean implementation?	√	×	×	×	√	√
Data analysis methods			With in process study - cross study analysis		process	Thematic analysis	Statistical analysis

Key √ relevent data collection method × inappropriate data collection method

1.7 SCOPE OF THE STUDY

The study focuses on a single construction project in Auckland, NZ. The project duration coincides with the research programme period (2010-2012).

Ballard (2008) categorised the principles and techniques of lean project delivery into four project areas namely project definition, design, supply and assembly. In 2009 the project definition phase of the selected case study was completed and the design stage was started. Additionally, lean design is a relatively immature discipline in the literature compared to lean assembly and lean supply areas (Alves & Tsao, 2007). Therefore the research was limited to finding the suitability of lean assembly and lean supply principles for an alliance project.

Five sub-processes were selected for the process studies based on process characteristics and process performance. Certain processes are excluded due to the project programme structure and safety restrictions. During the initial process studies which were conducted at the south bound construction phase, every process was observed at least three times and the durations of observations were determined through statistics.

One of the more common lean tools called value stream mapping (VSM) was used to identify process waste in targeted processes. In every process study, the activities were sub-divided into VA, NVAN and NVAU activities. The current study tried to minimise NVAN and NVAU activities. The follow-up studies were conducted at the northbound construction phase and only one cycle was covered at that time.

The interviews and a questionnaire were conducted with the middle and top management level. Only questions approved by the university ethics committee are included in the questionnaire and interviews.

1.8 KEY ASSUMPTIONS OF THE STUDY

The study is grounded in the assumption that there is a potential growth and need for infrastructure projects in NZ and such endeavours will result in a growing interest in alliancing projects in NZ.

Furthermore, past studies have shown that alliancing principles have improved the performance of projects mainly removing interferences at the contractual and organisational levels. It has been hypothesised that there is still an opportunity to improve performance in alliance projects mainly considering operational aspects.

The study regards the selected case study project a representative case study for NZ alliance projects. This assumption is based on the fact that the same participant organisations have been working together over a long period of time and with the New Zealand Transport Agency as the owner of all road construction alliances in NZ.

Participants in the interviews and questionnaire have been top and middle level managers of the selected case study. The study is based on the assumption that respondents are sufficiently knowledgeable in current practices of the project and motivated to answer questions carefully. The purposive sample was selected based on their area of expertise and experience to improve the validity of the data collected (Table 6.2 and Table 6.10). It is assumed the contributions of the interview and questionnaire participants are true and honest. The voluntary participation, anonymity and confidentiality of the respondents were assured to get optimum contribution from the participants.

The scope and assumptions of the study lead to different limitations which are explained in the following chapter.

1.9 LIMITATIONS

In the selected case study organisation top level managers who are directly engaged in project work were limited to 11 members and the middle level managers (project engineers, site engineers and supervisors) were limited to 31 members. Therefore, the overall number of participants is limited and it can raise concerns about population generalizations. However, statistical generalizability is not necessarily the goal of case study methodology (Yin, 2003). Since the selected case study is a representative of alliance projects the findings can serve as a pool of potential actions for future alliance projects.

This research work is designed for a PhD thesis so a single person has carried out the research plan development, data gathering and analysis. There is a potential bias in gathering, reporting and analysing of data due to the absence of multiple investigators in this research. After completion of each process study, the process study findings were validated through process study reports and presentations to the project management. For this study, the researcher has used standard data collection protocols (Appendix M - Appendix P) which assures the consistency of the data collected. Therefore the member checking technique and standard protocols have decreased the potential bias of the research.

Another limitation of this study lies in the tracking of the sustainability of lean initiatives. Speroff and O'Connor (2004) suggested that ideally, one should study interventions over a long period of time to reinforce the conclusion that the change in outcomes was indeed due to the intervention effect. This study consisted of two phases of process studies (initial process of the south bound of the viaduct and follow up study of the north bound). It was observed that during the overall study period of three years the learning from the first phase was adhered to during the second phase.

Further limitations faced in the course of the research include accessibility to information, difficulty in approaching the site management due to the busy nature of their operations and possible unwillingness of some participants to explain their views due to the fear of victimisation if discovered. However, voluntary participation, anonymity and confidentiality of the respondents were assured to achieve their optimum contribution.

An on-line questionnaire was used and it is of course not possible to explain every aspect of the questions that participants might misinterpret. This was partially solved by pre-testing the questionnaire with a small group of participants (four construction specialists and two academics) and conducting a workshop before launching the questionnaire with the questionnaire respondents.

The most significant limitation of the study would be that the conclusions and recommendations drawn from the interviews and questionnaires are a person's individual perception and not necessarily the same as anyone else's perception. Since the research is being conducted from an interpretivist view, it is accepted that individual differences and perceptions cannot be mitigated. The conclusion from the case study may be applicable to a certain degree to other alliance projects, but of course the study findings were generated from one particular project culture.

1.10 THESIS PLAN

The thesis is structured into eight chapters (Figure 1.6) and the thesis outline is explained below.

Chapter one provides an overview of the research including research background, purpose and focus of the research. Consideration is also given to the delimitations, assumptions and limitations of the research before providing a summary of the various elements of the thesis.

Chapter two comprises the academic literature on procurement methods and subsequently evaluates the existing relational project delivery systems within construction management in particular. This chapter concludes by identifying scope for improvement in alliancing projects by setting the research focus that the research seeks to answer.

Chapter three provides a theoretical basis of process management methodologies available in the construction literature. This section identified that other process improvement methodologies can easily be integrated into Lean without contradicting the strategic objective of Lean. Lean principles are evaluated with reference to the relational contracting and alliancing principles.

Chapter four discusses the research methodology adopted for the conduct of this research and the reasoning behind the choice of the research strategy and approaches. Particular attention is given to the issues of the philosophical construct of the research, philosophical positioning of its design and consequent quality criteria of the study.

Chapter five presents the analysis of five process studies that measured the existing process waste parameters of an alliance construction project in Auckland, NZ using a lean tool called VSM. The purpose of the initial process studies is to explore the operational deficiencies existing in the selected case study. The follow up process studies were conducted in order to show the applicability of Lean in an alliance.

Chapter six presents an analysis of the interviews and questionnaire that evaluated the existing behavioural waste caused by sub-contractors and site workers at the alliance construction project in Auckland, NZ. The study identified that 80% of the workforce at the alliance project site worked under sub-contractors and 40-45% of the construction work was conducted by sub-contractors. However, the creativity or ideas of site workers and sub-contractors were not used to eliminate process waste in the selected alliance project. Therefore this chapter focuses on behavioural waste due to the unused creativity of site workers and sub-contractors.

Chapter seven summarises the key findings of the study and the validation exercise. This chapter compares the research findings with literature. By evaluating the research questions, this chapter pulls the whole thesis together. The chapter paves the way for drawing of conclusions and subsequent recommendations.

Chapter eight draws conclusions about the research questions, fulfilment of the research objectives and implications for theory and practice. Finally, recommendations are made for future work.

Appendices comprise the raw facts of each of the process studies along with details of other data collection tools.

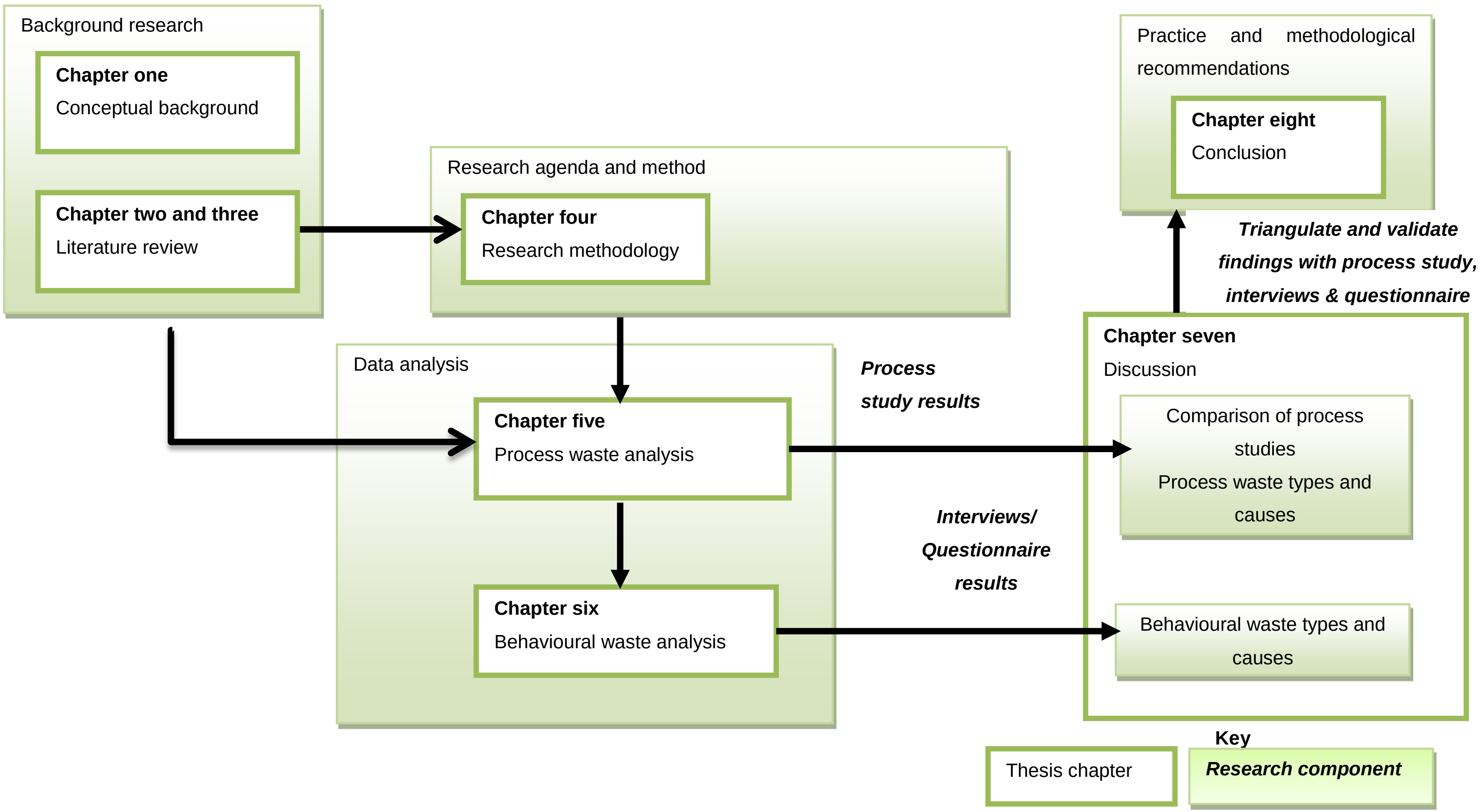


Figure 1.6: Thesis structure

1.11 CHAPTER SUMMARY

This first chapter laid the foundation to this thesis. It has outlined the background of the research by explaining the research motivation and the existing knowledge gap. The preliminary literature review revealed that a frequent critique of an alliance is whether alliancing delivers value for money. Apart from that, limited research studies have been conducted to identify improvement opportunities in alliance contracts especially at the operational level.

This research was carried out to explore how lean thinking can be utilised in alliance projects to improve the alliance project performance. Case study methodology was used in this research. The research has evaluated ways of improving existing deficiencies in alliances through a lean implementation. The study was focused on the construction phase of an alliance project in NZ. Participant observations of five construction processes were used to identify operational deficiencies in the selected case study. Interviews and a questionnaire were conducted with middle and top level management of the selected alliance project. This chapter has also discussed the research approach, scope, limitations of the study and the thesis structure.

As the first step of the actual research process, a systematic literature review was conducted primarily to choose certain methodologies or theories to work with and to identify a knowledge gap. Consequently the following two chapters deal with theory of alliance contracts and lean construction, divergence and convergence of two concepts and appropriateness of merging the two concepts.

2 THEORETICAL CONTEXT – ALLIANCING PHILOSOPHY

2.1 INTRODUCTION

This chapter reviews available literature on alliancing to gain an understanding of the main principles and to identify improvement opportunities in alliance projects. This chapter consists of seven sections including this introductory section. The next section (2.2) discusses the significance of the industry and various challenges present in the construction industry. A large and growing body of literature has investigated these existing issues and productivity has been identified as a major one. Previous studies have pointed out that the productivity in construction is greatly affected by the procurement method used. Therefore, existing contractual agreements are discussed in section 2.3. It points out that traditional contracts may lead to adversarial relations and could create negative effects on the project outcome. This has led to the emergence of innovative contracts known as relationship contracting. A detailed analysis of relational contracting is provided in section 2.4. Section 2.5 and 2.5.2 present a review of alliance contracts. This analysis consists of an introduction to alliance, alliance benefits and scope for improvements in alliances. Section 2.6 concludes the review of literature particularly on alliancing.

2.2 NATURE OF THE INDUSTRY

The poor performance in the construction industry is a global phenomenon. This leads to reflections on the nature of the industry itself, which will be discussed in the next sections.

2.2.1 Significance of the industry

The construction industry plays a major role in the economy of any country as it generates substantial employment opportunities and contributes to the gross domestic product (GDP). According to the statistics, the construction sector contributes 10% of the global GDP (National Research Council of the National Academies, 2009) and has an average overall growth of 3% (Davis Langdon Management Consulting, 2007). The importance of the construction sector is related not only to its size but also to its role in economic development. It is estimated that around 111 million people are employed in construction worldwide (National Research Council of the National Academies, 2009).

2.2.2 Significance of New Zealand construction industry

The construction industry is NZ's fifth largest sector. The sector has a significant impact on NZ's economy as the sector contributes more than 4.3 % to GDP. The sector also contributes to the activities in other related sectors such as manufacturing, transport and business services. Currently, about 178,000 people are directly employed in construction which is about 8% of the total work force (Department of Building and Housing, 2010). Considering also the large number of employees who are indirectly employed with materials suppliers and a range of related industries, efficiency improvements in construction have a direct benefit on the NZ economy (Miller, 2008) .

2.2.3 Current status of the industry

Despite the significance of the industry, productivity in the construction industry has been lower than productivity in other industries. Root causes for low productivity in construction are mainly related to the industry peculiarities. Different researchers have looked at these peculiarities from different angles. Because of the complexity of the identified peculiarities, this study summarised the identified peculiarities and grouped them into different categories. These peculiarities are classified under seven categories namely time, people, place, money, process, management and product (Figure 2.1).

McGrath-Champ and Rosewarne (2009) concluded that the long production time and the cyclical nature are the major peculiarities in the sector. Reasons for not being able to improve the productivity of construction projects are mainly the project features like complexity, site production, harsh work settings and temporary multi-organisation (Koskela, 2000). These features demand a high degree of manual skills and worker mobilisation (Koskela, 2000) which lead to low job security (Picchi, 2001). Evidence suggests that lack of communication (Weeleng, 2004) and high competition due to low profit margins (Salem, Solomon, Genaidy, & Luegring, 2005) cause adverse contractual relationships (Barret, 2005). While other sectors have been modernised, the construction industry retains its craft method of operation (Yitmen, 2007). Therefore, construction practices are under examination around the world. A UK study has shown that three quarters of projects have exceeded their budgets by 50% and two thirds have exceeded their original completion date by 63% (Cain, 2004).

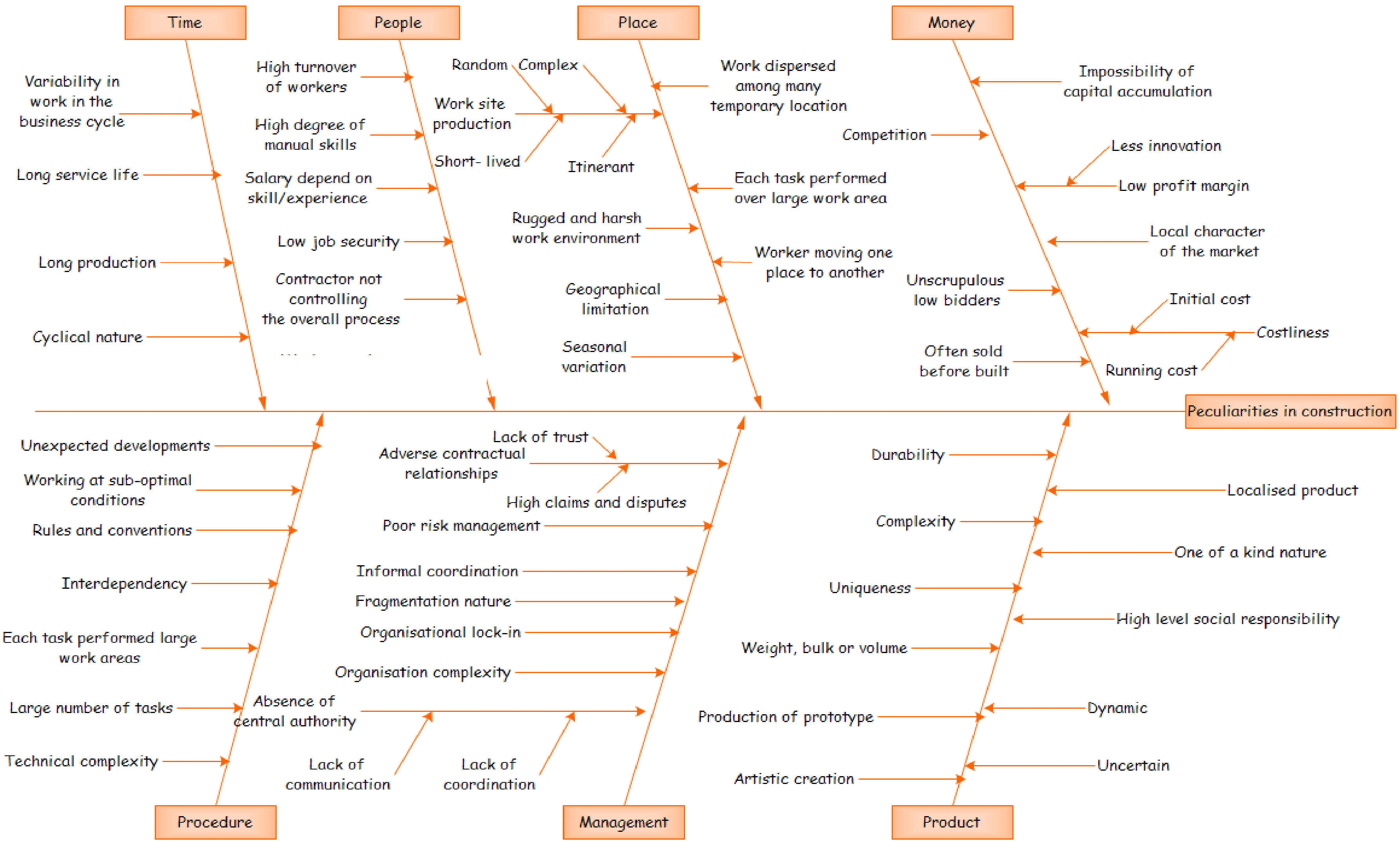


Figure 2.1: Analysis of existing peculiarities in the construction industry

Source: (Koskela, 2000; McGrath-Champ & Rosewarne, 2009; Picchi, 2001; Salem et al., 2005; Weeleng, 2004)

The amount of work on NVA activities was found to be as high as 40% of the overall project duration (Hampson, Peters, & Walker, 2001).The construction workers also experience a higher non-fatal injuries rate than workers in other industries (Cain, 2004). Love and Irani (2004) have explained that the Australian construction industry has suffered from lack of productivity gains due to slow innovation. Since this study focuses on the NZ construction industry, the next section will discuss the current status of the NZ construction industry.

2.2.4 Issues of the construction industry in NZ

In recent years, construction in NZ has been subject to a series of reports that pointed out the reasons for its poor performance. The NZ Infrastructure Development Council's study, conducted in 2005, (as cited by in Miller, 2008) estimated that the NZ workforce is 30% less productive than the Australian workforce. Miller (2008) has shown that productivity in the NZ construction industry for the period of 2001-2006 was fourth from bottom among the developed countries. The NZ construction industry has accounted for 34% of work-related fatalities and the second highest incidence rate of serious injuries (Statistics New Zealand, 2010).

A series of construction related key performance indicators (KPI) were measured in NZ and compared with UK figures (Miller, 2008) (Figure 2.2). There is a significant underperformance of the NZ construction industry compared to the UK construction industry mainly in health and safety, profitability, and predictability in delivery of projects on time and budget. These findings show that there is a requirement to improve construction performance.

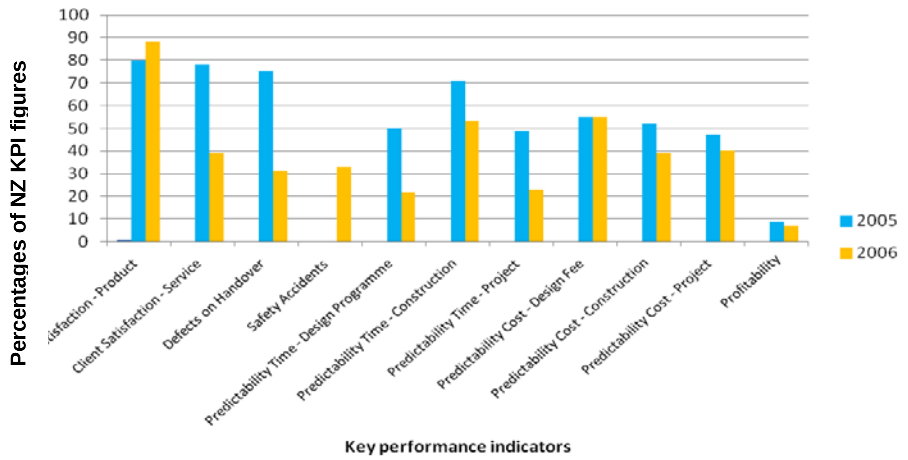


Figure 2.2: The NZ construction industry performance indicators (UK=100)
Source: (Miller, 2008)

2.3 PERFORMANCE IMPROVEMENT VIA PROCUREMENT METHODS

A large and growing body of literature has examined the existing issues in construction. Construction productivity has been mentioned as the main concern. Most of the existing issues in construction have a direct or indirect impact on productivity. For example, low productivity results in time overrun and safety issues. For that reason, productivity is a major factor to be considered and different developments have taken place in the industry. Construction productivity is influenced by different factors namely work methods (Enshassi et al., 2007), procurement method (Baiden, Price, & Dainty, 2006) and site management (Cheung, 2009). The New Zealand Ministry for Building and Construction (2008) has pointed out that construction productivity is greatly influenced by the procurement method. The next section will discuss different procurement methods in construction.

The construction procurement method covers the payment framework and duties and authorities of participants (Love, Skitmore, & Earl, 1998). The construction industry remains a victim of conflicts inherited in most of the procurement methods. Traditional methods where 'value' is achieved through price competition lead to adversarial relations (Egan, 1998) and poor performance (Rahman & Kumaraswamy, 2004). Furthermore, traditional methods do not encourage process innovation (Blayse & Manley, 2004) due to price competition and absence of early collaboration (Mathews & Howell, 2005). The NZ construction industry council (2004) has shown that a number of key issues faced by NZ construction can be addressed through apt procurement practice. Consequently, different procurement methods have been developed and each method contains its inherent strengths and weaknesses. The features of different procurement methods discussed in the literature are summarised in Table 2.1 which is based on the procurement categories developed by Love et al. (1998).

In the separated approach, tasks of different project phases are separated and conducted by various independent organisations namely designers and contractors (Masterman, 2005). The main procurement method in this category is 'design-bid-build'. Main procurement methods under the management approach include 'design, build and manage', 'build-own-operate-transfer', 'construction management', and 'management contracting'.

Table 2.1: Characteristics of different procurement methods

Source: (Vilasini, Neitzert, & Rotimi, 2011)

Procurement method	**Separated**		**Integrated**			**Management**		
Procurement / Factors	**Design bid build**	**Novation**	**Design & Build**	**Relationship**	**Design, Build and Manage**	**Build, Own, Operate, Transfer**	**Construction Management**	**Management Contracting**
Time of awarding the contract	Procurement stage	Design development	Design development	Project definition	Design development	Project definition	Procurement stage	Concept development
Collaboration	No collaboration	Early collaboration	Early collaboration	Long term co-operation	Project collaboration	Project life cycle collaboration	No collaboration	No collaboration
Risk culture of owner	Totally risk averse	Totally risk averse	Totally risk averse	Sharing risk	Short-term operating risk	Long-term operating risk	Contractual risk to client	Contractual risk to construction manager
Degree of complexity	Very low	Very high	Medium	Medium	High	High	High	High
Selection criteria	Price	Price	Price	Price/non-price	Price	Price	Price	Price
Conflicts/Disputes	High risk	High risk	Low risk	Low risk	Low risk	Low risk	High risk	High risk
Design controllability	High	High	Low	High	High	High	Low	High
Owner’s controllability	High	High	Low	Medium	Medium	Medium	Medium	Low
Quality of output	Low	High	Low	High	Medium	Medium	Low	Low
Time frame	Long	Long	Flexible	Flexible	Flexible	Flexible	Flexible	Flexible
Price certainty	High	High	High	Flexible	Low	Low	Low	Low
Profitability	Low	High	Low	High	High	High	Medium	Low

In the integrated approach, a single organisation takes responsibility for design and construction work with the client (Masterman, 2005). Variations of this approach are 'novation', 'design and build' and 'relational' and they are distinguishable by level of risk involvement by each party. In the management approach, the management function involves a construction project management organisation that works with both designers and contractors (Masterman, 2005).

Table 2.1 reveals some aspects of procurement methods where relationship methods provide positive impact on profitability, time flexibility, risk and controllability but lead to a complex operational framework. Therefore, the next section will focus on the relationship procurement methods.

2.4 RELATIONAL PROJECT DELIVERY METHODS

Relationship contracting aligns participants' interests with the project objectives through a management framework underpinned with a governance structure. In relational contracts, the contract terms have less importance than the relationship among project participants. Therefore, relationship contracting significantly reduces the claims and disputes between the parties through the use of collaborative legal and commercial arrangements (Henneveld, 2006). Accordingly, these relational contracts are becoming increasingly used in place of traditional contracts (Egan, 1998). Previous studies have used different definitions of relational contracting as revealed below.

Rahman and Kumaraswamy (2008) have described relational contracting as:

> *"A working arrangement which is based on recognition of mutual benefits and win-win scenarios through cooperative relationships between contracting parties"*

ACA Commercial and Contract Task Force (1999) has defined relational contracting as:

> *"A process to establish and manage the relationships between the parties that aims to remove all barriers, encourage maximum contribution and allow all parties to achieve success"*

McLennan (2000) has described relational contracting as:

> *"A way to maximise project outcomes for all parties by adopting a conscious approach to manage relationships with the co-operative application of improving project delivery systems and processes"*

Relational contracting is defined in various ways. There is a tendency to equate the term relational contracting with long-term contractual relationships. It is not difficult to identify some similarities in aforementioned definitions although a single, concise definition is yet to be derived. An analysis conducted by Hampson et al. (2001) has identified trust, commitment, cooperation, common goals and win-win attitude as important elements in relational contracts. Relationship contracting contains proven delivery strategies which optimise project outcomes and deliver optimal commercial benefits to all project participants (ACA Commercial and Contract Task Force, 1999).

Traditional contracts are adversarial in nature mainly because the project participants have being selected mainly on price competition. Various authors have suggested that a relational approach requires long term relationship between parties, mutual trust, and cooperative problem solving. Unlike traditional contracts, alliance contracts allow a much higher flexibility which is suitable for the construction industry. These relational type delivery strategies can be distinguished from traditional contracts as shown in Table 2.2.

Table 2.2: Traditional contracts versus relational contract

Attribute	Traditional contract	Relational contract
Selection criteria	Price based	Price and non-price based
Teams	Fragmented Assembled on 'just-as-needed' Hierarchical and controlled	An integrated team Assembled early in the process Open and collaborative
Agreements	Unilateral effort Allocate and transfer risk Individual decision making	Multi-lateral collaboration Risk sharing Unanimous decision making
Relationship	Transactional driven Adversarial	Relational driven Collaborative
Knowledge and expertise	No opportunity to share	Shared openly and early
Risk	Individually managed Transferred to the greatest extent	Collectively managed Appropriately shared
Compensation/reward	Individual performance driven Individual reward maximisation	Project success driven Team success maximisation
Culture	Blame Risk averse and finger pointing	No blame Learning, continual improvement
Thinking	Self interest Traditional	System and best for project Innovative
Performance measures	Cost related Win-lose	Cost and non-cost Win-win

Relationship contracting is frequently used to describe a broad spectrum of project delivery systems including partnering, early contractor involvement (ECI), alliancing and integrated project delivery (IPD). Kumaraswamy and

Abeysekera (2008) pointed out that recent advances in project delivery systems have led to misunderstanding of overlapping terminology. Different literature has discussed principles, benefits and suitability of each concept. Some studies have used these concepts interchangeably. In the context of existing literature, it can be found that there is a lack of studies that explicitly address similarities and differences of these relational contracting concepts. Therefore, the following sections will examine the features of prevailing relational contracts.

2.4.1 Partnering

Partnering is a structured management approach where two or more parties gather to achieve specific business objectives to maximise effectiveness of each participant's resources (Naoum, 2003). Alliancing has been often used interchangeably with partnering in the literature (e.g.: (Bresnen & Marshall, 2000a), (Li, Cheng, & Love, 2000) and (Porter & Rayner, 1992)). Partnering is not a formal contract. It is applied outside a contract to align the objectives of the parties, facilitate good teamwork and solve problems. Advantages of partnering include better communication, improved learning, more informed decision making and increased effectiveness.

The majority of partnering agreements work on a lump-sum contract basis without any gain:pain share mechanism (Chan, Chan, & Yeung, 2009). As a result, cost savings which are realised under partnering arrangements are not given to contractors but they are kept by the clients. This does not encourage the contractors to add value to the project (Alderman & Ivory, 2007). Reluctance of the project parties to commit to the partnering agreement (Ng, Rose, Mak, & Chen, 2002) and difficulty in changing behaviour of project participants (Bresnen & Marshall, 2000a) are the main reasons for ineffective partnering. Partnering does not provide a legal binding to the partnering charter; thus parties try to resolve problems through litigation (Quick, 2002). A wide range of studies have been conducted to find out the relationship between partnering and TQM and it has been accepted that TQM and partnering are positively linked (Black, Akintoye, & Fitzgerald, 2000).

2.4.2 Early contract involvement

ECI is termed as a form of an alliance (Mohamed & Tucker, 1996) or similar to an alliance with a fixed price (Miller, Furneaux, Davis, Love, & O'Donnell, 2009) or as a separate project delivery model (Queensland Government Chief Procurement Office, 2008). The ECI model was started in the construction industry to avoid waste due to constructability issues (Griffith & Sidwell, 1997). To achieve this, ECI brings contractors in at the early project phase and seeks contractors' inputs for the design process. This early involvement also provides 'a sense of ownership' to the contractors which eliminates disputes in later phases of the project (Molenaar, Triplett, Porter, DeWitt, & Yakowenko, 2007).

ECI contract is a two stage approach. Stage one, which is design concept and budget development, is similar to a project alliance. Stage two, which involves detailed design and construction, is similar to a design and build contract (Mosey, 2009). ECI is suitable when the project contains time constraints with uncertain and high risk factors. ECI potentially improves the project time and price certainty through active involvement in constructability and programme sequencing issues at the project initiation. There is no defined process management technique or governance structure in ECI contracts.

2.4.3 Alliancing

Kwok and Hampson (1996) have defined alliancing as a cooperative arrangement between two or more parties that forms their overall strategy and contributes to achieve project objectives. Clifton and Duffield (2006) have defined alliancing as an agreement between parties to work cooperatively to achieve agreed outcomes on the basis of sharing risks and rewards. These two definitions referred to two types of alliances and the former is a definition of project alliancing while the latter is strategic alliancing. Project alliancing features noted by different scholars are:

- Collective sharing of all project risks
- No fault, no blame, no dispute between the alliance participants
- Payment of non-owner participants for their services under a '3-limb' compensation model comprising:
    - Re-imbursement of projects costs on 100% open book basis
    - Fee to cover corporate overheads and normal profits and
    - Gain:pain share regime where rewards of outstanding performance and pain of poor performance are shared fairly among all alliance participants

- Unanimous principle based decision making on all key project issues
- Integrated project team on the basis of best person for each position.

A commercial framework of an alliance creates an incentive to achieve project objectives and a ‘best for project’ focus among participants. Unlike the partnering charter, the project alliancing agreement is legally enforceable. This section serves as an overview of the alliance concept while section 2.5 and 2.5.2 provide a detailed review of alliancing.

2.4.4 Integrated project delivery

IPD is a relatively new concept, which has been widely used in the USA. IPD is defined as an approach that integrates people, systems and practices and harnesses the talents and insights of all participants to reduce waste and optimise efficiency through all phases of a project (Eckblad et al., 2007). Similar to the other contract systems, there is no common definition for IPD. However, there are common themes. These themes are an integrated and high performing team, early involvement of participants, mutual benefit and advanced production management concepts (Eckblad et al., 2007; Singleton & Hamzeh, 2011; The American Institute of Architects National & The American Institute of Architects California Council, 2007). The IPD literature has identified four catalysts for successful IPD implementation namely multi-party agreement, BIM, lean construction and co-location of the team.

From the comparison of main themes of IPD, it can be noted that the IPD concept adopts certain practices from other relational contracts especially from alliancing and ECI. When the ECI concept is adopted, IPD improves the sense of ownership and belonging to the project, eases communication barriers and minimises litigation issues. A combination of a Lean operating system and multi-party agreement improves the effective collaboration in IPD (Ghassemi & Becerik-Gerber, 2011). Similar to alliancing, IPD is most likely suitable for highly complex, large and unique projects with time constraints (Kim & Dossick, 2011). However, there is no defined team selection or project governance structure referred to in the IPD literature. Table 2.3 presents the characteristics of four relational contracts and it is a result of a literature review conducted on those relational contracts. Table 2.3 will be discussed further in the following section.

Table 2.3: The characteristics of various relational contracting models

Source: (The American Institute of Architects National & The American Institute of Architects California Council, 2007; Victorian Government, 2006)

Attribute	Partnering	ECI	Alliancing	IPD
Risk	Defined dispute resolution	Not mentioned	No dispute clause	No dispute clause
	Individually managed and transferred to the greatest extent	Owner bears most of the risks in phase one and transfers risk in phase two	Share and jointly manage the project risks	Share and jointly manage the project risks
	Commercial and risk allocation framework is usually prepared by the owner	Risk/reward framework is developed during the project development phase jointly by all participants	Risk/reward system is developed during the project development phase by all participants	Risk/reward system is developed during the project development phase by all participants
Reward	No gain:pain share mechanism	Gain:pain share mechanism	Gain:pain share mechanism	Gain:pain share mechanism
	Reward for participants proportionate to the performance	Reward depends on the overall project success	Reward depends on the overall project success	Reward depends on the overall project success
	No win:win thinking	Win:win thinking	Win:win thinking	Win:win thinking
Agreements	Informal contract	Formal contract	Formal contract	Formal contract
	No contractual and legal force	Legally binding	Legally binding	Legally binding
Team selection & process	The partners in the partnership select by themselves	Participants are selected by the owner of the project	Participants are selected by the owner of the project	No consistent, formal process for selecting participants
	Price based selection in construction phase the single contract procedure	Rigorous and transparent selection criteria qualifications-based selection in early design phase	Rigorous and transparent selection criteria qualifications-based selection in early design phase	Qualifications-based selection in early design phase
	Single contract procedure	Well-defined team selection process with different stages	Well-defined team selection process with different stages	Single contract procedure
	No integrated team entity composed of key project stakeholders	No integrated team entity composed of key project stakeholders	An integrated team entity composed of key project stakeholders	An integrated team composed of key project stakeholders
	No joint governance structure, unanimity of decision making	No joint governance structure, unanimity of decision making	Joint governance structure, unanimity of decision making	No joint governance structure, unanimity of decision making
	No on-going structured financial audits with financial auditor	No on-going structured financial audits with financial auditor's involvement	On-going structured financial audits with financial auditor's involvement	No on-going structured financial audits with financial auditor
Communication	Open, direct and honest communication	Open, direct and honest communication	Open, direct and honest communication	Open, direct and honest communication
Technology	No cutting edge technologies	No cutting edge technologies	No cutting edge technologies	Cutting edge technologies (BIM)
Operational system	Total Quality Management	No operational framework	No operational framework	Lean management

2.4.5 Comparison of relational contracting models

Although different relational contracting models have originated in geographically separated areas, they have adopted practices from each other, and evolved over time. Differences between partnering contracts and alliance contracts are mentioned in various ways in the literature. It is difficult to find a clear demarcation between ECI contracts and alliance contracts as alliancing is an extension of ECI. The relationship between alliancing and IPD has been reviewed in a few trade magazines. These differences of relational contract models are displayed and summarised in Table 2.3. Key attributes which are the bases of Table 2.3 are summarised below.

Risk management

Alliancing and IPD involve an integrated team with no blame/no sue clauses respectively (The American Institute of Architects National & The American Institute of Architects California Council, 2007; Victorian Government, 2006) which are not mentioned in ECI and partnering contracts.

Moreover, in alliancing and IPD, all participants share and jointly manage project risks whereas in partnering risks are individually managed and transferred to the greatest possible extent to the other parties. However, during phase one of the ECI process, the owner bears most of the project risks since the contractors' responsibilities at this stage are limited to developing a competent design. Phase two is a risk transfer type contract which would lead to common adversarial behaviour in traditional contracts. Moreover, it can be noticed that the commercial and risk allocation framework is developed during the project development phase jointly by all participants under ECI, alliancing and IPD contracts (Mashiah, 2008; The American Institute of Architects National & The American Institute of Architects California Council, 2007; Victorian Government, 2006). However, in partnering, the owner usually prepares a commercial and risk allocation framework which leads to adversarial behaviour (Morwood, Scott, & Pitcher, 2008).

Sharing the risk in alliance and IPD ensures that the commercial terms of the contract are aligned with project objectives. This cannot be achieved in partnering where one party can win while another party loses. The "win-win" or “lose-lose” outcome is the fundamental characteristic of ECI, alliance and IPD contracts. This feature drives all the parties in the right direction.

Reward mechanism

The majority of partnering agreements are based on traditional contractual frameworks (Yeung, Chan, Chan, & Li, 2007). These traditional frameworks are based on a lump-sum contract with no gain:pain share mechanism (Chan et al., 2009). This no gain:pain share mechanism differentiates partnering from the other three relational models. In partnering, the reward for participants is proportionate to the performance, whereas in alliancing, ECI and IPD, the reward depends on the overall project outcome (The American Institute of Architects National & The American Institute of Architects California Council, 2007; Walker, Hampson, & Peters, 2002). Consequently, in partnering, partners try to obtain rewards at the expense of other partners (Alderman & Ivory, 2007). However, in alliancing, ECI and IPD, all the parties form a cohesive entity to share risks and rewards based on an agreed formula (O’Connor, 2009; Walker et al., 2002). This win:win thinking strengthens the relationship between participants.

Agreements

Partnering focuses more on the management structure rather than a legal scheme (Blayse & Manley, 2004). Mainly, the partnering charter signed by the parties is the main difference from traditional models but there is no legal binding of the obligations in the partnering charter (Quick, 2002). The primary disadvantage of partnering is that if major problems arise during the project execution, the formal contractual relationship overrides the relational contracts. This leads to adversarial relations. On the other hand, the other three models employ contractually established commercial drivers such as gain:pain share model which promotes the cooperation through contractual means (Mashiah, 2008; The American Institute of Architects National & The American Institute of Architects California Council, 2007; Victorian Government, 2006) . Therefore, partnering can be considered as a pure relationship management system rather than a procurement method or project delivery system. Conversely, project alliancing, ECI and IPD behave as a relationship management system as well as a delivery system.

Team selection and procedures

In project alliance and ECI, contract participants are selected by the owner of the project through rigorous and transparent selection criteria whereas the partners in a partnership are selected by themselves (Mashiah, 2008; Victorian Government, 2006). In IPD, guides and manuals do not mention standardised, formal processes for selecting participants. Unlike in partnering, participants of alliance, ECI and IPD are typically selected through a qualifications-based selection criterion during the early design phase. However, compared to alliancing and IPD, an integrated team entity of key project stakeholders is absent in ECI contracts. Alliancing and ECI contracts define a proper team selection process with different stages (Mashiah, 2008; Ross, 2003) whereas IPD and partnering follow a single contract procedure (Naoum, 2003; Thomsen, Darrington, Dunne, & Lichtig, 2009). The joint governance structure, unanimity of decision making and on-going structured financial audits features appear only in alliancing (Ross, 2003).

Communications and technology

All four relational models insist on open, direct and honest communication among all participants. A major deviation in IPD from the other relational models is the usage of cutting edge technologies. This is mainly due to the time period in which it was developed. The partnering concept first originated in 1980s in the USA (Nystrom, 2005) while ECI contracts were first introduced in the UK in 1990s for complex offshore oil and gas projects (Frazer, 2010). Australia adopted ECI in 1994 for the Wandoo project (Sakal, 2005) with few modifications to the UK model (Queensland Government Chief Procurement Office, 2008). IPD contracts were pioneered in the USA for Sutter Health in 2005 (Johnson, Sitzabee, & Feng, 2011). IPD was the only model developed when computer-aided design had become an industry standard. Consequently, BIM is a new add-on to the relational contracting and catalysts for project performance.

Operational system

Mitropoulos and Tatum's (2000) study recommends project participants adopt global integration mechanisms in contractual, organisational and operational domains to deliver a success project. Aforementioned all attributes deal with contractual and organisational practices. TQM and partnering are complementary processes and application of partnering in Japan was encouraged by the Japanese management revolution 'Kaizen' which focuses on TQM (Naoum, 2003). However, ECI and alliancing contracts are silent in this operational system while IPD has introduced the lean management principles to IPD projects.

In summary, the review of relational contracting models shows that all four relational models mainly stress organisational factors focusing on different operational and contractual factors. The alliancing concept upgrades partnering and ECI concepts to the next level in a structured way by using the contractual and commercial framework. While fundamental similarities exist between alliance and IPD concepts, IPD has been improved with new technologies. These improvements include: BIM, process management technique (lean technique) and early stage co-location.

The following section presents a review of the alliance literature and it follows the systematic literature review steps introduced by Tranfield, Denyer, and Smart (2003).

2.5 SYSTEMATIC LITERATURE REVIEW OF ALLIANCING

A full systematic literature review consists of scoping the study and extracting and synthesising data from the selected literature. Tranfield et al. (2003) have explained the three basic stages of a systematic literature review as:

Stage I: Planning the review
Stage 2: Conducting the review
Stage 3: Synthesis of the review

2.5.1 Systematic literature review methodology

Stage 1: Planning a review of alliancing literature

In stage one, appropriate keywords were defined, namely 'alliancing', 'project alliance', 'alliance' and 'construction industry'. The automated search is limited to publications of the last 12 years (2012-2000) in electronic scientific databases mainly Scopus and Google scholar. The rationale behind this is that alliance projects and studies have mostly emerged since 2000. The titles, keywords, and abstracts were scanned with the related keywords.

Stage 2: Conducting a review of alliancing literature

After defining the study focus in stage one, a systematic search in scientific databases and websites of relevant institutes was conducted. Papers found during the automated search were further studied to check for relevance. Over 130 items were left for further reviewing. A manual search was also conducted in parallel to the review. This search included seminal references that have been referenced frequently in an initial article pool. An assessment of the abstracts of the papers was conducted to find irrelevant and duplicate papers. There were 84 items related to alliancing in construction. The list of reviewed publications can be found in Appendix B.

The next step is to assess the quality of the literature. The quality of the literature can be assessed through a citation/co-citation analysis method or data envelopment analysis based on the study nature and the research strategy type. This study does not use a citation/co-citation analysis method due to the lack of academic literature on alliancing. The percentage of each research strategy used in alliance publications is shown in Figure 2.3.

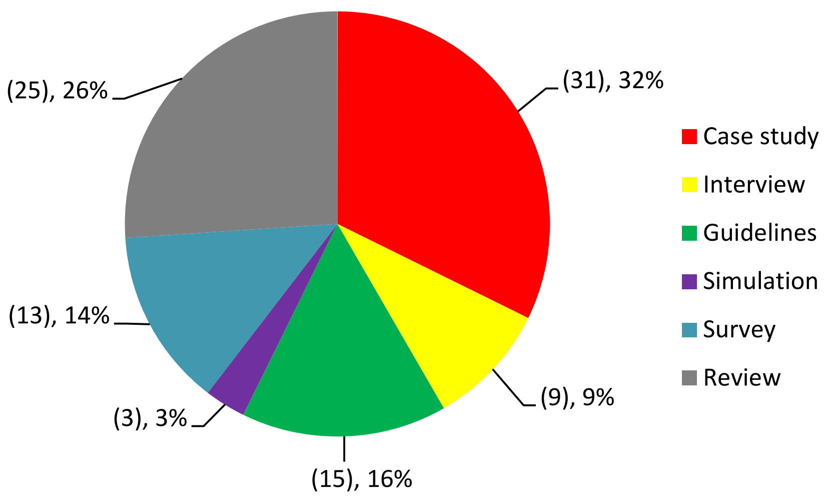


Figure 2.3: Types of publications from the systematic review

Note: Number of relevant papers recorded within brackets

It was found a case study is the most frequent form of alliance publications (32%) as it is easier for researchers to draw some implications from real cases rather than other research methods. The Australian National Museum project and the British North Sea oil and gas project have been the most frequently cited case studies. Expert guidelines of alliances (16%) have consistently recorded alliance fundamentals. There were 41 papers of non-empirical research. These non-empirical studies have mainly discussed the alliancing principles or the development of conceptual models to improve the existing practices. Regardless of the level of interest shown in alliancing, real empirical research is rather thin on the ground and highly reliant on anecdotal data.

The majority of the academic reviews (26%) have focused on providing practitioner related insights on future research. Qualitative research (54%), typically of a single case study (33%), is the dominant methodology among the current alliance academic studies. A few quantitative studies (12%) have been performed on alliances, where simulations and surveys have been used as the methodology. Overall, there have been few studies with multiple methodologies. This indicates the low maturity level of the field suggesting the need for multiple methodologies in alliance research.

The selected articles can be further classified by the country of origin (Figure 2.4). Australia has been leading in alliance related articles (53%), followed by the UK (15%) and USA (6%). The number of NZ based alliance publications (2) is the lowest. In order to investigate the popularity of the topic, the variation of recent alliance studies was plotted.

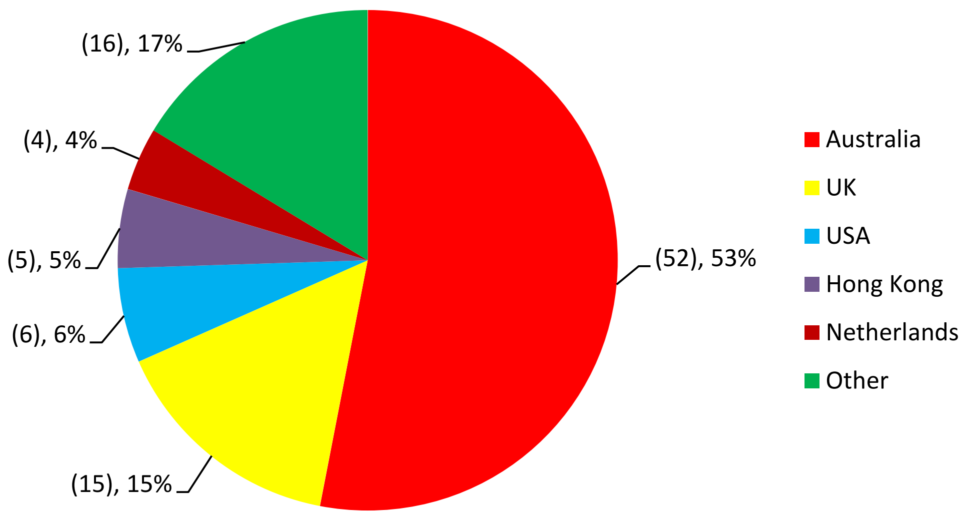


Figure 2.4: The country of origin of publications from the systematic review

Note: Number of relevant papers recorded within brackets

As shown in Figure 2.5, research interest in alliances has been growing at a steady rate over the last decade.

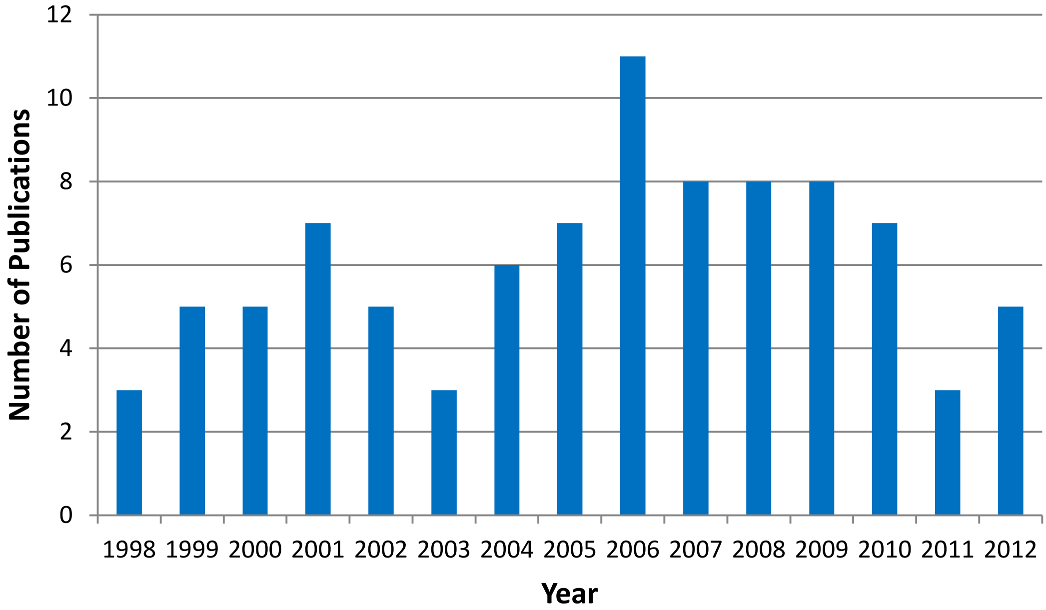


Figure 2.5: Number of relevant papers published from 1998 to 2012

In summary, the alliance research stream is a developing area. The case study based studies have been dominating (32%) in the field of alliancing. These articles indicated some best practices from real cases. More than half of the reviewed studies (68%) were conducted in Australia (53%) and the UK (15%). This indicates that even though alliancing originated in UK it is now growing in Australia. The alliancing research stream has a limited set of variables, models and methodologies to explain the phenomenon due to only a small number of academic investigations and little theory testing in publications.

The next section provides the synthesis of the review of past alliancing studies.

Stage 3: Synthesis of review

Kumaraswamy and Abeysekera (2008) have pointed out that recent developments in project delivery systems lead to confusions of overlapping terminology. Therefore, it is important to understand the key principles and features of alliancing to distinguish alliancing from other relational contracting methods. Two types of publications were used to achieve this. The first category covers alliancing guidelines (e.g.:(Department of Infrastructure and Transport 2006; Department of Infrastructure and Transport, 2011; Ross & PCI Alliance services, 2009; Victorian Government, 2006)). The second category of publications deals with the early case studies in alliancing such as North Sea offshore project in the UK (Halman & Braks, 1999), the Wandoo Oil Alliance in Australia (Campbell & Minns, 1996), the National Museum project in Australia (Hauck et al., 2004; Walker et al., 2002) and a water treatment project in Australia (Jefferies, Brewer, Rowlinson, Cheung, & Satchell, 2006). These two types of publications on alliancing primarily explain alliance definition, features and principles, benefits of alliancing and establishment stages of alliancing. The following sections provide an overview of the alliancing concept based on these themes. It covers an overview of the project alliancing concept as well as the benefits and limitations identified in past alliance studies.

2.5.2 Overview of the project alliancing concept

Alliances are relational arrangements where project participants jointly work together to deliver the project. They are characterised by risk sharing and a no-disputes/no-blame regime. This suggests that since alliances are typically used for high risk projects with high levels of uncertainty.

Alliance contract defined

Alliancing is an inter-organisational collaboration which evolves into a unique project delivery form as it satisfies the basic components of project delivery systems defined by Azari, Ballard, Cho and Kim (2011). There are numerous definitions for alliancing based on different perspectives as stated below.

- Alliancing is defined from a relationship perspective

'a project delivery method where project participants join together and align participants' objectives and proactively manage risk to achieve outstanding project performance' (Yeung, Chan, & Chan, 2007).

- Alliancing is defined from a process perspective

'*a cooperative arrangement between two or more organisations that forms part of their overall strategy, and contributions to achieving their major goals and objectives for a particular project' (Kwok & Hampson, 1996).*

- Alliancing is defined from an advantage perspective

'an agreement between parties to work cooperatively to achieve agreed outcomes on the basis of sharing risks and rewards' (Clifton & Duffield, 2006)

These definitions put forward participants' integration as a key requirement of an alliance. The most common and descriptive definition for an alliance which is adopted for this study is stated below.

> '*An agreement between two or more entities, which undertake to work cooperatively, on the basis of a sharing of project risk and reward, for achieving agreed outcomes based on principles of good faith and an open-book approach towards costs' (Queensland Government Chief Procurement Office, 2008)*

Alliances are categorised into four main forms based on the duration of an alliance agreement and they are strategic, project, programme and service alliances (Department of Infrastructure and Transport, 2011). Strategic alliances are established to undertake projects of a similar nature over an extended period whereas project alliances are established as a project delivery method to share risks and outcomes of a project (Rowlinson, Cheung, Simons, & Rafferty, 2006). Program alliances incorporate multiple projects under an alliance usually under a long term arrangement. Service alliances are developed to ensure to sustain the performance of operations and maintenance contracts.

An analysis of past infrastructure alliances in NZ has shown that nine out of the past 12 road construction alliance projects have been operated under a project alliance arrangement (Alliancing Association of Australasia, 2011b). It should be noted that other types of alliances are rarely used in NZ since the industry is dominated by one-off projects.

Alliance features and principles

The success of an alliance depends on the alliance principles and relevant features. Table 2.4 shows an analysis of the alliancing literature highlighting vital principles and features of alliancing based on authors' view and frequency of citations by authors. Nevertheless, there have been certain debates of alliancing principles. Some authors have suggested that relationship aspects tend to be more important for project success and the contribution of an incentive system on relational development is very small (Bresnen & Marshall, 2000b). Some studies have noted that success of relational contracts is highly dependent on an incentive system (Rahman & Kumaraswamy, 2008); hence incentive systems facilitate the development of trust by information sharing and perceptions of relative equity (Eriksson & Westerberg, 2011). Since alliancing differs completely from partnering in respect to the incentive mechanism, the gain:pain share mechanism is included as a guiding principle in alliancing.

Some researchers, for example (Yeung, Chan, & Chan, 2007), have identified trust as a key element of an alliance. Conversely, Ross (2003) viewed the trust in the competencies of project participants as a fundamental pre-requisite of alliancing but in terms of behaviour, trust in performance is an outcome rather than a prerequisite of alliancing. Therefore, trust is not included as a core value or principle in Table 2.4.

Table 2.4: Core values, guiding principles and features of alliancing

Core value	Principle	Feature
Integration	Project proposal development	Develop the project proposal collectively with the owner's involvement
		Develop the project objectives and commercial arrangements at the initial stage of the project
		Deliver the project by one integrated team
Commitment	Gain:pain share mechanism	Align the project objectives with project participants' objectives
		Share risks and rewards between all participants
		Create win–win or lose–lose situation to all participants
		Commit to teamwork in achieving the objectives
		Act fairly instead of in self-interest
Respect	Governance and management	Make project decisions collectively and unanimously
		Share information and knowledge
		Create a peer relationship where all parties have an equal say
Innovation	Team selection and incentive mechanism	The selection criteria used for selecting the project participants should encourage innovation and efficiency
		Encourage innovation through incentive mechanism
Fairness	Team selection	Focus on project participants' competence, reputation and attitude
		Select personnel on a 'best for project' basis
Transparency	Communication and accounting	Maintain 'open book' in terms of cost
		Encourage open and honest communication among all project participants
Flexibility	Dispute resolution	Commit to 'no fault-no blame' culture
		Resolve conflicts and disputes internally

Alliance formation

An alliance is a powerful risk mitigating process, but it incurs high initial set up costs and monitoring costs. As a result, scholars do not recommend alliancing for small projects where the tender selection costs are out of proportion compared to the cost of the work and for simple projects with little room for

improving outcomes. Ross (2003) noted that alliancing is more appropriate for projects with very tight and uncertain timeframes, difficult stakeholder issues, complex external threats and changing scope. Thus, project alliancing is appropriate for projects which require innovation to achieve project objectives.
There are three main phases in forming an alliance. They are selecting project participants, interim and full alliance phase. Figure 2.6 provides an overview of the formation phases of an alliance. In this example, two proponents are shortlisted based on the companies' past record, experience of project team and response to draft commercial arrangements. An alliance development agreement is executed with each of the shortlisted proponents.

Once the primary parameters are agreed, the participants enter into an interim project alliance agreement. The shortlisted proponents will develop a final project proposal which includes the team, target operating cost and commercial arrangements. The owner uses this interactive development process to assess the proponents' performance against the non-price selection criteria. Once the target operating cost and other targets have been agreed, the participants enter into the full project alliance agreement forming the alliance. The alliance formation model covers only the integration process of main alliance participants and there is no reference to the sub-contractor selection process.

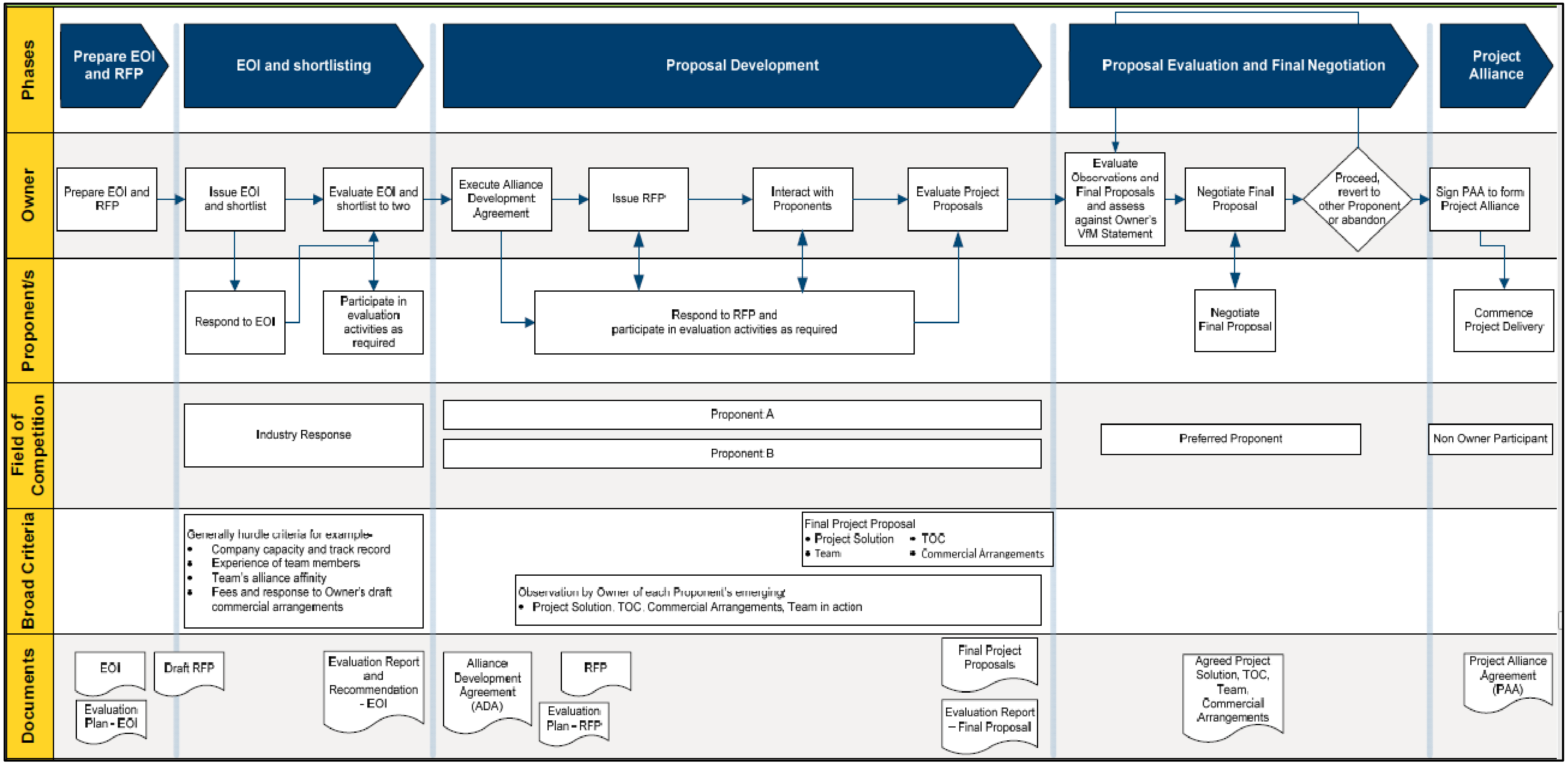


Figure 2.6: Alliance participant selection and formation process

Source:(Department of Infrastructure and Transport, 2011)

2.5.3 Alliancing benefits

There is still a growing Interest in the area of alliancing because of potential benefits created for collaborative parties. These benefits are derived through alliancing principles and features.

A positive relationship

Manley and Hampson (2002) have considered an early selection of parties based on non-price factors as one of the key features of alliancing. Forming the project team earlier provides an understanding of the owner’s needs (Song, Mohamed, & AbouRizk, 2009) more informed decision making (Victorian Government, 2006) and strengthening of the peer relationship (Ross & PCI Alliance services, 2009). A positive relationship allows knowledge to be shared among the participants (Kwok & Hampson, 1996). The integrated team grants fast project progress and releases project benefits sooner to the end users (Ross, 2003). A positive relationship among the project team guarantees clear project goals at the project onset and this will not be forgotten as the project progresses.

Tied into a shared vision

The gain:pain share regime allows the alliance project team to align goals to drive the project performance specifically in non-cost areas (Henneveld, 2006). The alliance shares and manages all the risk successfully through an incentive system that provides the right incentive to drive the right behaviour. This encourages all alliance participants to continuously improve the project performance (Walker, Hampson, & Ashton, 2008). Thus, participants give more preference to alliance projects especially when they have to decide the staff allocation among different projects.

Improved communication

Communication and information sharing are critical to the success of alliances (Rezgui, 2007). Successful formation of team spirit and prominence of the project goals will assure open, honest and effective communication among project participants. Co-location is a concept that can be used to improve the high degree of collaboration and effective communication (Ross & PCI Alliance services, 2009).

Better performance

Ross (2008) noted that some practitioners are still arguing whether the alliances actually deliver value for money as there is no price competition in the selection process. Lin (2005) confirmed that compared to traditional contracts, the alliance model delivers value for money for large and complex projects.

According to past studies, a collaborative approach like alliancing can provide real benefits to project participants in terms of project outcomes (Bresnen & Marshall, 2000a), added value in cost, time, safety, relationship and innovations (Hauck et al., 2004). In addition, high performance work systems lead to improved work life balance of the employees (Lingard et al., 2007). The performance of past alliance projects is shown in Table 2.5. In general, most of the projects are on or under time and budget. This is mainly due to the inherent features of the alliance model.

Table 2.5: Comparative analysis of target costs and target duration

Source: (Blismas & Harley, 2008; Mills & Harley, 2010)

Year	Parameter	N	Under planned			Over planned		
			N	Average	Range	N	Average	Range
2008	Target cost	30	25	8.3%	1-29%	5	1.7%	3-5%
2008	Duration*	30	11	4.7 months	½-18months	6	2.5 months	½-6 months
2010	Target cost	18	7	5%	2-11%	11	19.2%	1-128%
2010	Duration**	18	6	2.2%	1-6%	5	1.2%	3-14%

Note: * 13 projects are delivered on schedule and ** 7 projects are delivered on schedule
N - number of projects

Flexibility

During the alliance project, the internal and external conditions could change due to the project complexity (Ngowi, 2007). Thus, alliance success depends on how project participants adopt to those changes. Flexibility is a basic requirement for moving to high performance. It is found that alliances are more flexible than other contracts due to the solid legal and commercial framework (Clifton & Duffield, 2006). An alliance agreement outlines key decision making processes, payment procedures and ways to address the issues of variation. Therefore, conflicts can be settled more amicably and quickly. This will result in fewer adversarial disputes among participants.

Industry sustainability

Project success is a result of effective team working. The development and sharing of knowledge within the project team lead to benefits for all project participants. Successful projects advance the reputation and relation of project partners, which can also be an advantage for future projects (Ross & PCI Alliance services, 2009). The present project learning would be useful for future projects and even the prequalification assessment process of project participants could be accelerated due to long-term relationship building with confidence. The learning during an alliance project is also beneficial to the project team members as it leads to enhanced contribution to their own organisation and the construction industry (Ingirige & Sexton, 2006).

Sub-contractors are involved in a large proportion of work within alliance projects. Consequently, alliance initiatives like training and development, knowledge sharing and experience in complex projects will strengthen the sub-contractors' expertise.

Improved innovation

An incentive mechanism and the early collaboration in an alliance model result in new or improved designs (Yeung, Chan, & Chan, 2007) which will provide improved project outcomes. This will generate innovation led performance improvements in the sector. The number of innovations introduced by individual organisations will also be a long-term measure of alliance effectiveness.

To study the long-term sustainability of the alliancing concept, it is necessary to identify the factors that would provide advantages as well as potential disadvantages. The following section summarises the improvement opportunities in alliancing.

2.5.4 Scope for improvements in alliance projects

Bleeke and Ernst's study, conducted in 1990, as cited in Khanna, Gulati, and Nohria (1998), shows that at least one partner of half of 59 alliances in non-construction sectors, has felt the alliance to be a failure. The Mills and Harley (2010) study shows that only half of the participants representing 18 construction alliance projects noted that construction alliances are meeting the project value statement and deliver value. In Australia, alliancing is accepted for public sector projects; nevertheless only nine out of approximately 50 projects have been successful (Ross, 2003).

Despite the proven benefits of alliances, there is a tendency to reduce the number of alliance projects (Ross, 2007) and increase usage of alternative procurement methods such as public private partnerships (PPP) (Department of Treasury and Finance, 2009a). Therefore, an exploration is necessary to find out improvement opportunities in alliances. The following points demonstrate improvement opportunities in alliance.

Commitment to alliance principles

Since alliances target joint innovation in uncertain projects, there is a relatively higher chance of failure (De Man & Roijakkers, 2009). Recent project evidence suggests that projects could fail due to lack of commitment to the underlying alliance principles (Ross, 2007). Alliance project participants are liable for the behaviour and performance of the non-alliance project participants (Victorian Government, 2006). Basically, the key to successful alliancing mostly depends on the quality of the individuals, the commercial drivers and the spirit within the alliance (Abrahams & Cullen, 1998). Therefore, both corporates and individuals need to agree on core alliance principles at the onset of the project and continue to act in line with those principles.

Game breaking level of performance

Additionally, many researchers (e.g.: (Morwood et al., 2008) and (Ross, 2003)) have argued that initial time, cost and resource requirements for establishing an alliance are higher than those of other forms of contracts. Walker and Hampson (2008a) have identified financial, technological, management and strategic motives in collaborative projects in the UK and Australia. The study shows outstanding results in technical, managerial and strategic areas but little evidence of financial success.

These findings have been proven by the survey conducted by Blismas and Harley (2008) and Mills and Harley (2010) (Table 2.5). The analysis in Table 2.5 indicates that the best-performing alliances in the 2008 survey have recorded an average actual operating cost of 8.3% less than the target operating cost while the average completion time is 4.7 months less than the agreed time. The 2010 survey shows that the best-performing alliances have recorded an average actual operating cost of 5% less than the target operating cost while the average completion time is 2.2% less than the agreed time. Blismas and Harley (2008) have found scope changes in projects and favourable variances in time and cost due to innovations realised during the project as main reasons for unfavourable variances in time and cost overruns. Thus, game breaking levels of performance have not been fully detected under the current system of work specifically in terms of time and cost.

A study conducted by Wood and Duffield (2009) has analysed 14 past alliance projects based on owners and non-owner perspectives in different performance areas. The study shows that a small number of projects were achieving game breaking levels of performance in terms of time, cost, and quality as well as achieving key result areas (KRA). Although high performance teams are allocated to projects, there still seems to be a long way to go in achieving a game breaking level of performance.

Absence of price competition

According to Ross (2007), some practitioners have argued that value for money cannot be assured in the absence of price competition and it makes it harder to confirm the financial viability to the project owner. This weakness can be overcome by implementing a price competitive approach. This approach leads to resource waste as only one set of participants will carry out the project after the dropping out of the other parties. Greater innovation could be achieved but the appropriate compensation for the intellectual property of the losing team must be granted. In addition, absence of price competition potentially creates an artificially inflated target cost and time (Green, 2002). Incorrectly weighted incentive terms may entice participants to compromise the performance of certain KRA to increase the gain. Such fraudulent alliances could result in alliance failures.

Alliance compensation structure

There can be a credibility problem and conflict situations with subjective evaluations of non-cost KRAs in an alliance compensation structure. Consequently, the participants will try to place high quotations for target cost and time to compensate payments under limb 3 (Appendix A). All the alliance participants are encouraged to continuously improve the project performance.

External auditors' services are used to overcome these disadvantages and finally this will add more administrative cost to the alliance. Also, the sharing of pain:gain under limb 3 promises that each non owner participant shares equitably in the pain associated with wasted effort and rework (Ross, 2003).

Thus, the compensation model will allocate unwanted risk to the participants due to collective ownership of risks in the pain:gain share. Still, the cooperation model and shared risk limit the possibility of seeking compensation for others' mistakes. Therefore, to reduce rework and mistakes in an alliance framework, the participants are required to build up relationships based on trust and to share their mistakes as learning opportunities for the project.

'No blame/no dispute' principle

The 'no blame/no dispute' principle raises legal and practical issues such that the rights of third parties cannot be restricted from obtaining insurance since participants are not liable for any loss and no blame regimes will be construed as legally ineffective (Department of Treasury and Finance, 2009b). Alliances have a track record of being difficult to manage but none of them have so far resulted in legal proceedings during construction or in the post delivery period (Mills & Harley, 2010). An alliance enables tailored insurance policies that meet project specific requirements (Henneveld, 2006). These approaches remain complex and it is uncertain how they would operate under an alliance agreement with no expressed risk allocation terms (Department of Treasury and Finance, 2009b).

Complex and high prominence of incentive system

Alliance contracts aim to align the project participants' objectives with the project objectives. This is mainly done through risk:reward compensation models and KRA definitions. A problem could arise when the incentive system gets more complex in measuring and monitoring KRAs. Therefore, appropriate prioritisation of KRAs and management of their mutual interaction are required. Alliance projects have revealed that there is too much emphasis placed on gain:pain share regimes and other contractual provisions at the expense of building and maintaining a high performance team. However, the success of alliances largely depends on the people factor. As the project failures influence the project participants' reputation, there is a high risk of adopting alliance as a project delivery model.

Top management support

Compared to traditional contracts, project alliances typically require significantly more involvement of senior representatives (Victorian Government, 2006). Moreover, contract preparation, particularly tender preparation and comparison, requires more work from the owner than usual traditional contracts. Furthermore, project monitoring and performance measurement may increase the workload for the alliance management team. These resources can be difficult to source and limited in construction.

A study conducted by Wittmann, Hunt, and Arnett (2009) has verified that there is a positive correlation between top management support and alliance competence. This could be a challenge due to the daily workload and power imbalance among alliance partners particularly in the decision-making process. These issues can be minimised by a proper alliance governance and member selection system. However, an invisible alliance leadership team (ALT) and large alliance management teams are the main factors that limit alliance performance.

Appropriate cultural shift

A critical factor for an alliance success is an effective and efficient collaborative working model which requires significant cultural shift (Xue, Shen, & Ren, 2010). Yet, the old culture and traditional construction practices persist in the industry (Ibrahim, Roy, Ahmed, & Imtiaz, 2010). It is difficult to obtain such a cultural change within a short period of time. The success of the alliance model greatly depends on personal relations and trust between the project participants. Reed and Loosemore (2012) have identified that the alliance approach can result in a cultural shock for project members who are transitioning from non-alliance projects. So, alliance management needs to be equipped to manage and steer the individuals in the direction of appropriate behaviour to obtain better project performance.

Participant resistance and partial collaboration

The joint organisation and decision making process force the project members to give up part of their authority of the project (Green, 2002). Therefore, project members may feel like their power is lost in alliance projects and this could be a reason for resistance to alliances. Particularly, architects and construction managers may feel the same way (Walker et al., 2002).

Project alliancing involves the collaboration of owners and non-owner participants (designer, contractors, and suppliers) to deliver projects, with all participants sharing the responsibility of project risks to achieve project objectives. In reality, this can fail to create a true alliance environment since only part of the value chain (owner, designer, and main contractor) is considered for collaboration. Literature about alliances shows that most projects focus on owner–designer-main contractor alliances while a few projects extend alliance practices to critical sub-contractors. Consequently, sub-contractors are not within the alliance and alliance members may not be interested in improvements in sub-contractors' processes. However, it is unlikely that collaborative working methods from alliance participants will produce promised gains until sub-contractors are fully integrated into the process (Hughes, Hillebrandt, & Greenwood, 2006).

Francis and Hoban (2002) have revealed that a lack of alliance experience, complexity of legal arrangements and high cost of implementation are the main reasons for non-inclusion of sub-contractors in alliances. A study conducted by Stringer (2007) has identified that high risk and complex projects with new technology need to adopt a bottom-up approach. Worker participation positively affects innovation and continuous improvements. However, employee participation practices in alliance projects have not yet surfaced in the literature and these practices are not explained in any alliance manual or guidelines.

Focus on operational level and process management techniques

Many of the aforementioned performance problems can be traced to cultural differences that exist at organisational level (Soetanto, Proverbs, & Holt, 2001) and debates in contractual terms (e.g.: complex KRA system, joint warranty obligation, no dispute clause). Buffet (2010) has noted that even though there are many contractual and organisational guidelines in alliancing, there is little attention paid to achieving innovation and efficiency throughout projects.

A review conducted by Chen, Zhang, Xie, and Jin (2012) on past alliance studies identified that little research has analysed how alliancing and existing support management tools and practices could be combined together. The project success depends not only on the project delivery method adopted but also depends on how activities and resources of the project participants are managed and what strategies are used to organise project activities.

Mitropoulos and Tatum (2000) have recommended project participants adopt integration mechanisms in contractual, organisational and operational domains to achieve high project performance. In order to generate optimal results, the project should be considered in all three domains, while maintaining the alignment and balance between them (Alarcon et al., 2011). Although extensive research has been carried out on alliancing in organisational and contractual aspects, there has been relatively little research on operational aspects.

The analysis of 93 alliancing articles shows that only 11 articles dealt with operational improvement practices. Most of the operational improvement research in alliancing has discussed information systems (e.g.: (Baldwin, Thorpe, & Carter, 1999; Hampson, Peters, Walker, & Tucker, 2000)); design development (e.g.: (Miles,1998)), quality management systems (e.g:(Love, Irani, & Edwards, 2004; Walker & Keniger, 2002)) and employee work-life balance ((e.g.: (Lingard et al., 2007)). In contrast, there has been relatively little research in emerging methods of process management techniques such as lean construction.

From the analysis conducted in section 2.4.5, it can be seen that the focus of an alliance is on commercial and organisational domains through collaboration. However, these two domains mainly affect the way people work together. This means the third aspect of a project delivery system, the operational system, plays a vital role. In connection with growing interest in integrated approaches such as blending collaborative project delivery systems with process management techniques, this study is intended to improve alliance project performance through a suitable process management technique. Therefore, this study focused on exploring how operation systems, specifically lean thinking, can be utilised to improve alliance project performance. The reason for the selection of Lean as a process management technique is explained in section 3.3. The next chapter will cover a Lean related literature review which was used as a potential concept to improve alliance performance.

2.6 CHAPTER SUMMARY

The literature review identified that significant changes are happening in the construction industry particularly in procurement methods. A shift towards more relational contracting is found in the sector and alliance contracts embrace the principles of relationship contracting. An analysis of alliancing literature identified improvement opportunities in alliance projects. With this respect the main observations of alliancing practices are:

- partial collaboration in alliancing (absence of sub-contractor and worker participation)
- focus on organisational and contractual systems but little concern for the operational system
- no defined process management technique

From the literature review, it was identified that a limited number of research studies have been conducted to identify improvement opportunities in operational aspects in alliancing. Consequently, this research was carried out to explore how process management techniques, in particular lean thinking, can be utilised at operational level in alliance projects to improve the alliance project performance. The following chapter deals with the lean construction literature.

3 THEORETICAL CONTEXT – LEAN PHILOSOPHY

3.1 INTRODUCTION

This chapter presents an overview of previous research work on lean construction to provide the necessary background for this research. This section covers a brief discussion of lean philosophy, lean principles and their applicability in alliance projects. This section also presents a theoretical framework as an aid for empirical data collection and analysis during process studies. In particular, the theoretical framework focuses on eight types of waste namely motion, waiting, defects, transport, overproduction, inventory, unnecessary processing and behavioural waste. The alliance literature review in chapter two identified that there is a lack of integration of sub-contractors and site workers into alliance practices. Due to this lack of integration of bottom layers in alliance projects, there could be behavioural waste in alliancing. As a result, a further literature review was conducted to recognise the sub-contractor and site worker positions in alliance projects.

This chapter is divided into ten sections. Following this introductory section, the second section (3.2) explains the necessity of a process improvement approach for alliance projects. The next section (3.3) explores suitable process improvements of an alliance contract by comparing available approaches. Section 3.4 provides a brief review of lean philosophy while the next section (3.5) explains the relationship between Lean and procurement types. After identifying relational contracts as a suitable contract type for Lean, the next section (3.6) looks at the leanness in alliance frameworks. The following section (3.7) lays the foundation for the process study framework. The sub-contractor and worker integration aspects as the eighth type of waste in an alliance are scrutinised in the next two sections (3.8 and 3.9). The summary of theoretical findings and identified knowledge gaps are discussed in the last section (3.10).

3.2 INTEGRATING PROCESS MANAGEMENT SYSTEMS INTO ALLIANCES

Productivity improvement studies in construction have had a surge of interest over the last two decades since productivity improvements have been equally crucial from a micro and macro perspective. Due to an urgent requirement for improvement of the current performance in construction, various alternative procurement models have been developed. Over the past 20 years, research responses have primarily focused on front end construction activities (Fearne & Fowler, 2006). So, innovations have brought major changes to the project organisation and commercial domains through relational contracts.

Mitropoulos and Tatum (2000) studied the problems in construction and suggested integrating three domains of project delivery namely the project organisation, operating and commercial domains in a balanced manner. Based on the critical review of relational contract types (section 2.4.5), it is clear that all the contract methods give priority to blending only two domains. For example the partnering concept shows less focus on contractual factors but pays more attention to organisational factors and operational systems like TQM. ECI and alliancing emphasise early involvement and contractual terms to blend organisational and contractual terms. IPD more often refers to organisational and operational factors and has less focus on the contractual domain. There has been comparatively little empirical research focus on the blend of all three domains in a balanced manner.

Despite the potential benefits attributed to alliances, the true performance enhancements have not been fully realised in existing alliances. It is noticed that the main focus of an alliance framework is on contractual and organisational domains but there is less focus on the operational domain. In that situation, the operational system as the third aspect of a project delivery system plays a vital role. Although extensive research has been carried out on alliancing in recent years, there has been comparatively little research to investigate the integration of operational systems into alliances.

With the development of a tripartite view of production (transformation-flow-value view) by Koskela (2000), the construction industry has been inspired by this new operational approach. Different process management approaches have been introduced to the industry and they have gained rising popularity in many construction companies (Koskela, 2000). Certain types of relational contracts namely partnering with TQM, and IPD with Lean often refer to these advanced production philosophies. It is noted in Table 2.3 that project alliancing does not refer to any operational management system and it leaves the project team to find the best way to attain the project objectives. Accordingly, the applications of individual methods in an ad-hoc and fragmented manner have gained partial success. Therefore, complete integration of such operational systems would create a framework in alliances for improving performance.

3.3 LEAN AS A PROCESS MANAGEMENT APPROACH IN AN ALLIANCE

This section discusses various process management approaches with an outline of their features in order to select a suitable approach for alliances. A comparison of different methodologies has been demonstrated by different researchers (e.g.: (Andersson, Eriksson, & Torstensson, 2006; Josephson & Saukkoriipi, 2007; Mullin & Wilson, 1998; Nave, 2002)). A comparative summary of those methodologies is presented in Table 3.1. The approaches, namely Lean, TQM, Six Sigma, TOC, Agile, TPM and BPR have been used for the analysis. These approaches differ from each other in terms of:

- The focus (e.g. waste, quality, process variation and responsiveness)
- The scale of deployment (e.g. strategic, tactical and operational)
- The scope of operation coverage (e.g. plant, division and supplier) and
- The expected change (e.g. small-step, incremental or radical change)

Despite the differences that separate them, they share common roots focusing on operations and on process improvements. A comparison shows that the lean system fully focuses on the entire value streams from the factory floor to the networked enterprise. The other approaches concentrate primarily on improvements at the business unit and factory floor levels but place relatively little emphasis on improvements at the networked enterprise level. Lean and TPM offer guidance for continuous improvement efforts and planned change initiatives at multiple levels. In contrast, TQM and Six Sigma make no distinction between continuous improvement and systemic planned enterprise change. Thus, the implementation of TQM and Six Sigma concerns top-down driven improvement rather than planned multilevel systemic change.

Lean, TQM, TPM and Six Sigma methodologies are tightly interconnected approaches and can be brought together as an integrated system. For that, the lean system is serving as a framework and the other approaches can be incorporated into the integrated system to enhance its overall effectiveness. Hines, Holweg, and Rich (2004) noted that the other process improvement methodologies can easily be integrated into Lean without contradicting the strategic objective of Lean.

In summary, it shows that Lean adopts a holistic view of the networked enterprise with an end-to-end enterprise value stream, encompasses all enterprise levels (e.g.: strategic, tactical and operational) and defines practices that enable creation of value for multiple enterprise stakeholders. Since these enterprise view and alliance principles are complementary to each other a lean implementation would reduce interferences in alliance contracts. In recent years, applications of Lean in construction are becoming popular (Simonsson & Emborg, 2009) especially in developed countries (Figure 3.1). This is because the Lean is a well-established concept and also provides a positive experience for employees in the organisation (Salem et al., 2005).

There is growing focus on applying lean principles to deliver goals in different project contexts. Concerns of past studies are with different construction contexts such as construction operations (e.g. carpentry work, bricklaying and concreting), construction activities (e.g. new build, maintenance and refurbishment), construction projects types (e.g. residential, commercial and heavy) and construction procurement methods (e.g. traditional and design and build). Past studies have focused on the full construction project range. Yet there are numerous types of procured projects where the use of Lean has insufficiently been explored, such as alliance type projects (section 2.4.5). Bryde and Schulmeister (2012) reviewed the literature on Lean application in different types of construction projects and pointed out that further empirical study of lean construction in different contexts is still valid. Therefore, this research aimed to explore how lean thinking can be utilised in alliance projects to improve the project performance.

Although the concept of lean construction is well defined, the subject has hardly been documented for relational contracts especially for alliance type projects. Similarly, case study reviews of Lean in relational contracts are few since relational contracts and lean construction are relatively new.

Table 3.1: **Review of process management techniques**

Sources : (Andersson et al., 2006; Mullin & Wilson, 1998; Nave, 2002; Stamm, Neitzert, & Singh, 2009), complied by author

Program		Lean	TQM	TPM	Six Sigma	TOC	Agile	BPR
First mentioned		1988	1960 / 1980	1970	Late 1980	Mid 1980s (1984)	Early 1990	Early 1990
Origin		Toyoda, Ohno and Shingo	Shewart, Juran, Deming, and Crosby	Nippondenso	Smith of Motorola and General Electrics	Goldratt	Goldman, Nagel, Preiss and Dove	Michael Hammer
Principles		Identify value	Customer focus	Detection	Define	Identify constraint	No consistent theory	Position for change
		Identify value stream	Cooperation	Restoration	Measure	Exploit constraint		Diagnose the existing process
		Flow	Leadership	Prevention	Analyse	Subordinate processes		Redesigning the process
		Pull	Data based decision		Improve	Elevate constraint		Transition to new design
		Perfection	People development		Control	Repeat cycle		
Focus		Flow focused	Focus on customers	Equipment losses	Problem focused	System constraints	Flexible production	Inefficient processes
Mode of change		Continuous incremental change	Continuous incremental change	Continuous incremental change with realignment	Continuous incremental change	Continuous incremental change	Continuous incremental change	Process specific radical change
Focus level	**Strategic**	Full	Very little	Full	Partial	Very little	Moderate	Very little
	Tactical	Full	Moderate	Full	Moderate	Partial	Full	Partial
	Operational	Full	Full	Full	Full	Full	Full	Full
Enterprise scope	**Networked enterprise**	Full	Partial	Partial	Partial	Very little	Moderate	Very little
	Core enter-prise	Full	Partial	Moderate	Moderate	Partial	Full	Partial
	Business unit	Full	Moderate	Full	Full	Moderate	Full	Full
	Factory floor	Full	Full	Full	Full	Full	Full	Full
Primary effect		Reduced flow time	Increased customer satisfaction	Improved OEE	Uniform process output	Fast throughput	Produced fast paced tailored products	Radical change of process
Secondary effects		Less variation Improved quality	Achieved customer loyalty, improved performance	Increased employee morale and job satisfaction	Less waste, less inventory, improved quality	Less waste, Improved quality	Met customer needs, established virtual organisations,	Revised processes, sought infiltrate process solutions
Criticisms		Statistical or system analysis not valued	No tangible improvements, Resource-demanding	Environment and plant specific issues are excluded	System interaction not considered, processes improved separately	Minimal worker input, Data analysis not valued	Lack of consistent set of principles	Lack of conceptual means to manage complexity

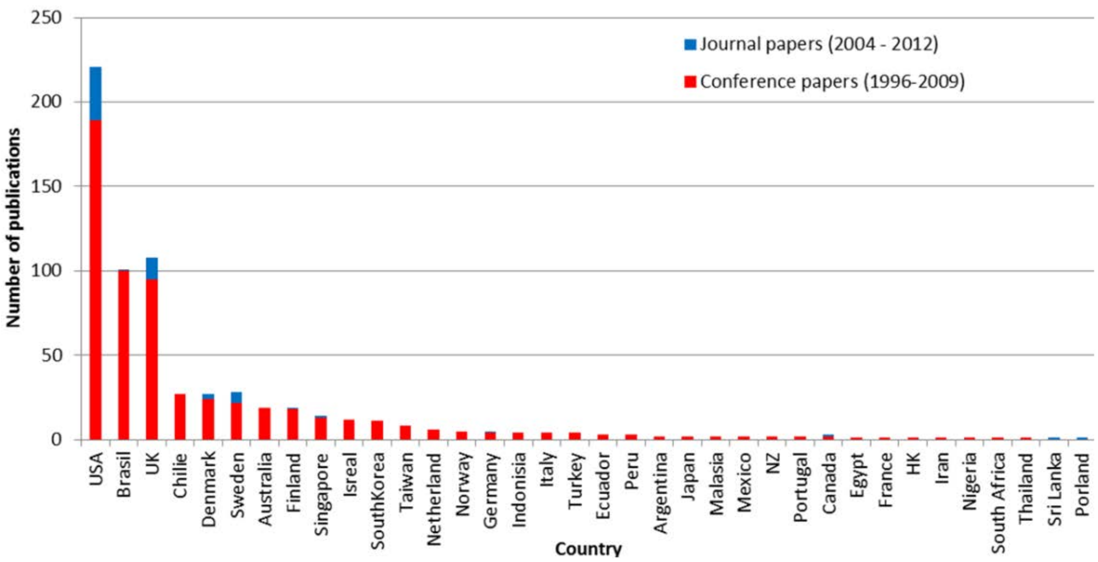


Figure 3.1: Research contributions in Lean Construction Institute

Evidence in the Australian building and construction industry has shown that the relational nature of alliance projects creates a favourable environment for exploiting improvement opportunities (Walker et al., 2008). Lean construction and sustainability share a common goal of continuous process improvements by eliminating waste and promoting health and safety in construction activities (Ferng & Price, 2005), which makes lean thinking a suitable operating system for alliances. Therefore, in this research, the lean approach is selected as a potential technique to improve the performance of alliance projects. Ballard and Howell (2005) have suggested that relational contracts best support lean project delivery in dynamic projects (Figure 3.2). Further analysis in section 3.5.3 shows that a relational contracting system correlates closely with lean thinking.

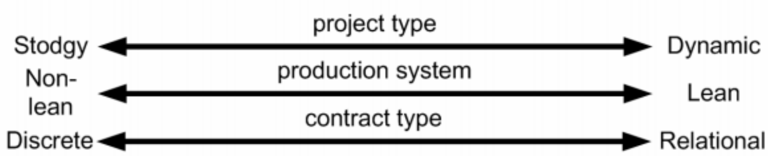


Figure 3.2: Contract correlated with production system and project type

Source: (Ballard & Howell, 2005)

There is a lack of lean construction research in NZ (Figure 3.1) similar to the alliance literature in the NZ context (Figure 2.4). Therefore, an in-depth theoretical study of lean construction and its application for alliance projects in the NZ construction industry should be of interest for both national practitioners and academics. The remaining part of this chapter explores more details of the lean concept.

3.4 BRIEF REVIEW OF THE LEAN PHILOSOPHY

In the early stages of its conception, the lean philosophy was used as a tool to improve operational performance, but has now become a management approach for improving operational and socio-technical performance (Joosten et al., 2009). The lack of distinction between lean application levels is complicated by the absence of a common definition of the concept. This section serves as a brief review of the lean definitions while next sub - sections provide a detailed review of lean concept in construction.

Several definitions of Lean have been offered in previous studies. Womack and Jones (2003) suggested that the central focus of the concept lies in continuous improvement to minimise waste and maximise value to customers. Sanchez & Nagi (2001) have described the lean concept as an operational practice that focuses on the productive use of resources. Similarly, Liker and Wu (2006) have explained that Lean aims at delivering the highest quality products at the lowest cost in the shortest time. Shah and Ward (2007) have suggested that the concept is a combined socio-technical system which eliminates waste by reducing the effects of external variability in a supply chain and internal variability in a production process. Overall, the above studies highlighted the expansive nature of conceptual definitions of the lean concept. Moreover, it could be concluded from the foregoing, that the lean concept is an integrated socio-technical system for eliminating waste and improving operational efficiency so that a production activity continuously meets customer expectations at the lowest possible cost.

3.5 APPLYING LEAN TO THE CONSTRUCTION INDUSTRY

Based on the results of lean transformations developed by Womack and Jones (2003), it can be seen that a lean implementation derives great benefits in manufacturing and other industries. In 1992, Koskela’s pioneering work was the first attempt to seek an understanding of lean thinking in the construction sector. Researchers have identified similarities between the two industries where both industries consist of socio-technical systems and construction is similar to the new product development phase in manufacturing (Kagioglou, Cooper, & Aouad, 1999). Consequently, there is a concern among scholars to customise lean manufacturing principles to construction (Ballard & Howell, 1998). Previous studies indicate that it is feasible to use lean techniques on construction sites (Picchi & Granja, 2004).

Past researchers (e.g.: (Diekmann et al., 2004; Solomon, 2004; Teze, 2007)), who have been working on the implementation of lean concepts in construction, have noted that lean construction is not just applying lean manufacturing concepts to construction. This is mainly due to the peculiarities of construction projects (section 2.2.3) compared to manufacturing processes (Bjornfot & Stehn, 2007). In addition, research investigations have pointed out that several obstacles account for the low uptake of lean principles by construction. These obstacles are poor investment in research and development (Shin, Collier, & Wilson, 2000), deep rooted project culture (Hook & Stehn, 2008a), limited knowledge of lean construction (Johansen & Walter, 2007) and resistance from construction project participants (Howell, 1999).

Lean construction theory has been developed based on two main views. The first view tries to extend the lean manufacturing practices to construction with or without modifications. The second view tries to extend only the principles of lean thinking to construction, which leads to unique lean construction practices. Both of these views have stimulated lean applications in construction. In this study, lean construction is assumed as a manufacturing process. This study also explores how lean thinking can be utilised in alliance projects.

3.5.1 Definition of lean construction

Similar to lean manufacturing, there seems to be no precise consensus definition of the principles of lean construction (Cullen, Butcher, John, & Richard, 2005; Green & May, 2005; Mossman, 2009c). Different authors have defined lean construction as a philosophy, method, a set of ideas, concept, tool or new term for construction management. This unavoidably leads to different implementation efforts, methods and techniques (Mossman, 2009c). Since the subsequent research investigations mainly evolved with the lean construction concept, there has to be an agreed view of the lean construction concept. The following review therefore attempts to draw a boundary between what is generally accepted as lean construction and what is not.

Mossman (2009c) has referred to lean construction as a philosophy which focuses on continuous improvement through value streams to respond to customer needs. Consequently, improvements are accomplished by eliminating waste in a manufacturing process. Abdelhamid (2007) has pointed out that lean construction is a neologism and it is drawn upon the principles of project management and principles that govern production management. This is a vague definition and it does not provide a clear guidance for lean construction research or implementation.

Stark and Field as cited in (Mossman, 2009c) have defined lean construction as a set of ideas based on the holistic pursuit of continuous improvement. Along similar lines, the Egan report (1998) described lean construction as an influential technique for eliminating waste, improving efficiency and quality in construction. Ballard and Howell (1998) have seen lean construction as a production control tool while Senaratne and Wijesiri (2008) believed that lean construction is a strategic option for productivity improvement. Lean construction has also been defined as a production management based project delivery method which offers a new approach to the design and building of capital facilities (Howell & Tsao, 2007), with reliable and speedy delivery of value (Pinch, 2005). Lean construction helps to minimise waste and to generate the maximum value (Koskela, Howell, Ballard, & Tommelein, 2002) and provides an integrated supply chain to reduce lead time (Naim & Barlow, 2003). Ballard (2008) has identified lean construction as a project delivery system.

Aforementioned lean construction definitions are generally derived from two points of view, either from a theoretical perspective (a set of principles and goals) or from a practical perspective (a set of practices or tools). Furthermore, it can be noted that the early definitions were very general and have become more expansive over time by adding project management practices and project delivery system themes. This study uses the following definition for lean construction because it consists of many basic principles of lean.

> *Lean construction is the continuous process of eliminating waste, meeting or exceeding all customer requirements, focusing on the entire value stream and pursuing perfection in the execution of a constructed project (Diekmann, Krewedl, Balonick, Stewart, & Wonis, 2004)*

This definition emphasises continuous improvement efforts of the entire value stream, which is achieved through the identification and elimination of waste.

3.5.2 Lean construction principles

In order to provide clarity on the principles of lean construction, this section assembles a summary of perspectives obtained from thirteen articles, where different lean construction principles were found. An analysis of these articles indicates that lean construction principles are not as structured as lean manufacturing principles. The review is summarised in Table 3.2. The authors do not usually use the exact terms in describing the same characteristics. Therefore, by using affinity analysis, ten lean principles in total were crystallised from the investigated articles. Affinity analysis is a TQM technique involving iterative steps to provide a header to a group which captures the essential links among the sub-principles of a group of elements (Andersen & Fagerhaug, 2006). The affinity analysis follows four steps namely generate ideas, display ideas, group the ideas and create headers.

Identification of lean principles from relevant publications covers the first step of the affinity analysis. A review of the second step of affinity analysis is displayed in Table 3.2. The third step attempts to cluster the results of the article reviews into a set of ten lean construction principles as shown in Table 3.3. A 'tick' in Table 3.3 indicates that the author has mentioned this principle as an important element in lean construction. A suitable principle header was nominated to cover the themes identified under each principle cluster.

These ten principles are further reduced to four and those four principles are philosophy, people, process and performance (Figure 3.3). These four lean construction principles are hierarchically arranged in a manner similar to Maslow's (1954) hierarchy of needs. This arrangement represents the areas where an organisation should commence its improvement efforts.

Table 3.2: Summary of lean construction principles

Source: (Vilasini et al., 2011)

Source	Identified LC principles
(Koskela, 1992)	Reduce the share of non-value-adding activities Increase output value through consideration of customer requirements Reduce variability & cycle time Simplify by minimizing the number of steps, parts and linkages Focus control of the complete process Build continuous improvement in the process and benchmark Balance flow improvement with conversion improvement
(Melles, 1997)	Simultaneous engineering Continuous improvement Customer orientation Multifunctional task groups and co-makership
(Koskela & Leikas, 1997)	Reduction of variability Process charting for identification of NVA activities Simplification & increased flexibility Focus on whole processes
(Miles, 1997)	Multitasking, multi-discipline, self-managing working groups Mutual respect and team performance incentives Risks are fairly allocated
(Egan, 1998)	Continuous improvement and annual target Reduce waste and increase value
(Howell, 1999)	Focus on the complete process Aligned stakeholder interests Combining project design with process design Downstream players are involved in upstream work Innovation and learning environment Reduction of variability Eliminate buffer and pull production
(Salem et al., 2005)	Customer focus Culture and people Workplace organisation and standardisation Elimination of waste Continuous improvement and built-in quality
(Pinch, 2005)	Establishing integrated team Combining project design with process design Quality assurance Decentralising decision-making Requiring a simple, direct hands off between tasks in the work stream
(Diekmann et al., 2004)	Customer focus Culture/people Workplace organisation/standardisation Waste elimination, continuous improvement with built in quality
(Lichtig, 2005)	Collaborate, improve networks of commitments Optimise the project not the pieces Tightly couple learning with action Increase relatedness
(Johansen & Walter, 2007)	Information transparency and work flow management Initiating improvement strategies and benchmarking Long term contractual agreements Early involvement of downstream players in the upstream process Participation and dedication culture Supply chain integration
(Senaratne & Wijesiri, 2008)	Elimination of non-value adding activities Making conversion activities more efficient
(Chua & Shen, 2008)	Managing hidden flows and reduce waste Smooth pace of production

Table 3.3: Assessment of lean construction principles

Source: (Vilasini et al., 2011)

Source Author (year)	Lean construction principles									
	Customer focus	**Systems thinking**	**Collaboration**	**Culture and people development**	**Work flow management**	**Simple & flexible**	**Decentralise decision making**	**Transparency (process/ information)**	**Performance measurement**	**Continuous improvement**
Koskela (1992)	√	√	-	-	√	√	-	√	√	√
Melles (1997)	√	-	√	√	-	-	√	√	√	√
Koskela and Leikas (1997)	-	√	-	√	√	√	√	-	-	-
Miles (1997)	-	-	√	√	-	-	√	-	√	-
Egan (1998)	√	-	-	-	√	-	-	-	√	√
Howell (1999)		√	√	√	√	-	-	√	-	-
Salem and Zimmer (2005)	√	-	-	√	√	-	-	-	-	√
Pinch (2005)	-	√	-	√	√	√	√	-	-	-
Diekmann, et al (2005)	√	-	-	√	√	-	-	√	-	√
Lichtig (2005)	-	√	√	√	-	-	√	√	-	-
Johansen and Walter (2007)	-	-	√	√	√	-	√	√	√	√
Chua and Shen (2008)	-	-	-	-	√	-	-	-	-	-
Senaratne and Wijesiri (2008)	-	-	-	-	√	-	-	-	-	-

Key √ ***relevant*** - ***irrelevant***

Philosophy or organisation strategy, which is the first category of principles in the lean construction hierarchy, addresses the basic values of an organisation. There are two sub-principles connected to this, namely, customer focus and systems thinking. The 'customer focus' sub-principle considers meeting requirements of the customer by defining value from the customer point of view. "Systems thinking" stresses the necessity of focusing on the entire process because focusing only on segmented flow leads to sub-optimisation. The second layer includes organisation building or development of people and culture and it focuses on alignment of interests of all stakeholders through early involvement of downstream players in the upstream processes, employee encouragement and development of a sense of responsibility.

The third layer in the hierarchy is dedicated to the process flow or organisation management through simple and flexible decentralised decision-making and work flow management sub-principles. Since Lean is a socio-technical system, its principles should address people and process factors. These principles mainly offer process streamlining through different efforts such as consolidating activities, standardising parts, tools and materials, waste and variability elimination and minimising the amount of control information. The last layer offers performance or organisation sustainability, which comprises transparency and performance measurement, as well as the continuous improvement sub-principles. This layer emphasises the continual attempt for incremental improvement of operations and management methods.

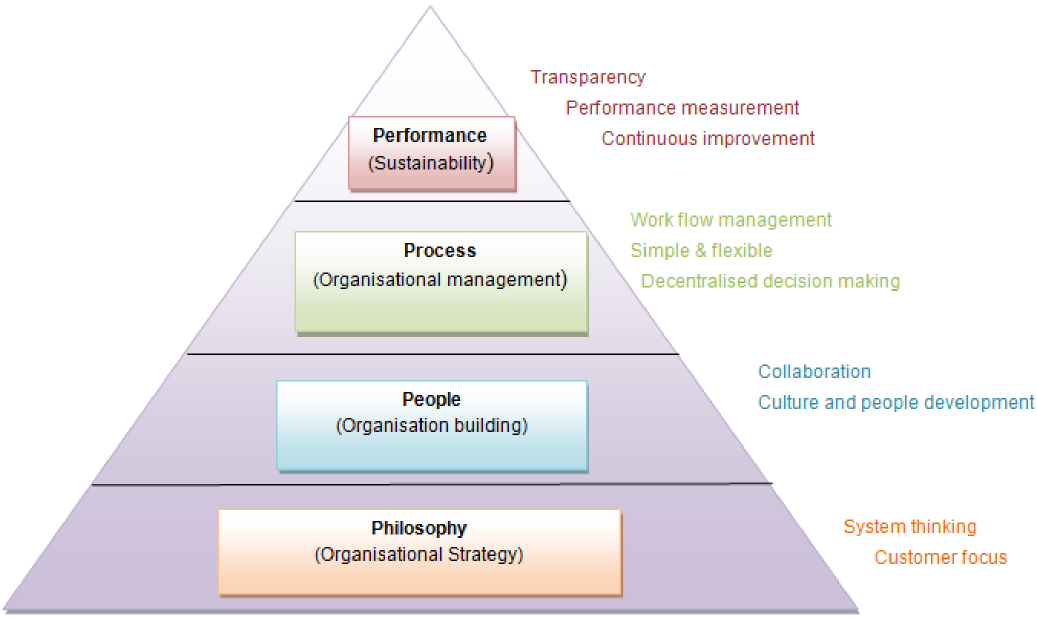


Figure 3.3: Lean construction principle cluster

Source: (Vilasini et al., 2011)

3.5.3 Comparison of Lean and procurement systems

This section correlates the lean construction principles identified in section 3.5.2 to the procurement methods outlined in the section 2.3. The objective is to identify a suitable procurement method for the application of the lean concept. Identifying a suitable procurement method for a particular project is vital for the overall productivity of the project. It is one of the most important decisions that a project owner would make during the development of a project (Naoum, 2003). The suitability of lean construction principles for each procurement type is identified in two steps. The first step is to find existing features in a selected procurement method. In a second step, a critical review is made on whether there is a favourable environment to apply those lean construction principles. Consequently, a suitability matrix as presented in Table 3.4 can be produced.

The separated approach (design-bid-build) in construction project procurement is in common use because of its simplicity (Bramble, 2003), whereas other methods contain complex frameworks for payment criteria, dispute resolutions and management structure (Quick, 2002).

As observed, in general, all the procurement methods except the relational approach are used to achieve value for money through price competition. This could lead to adversarial contractual relationships among different parties. On the other hand, these methods do not provide incentives for value addition or waste minimisation. The commercial core of relational arrangements is to set up relationships based on the reduction of the underlying costs by taking out wastes and inefficiencies (Cain, 2008). Therefore, it can be seen that customer focus, systems thinking, culture and people development, workflow management and performance measurement principles are stressed in relational contracts. Since strategic alignments are addressed only in relational contracts, there is a possibility for continuous improvement in relational type projects. Moreover, relational type projects are suitable for dynamic and long term projects (ACA Commercial and Contract Task Force, 1999). These types of projects allow project teams to learn from mistakes and continuously improve their processes.

In construction management contracts, construction managers work as agents of clients and are receptive to client needs (Rashid et al., 2006). There is no incentive for project participants to contribute any improvements to the design or construction process. In management contracting, all the contractual risks are transferred to the construction manager which results in a higher possibility of disputes with less priority for customer requirements.

Given the shift in mind-set from individual self-interest to a collective enterprise, Lean requires collaboration between all the parties involved in a project (Mathews & Howell, 2005). All of the integrated procurement methods (novation, design and build and relational) and some management procurement methods (design-build-manage, build-own-operate-transfer) are involved in collaboration and decentralisation of decision-making. However, these procurement methods do not refer to any practices that are related to the provision of decision-making capabilities to the lower tier participants such as site workers or sub-contractors, who are usually engaged with lean principles. In contracting methods, decision making mainly rests with the project owner (Rashid et al., 2006). Jorgensen and Emmitt (2009) have identified that the exchange of project specifications and work information among the supply chain leads to improved process transparency. This could be achieved through early involvement of project participants, which exists in novation, design-build, relational, design-build-manage and build-own-operate-transfer procurement methods.

Conclusively, traditional contracts do not facilitate the pursuit of lean principles while relational contracts facilitate the pursuit of lean principles as the relational arrangements provide suitable protocols to improve project outcomes through teamwork and incentive terms. Changing only contract and incentive terms is not sufficient to ensure improvements in project performance since value generation cannot be achieved without changing how work is done. This is where the project operating system plays a vital role. The next section inspects the lean thinking in an alliance and areas where lean thinking could be missing.

Table 3.4: Suitability matrix of Lean

Source: (Vilasini et al., 2011)

Procurement method	Lean construction principles									
	Customer focus	Systems thinking	Culture /people development	Collaboration	Decentralise decision making	Simplicity and flexibility	Work flow management	Performance measurement	Continuous improvement	Transparency
Design Bid Build	×	×	×	×	×	√	×	×	×	×
Novation	×	×	×	√	√	×	×	×	×	√
Design and Build	×	×	×	√	√	×	×	×	×	√
Relational	√	√	√	√	√	×	√	√	√	√
Design, Build and Manage	×	×	×	√	√	×	×	×	×	√
Build, Own, Operate, Transfer	×	×	×	√	√	×	×	×	×	√
Construction Management	√	×	×	×	×	×	×	×	×	×
Management Contracting	×	×	×	×	×	×	×	×	×	×

3.6 THEORY DISCUSSION: LEAN THINKING IN ALLIANCE CONTRACTS

The review in section 3.5.3 confirmed that relational contracts best support lean principles due to the following reasons:

- In relational contracting, continuous improvement at the operational level is easily achieved as the contractual structure improves the coordination, cooperation and innovation among project members (Mathews & Howell, 2005).
- Relational contracts favour the long term and dynamic nature of projects (Ballard & Howell, 2005). Such projects allow project participants to learn from their mistakes and continuously improve the process (Forgues & Koskela, 2009).
- Lean and relational contracts both try to optimise the project not the pieces (Thomsen et al., 2009).
- Relational contracts seek the active involvement of owners. Lean principles require positioning the project team toward the project objectives to produce value for the owner (Darrington & Howell, 2011).

Section 2.4.5 shows that alliancing tends not to establish defined process management techniques similar to Lean. This section tries to identify the lean thinking in alliancing and areas where lean thinking could be missing. The summary of the Lean vs. alliance comparison is depicted in Table 3.5.

Table 3.5: Overview of Lean methodology and the alliance model
Source: (Vilasini & Neitzert, 2012)

Item		***Lean methodology***	***Alliance framework***
Level of operation		Strategic and operational	Strategic
Project suitability		Dynamic projects	Dynamic projects
Goal	Time, cost, and quality Sustainability	Focus on NVA activities, safety environment, depletion of resources and environment	Strong focus on KRA. Common KRAs focus on sustainability concept
Principles	Customer focus	Customer driven value	All stakeholders focus
	Systems thinking	Integrate all levels	Integrate project phases
	Collaboration	Real collaboration	Partial collaboration
	Culture and people	Team environment	Team environment
	Work flow management	Operational	Contractual /organisational
	Simple and flexible	Simple and flexible	Complex but defined
	Decision making	Decentralised decision making	Integrated decision making
	Transparency	Process/information	Information/communication
	Performance measurement	Measured and rewards given for all participants	Measured and rewards only for alliance participants
	Improvement	Continuous improvement	Innovation

3.6.1 Level of operation

Lean favours a top-down and bottom-up approach since Lean is an operational technique (Morgan, 2005). The evidence suggests that alliance practices in construction are dominantly top-down driven processes, enacted by empowering project teams, essentially workers and supervisors (Green, 2002). Similar to Lean, an alliance includes various practices applied at levels of the organisation, which typically involve internal training programs and the use of external experts providing mentoring and facilitation. However, such practices depend on the attitudes of the alliance management and its belief in the importance of these practices (Lahdenperä, 2012). The value chain of the alliance project contains three distinct roles namely implementation, management and governance as shown in Figure 3.4. The alliance principles operate on management and governance aspects while lean principles operate on implementation aspects. Therefore, alliancing mainly focuses on efficacy and effectiveness and Lean focuses on efficiency of the value chain.

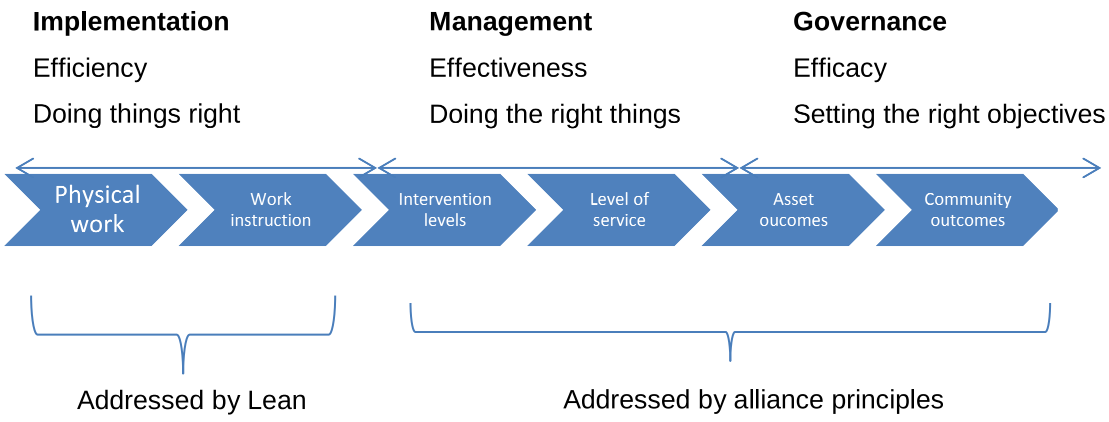


Figure 3.4: Value chain of the alliance project

3.6.2 Aims/Goals

Lean goals go beyond traditional construction goals, (time, cost, and quality), and converge to sustainability objectives by stressing waste-free, safe flow, energy and resource consumption and providing value for customers (Dulaimi, Ling, Ofori, & De Silva, 2002). Dainty, Cheng, and Moore (2003) have reported a list of common KRAs adopted by past alliances and have noted that in addition to traditional goals (cost, time and quality), alliances focus on environment, work life balance, as well as safety and community developments. Hence, sustainability may become the unifying theme under lean construction and alliance goals.

3.6.3 Principles

This section elaborates the use of lean principles in relation to alliances. Understanding and meeting the customer requirements is a focal point of Lean (Womack & Jones, 2003). In emerging lean construction practices, value is created in the iterative dialogue between project participants (Ballard, 2008) . In alliances, clients are members of the alliance team and they are in a very influential position. They are actively engaged throughout the project and they are well informed about the project status. Moreover, the alliance philosophy focuses on all project participants through commercial alignment. Therefore, as far as value generation is concerned, the alliance pays more attention to all stakeholders of the project including the community around the project.

In lean principles, system thinking stresses the need for focusing on the entire process, as focusing on segmented flow leads to sub-optimisation (Jorgensen & Emmitt, 2009). The alliance follows a holistic approach (Salman & Dainty, 2005) and it considers downstream-related aspects of a project at the early stage (Jefferies, 2006). Therefore, a common idea under both Lean and alliancing is to optimise the entire project rather than pieces as in traditional practice.

In order to achieve lean construction benefits, it is necessary to have a collaborative approach at all the stages with all parties including sub-contractors (Maturana, Alarcon, Gazmuri, & Vrsalovic, 2007) and site workers (Hook & Stehn, 2008b). The lean process pro-actively engages with project participants to develop the workflow plan. Team members are fully committed to each other and accountable for the project schedule and sequencing goals (Mossman, 2009a). Since alliancing is a form of contract and organisational governance, collaboration is dictated at the strategic level only (Cheung & Rowlingson, 2005). Most of the past alliance projects have focused on owner-designer-main contractor collaboration and only a few projects have extended alliance practices to the critical sub-contractors and site workers.

Development of organisation culture and people is an essential factor for lean success (Suzaki, 1993). This principle implies that the project should improve the mutual respect among project participants, management and workforce (Simonsson & Emborg, 2009). An alliance results in a shared culture which is based on trust, dedication to common goals, mutual obligation and win–win relationships (Yitmen, 2007). Thus, both concepts have common principles in culture and people development. For successful lean implementation, there need to be long-term, trust-based and mutually beneficial relationships among project participants. These characteristics are already present in alliancing.

Lean promotes an integrated approach not only to design and construction but also to the whole supply chain (Jorgensen & Emmitt, 2009). Alliancing is a form of contractual and organisational system while lean construction is an operating system. They adopt different strategies for optimising the project performance. However, lean principles overlook contract management aspects whilst the alliance principles disregard process management aspects. Additionally, one of the main KRAs highlighted in the Project Alliancing Practitioners' Guide by the Victorian Government (2006) is quality and workmanship which denotes meeting the performance specifications. Similarly, Lean tries to improve quality through inbuilt product characteristics like getting it right the first time. However, under the alliance, each non-owner participant is reimbursed costs of the work done under the alliance including reworks (Victorian Government, 2006). Accordingly, sharing of pain:gain under the alliance model guarantees that each non owner participant shares equitably in the pain associated with wasted effort (Ross, 2003). Thus, the motivation to reduce rework in an alliance depends on the team relationship and the culture of the alliance project.

The basic idea of Lean is to keep production systems and organisations simple and to avoid waste (Melles, 1997). Still, flexibility is required in all dimensions especially in method, workforce, machinery and process due to the complexity and dynamic nature of the industry (Ballard & Howell, 2004). Ballard and Howell (2005) have pointed out that Lean and alliance type relational contracts are suitable for dynamic (uncertain and complex) projects because traditional forms of operating systems and contracts are inadequate for dynamic projects.

The bottom-up approach of Lean aids a decentralised decision making process (Hook & Stehn, 2008b). This is achieved by workers having the choice of stopping work on a production line if a defect is detected. All alliance members are integrated into the decision making process and a high performance plan of an alliance encourages such integrated decisions (Morwood et al., 2008). One of the core principles of alliancing is improving the transparency of transactions via an open book concept and transparency of communications through peer relationships (Victorian Government, 2006). Lean principles focus on process and information transparency via pre-defined procedures.

Lean methodology encourages frequent measurements of the progress of applied lean practices by using KPIs (Bernson, 2004). In general, lean KPIs align all stakeholders of a company including suppliers and workforce to follow one common goal (Puvanasvaran, Muhamad, Megat, Tang, & Hamouda, 2008). Conversely, alliance KPIs are pre-requisites to the pain:gain share model which is continually measured during the project execution (Victorian Government, 2006). It mainly applies to the main alliance participants and disregards the workforce and sub-contractors involvement in such KPI settings.

Lean supports the continuous improvement culture throughout the organisation by using bottom-up approaches. The alliance incentive framework monitors all KPIs and provides insight into its future requirements. According to Walker et al. (2002), continuous improvement and innovation are vital elements of alliances to improve the current process to achieve results on time. However, there have been only a few studies found on operational level continuous improvement practices in alliances. In an alliance, there must be a commitment to learn from experience and to apply this knowledge to improve performance. It can be seen that there are certain aspects of lean thinking existing in alliance contract projects and their application depends on the management culture. Therefore, the next section discusses how alliance projects can be further developed and deployed by implementing lean principles.

3.7 LEAN AS AN OPERATING SYSTEM IN AN ALLIANCE

Ohno (1988) and Shingo (1992) have reinforced the necessity to identify and eliminate waste. The construction industry started its lean deployment by exploring what waste means for the industry, what causes waste, how it is formed and ways of eliminating or minimising it. As a result, the Construction Industry Institute (USA) has found that the construction sector on average contains 57% of waste and 10% of VA but the manufacturing sector is far better with 62% of VA and 26% of waste (Mossman, 2009a).

Identifying and quantifying the waste in an operation is an essential step of a number of performance improvement initiatives in construction (Horman & Kenley, 2005). Lean is a performance improvement initiative and therefore waste identification and elimination is a vital principle in Lean. The motivation for this is the improved productivity through waste free operations. A recent theoretical review of lean construction by Alves, Milberg, and Walsh (2012) has noted that the understanding of lean construction as a synonym of waste elimination is still valid as some countries and different project types are in the initial stages of lean construction implementation. In practice, Lean is more often regarded as a methodology that can be used to remove 'waste' from processes. According to Jorgensen and Emmitt (2008), lean philosophy is meaningful, only if waste is defined and eliminated. Hence, this study was carried out in three main stages to eliminate waste in alliance projects. Those main stages are identifying waste, quantifying waste and formulating suggestions.

This study mainly considers improvement opportunities at the operational level of an alliance because there has been done relatively little research into combining process management techniques in alliancing projects (section 2.4.5 and section 2.5.4). Workflow improvement is an operational level principle in lean construction (Figure 3.3). All types of waste in a process need to be identified to realise the improvement opportunities in a workflow.

3.7.1 What is waste?

The lean approach focuses on systematic identification and elimination of all types of NVAU activities which are also called waste (McGeorge, Palmer, & London, 2002). Waste takes many forms and can be found in policies, procedures, processes, product designs and operations. Womack and Jones (2003) have described waste as any human activity that absorbs resources but creates no value. Waste also consumes resources but does not add any value to a stakeholder (Dolcemascolo, 2006; Singh & Sharma, 2009).

It is clear that waste is a relative term, which can be defined in units of value. Based on the above definitions, it can be concluded that in lean thinking, in a wider scope, waste is identified in terms of worker productivity and customer value. The construction industry frequently refers to waste as material waste but process wastes like delays, inspection and transportation are not considered (Alarcon, 1997; Rahman, Wang, & Lim, 2012). However, process waste is significantly high (Senaratne & Wijesiri, 2008) and it is a major problem in construction which amounts to 60% of the construction effort (Mossman, 2009a). Most of these types of waste are intangible (Senaratne & Wijesiri, 2008) and invisible (Ng, Skitmore, Lam, & Poon, 2004). Horman and Kenley (2005) have concluded that construction processes can be characterised as processes with high waste activities resulting in low productivity. Due to lack of recognition of process waste as a waste (Alarcon, 1997) and high magnitude of process waste compared to material waste (Koskela, 2000; Weeleng, 2004), this study pays more attention to process waste rather than material waste in alliance.

In previous studies of construction, different measurements of waste have been considered and most of the waste has been limited to production on site (Table 3.6). Lean manufacturing consistently uses Monden's (1983) activity classification rule. Monden (1983) has identified three different types of process activities. The rule used in the activity classification is that activities that add value to the customer are considered as VA activities. Furthermore, any activity that does not add value to the customer but is necessary is considered as NVAN activities. Finally, activities that do not belong to any of the above two types are categorised as NVAU activities or waste. This scheme proved to be more generic and was used in different sectors and applications. Therefore in this study, Monden's (1983) activity classification was used to define waste activities on site.

Table 3.6: Magnitude of waste in construction

Source: (Abdel-Wahab, Dainty, Bowen, & Hazlehurst, 2008; Bertelsen, 2004; Koskela, 2000; Polat & Ballard, 2004; Weeleng, 2004) compiled by author

Waste	Cost (total of project cost)	Country
Quality costs (non-conformance)	10-12% 30%	US UK, Australia
External quality cost (during facility use)	4%	Sweden
Lack of constructability	6-10%	US
Poor materials management	10-12%	US
Excess materials on site	10% 10-18%	Sweden Germany
NVA activities on site	2/3 of total time 20%	US Denmark, Sweden
NVA material cost	1/3	Denmark
Lack of safety	6%	US
Potential labour efficiency	40% 40-60%	UK USA

3.7.2 Evaluating past studies of process waste

A large number of studies exist concerning the levels of wasted time. The results are good indicators of waste in construction. Nevertheless, there have been very few studies to identify patterns by combining the findings across the selected studies (Table 3.7). Such a study would provide a clear understanding on apt data collection techniques, typical levels of waste and the relationship between waste figures and different variables such as project type, country and time period.

This section examines waste figures based upon published papers in terms of the country of origin, data collection method and unit of analysis. The summary of the 43 articles is shown in Table 3.7 and a detailed analysis is attached in Appendix C. Criteria to include a published paper for the analysis are based on if it has: (1) used Monden's (1983) activity classification rule and (2) reported enough information on the data collection method used.

Table 3.7: Analysis of published research

Study variables		**Percentage of studies**	**Activity figure range (%)**			**Average**
			VA	**NVAN**	**NVAU**	**NVAU (%)**
Project type	Residential	23%	10-71	14-59	12-64	35.1
	Commercial	47%	8-58	18-56	15-73	43.0
	Heavy	19%	53-64	36-41	36-68	55.8
	Not specified	11%	0.3- 69	9-22	31-57	49.1
Country of origin	Developing countries	19%	37-71	14-21	11.6-72	34.2
	Developed countries	81%	0.3-69	9-59	15-73	45.0
Data collection method	Work sampling	65%	0.3- 71	9-59	12-73	45.3
	Time study	26%	10-58	21-56	15-90	37.1
	Multiple methods	9%	8-25	19-35	53-67	43.0
Total number of publications analysed						**43**

The analysis shows that most of the studies (39 articles) have used primary data. The majority of the studies have been conducted in developed countries while focusing on commercial buildings. Findings show that the magnitude of wasted time in construction is substantial ranging from 12% to 99.7% which indicates widely dispersed data. This analysis indicates that a heavy construction project type has a higher percentage of waste compared to other project types. This reveals the highly uncertain and complex nature of heavy construction projects. A few studies in heavy construction projects (8 articles) indicate that heavy construction projects have a poor initiative to manage uncertain and complex conditions.

3.7.3 Categorisation of waste

The Toyota production system has used the famous categorisation of waste from a manufacturing perspective which consists of over-production, waiting, transportation, over-processing, inventory, movement and defects (Cullen et al., 2005). Recent studies on waste identification in construction (e.g: (Diekmann et al., 2004; Josephson & Saukkoriipi, 2007; Kalsaas, 2010)) have used a classification similar to classification used in Toyota production system.

Lee, Diekmann, Songer, and Brown (1999) have used different types of waste, which are delays, quality costs, lack of safety, rework, unnecessary transportation, long distances, improper methods and poor constructability. According Formoso, Isatto, and Hirota (1999), the main categories of waste are overproduction, transportation, waiting, motion, processing, substitution, defects and inventories. Garas, Anis, and Gammal (2001) have classified waste into ineffective work, stoppages, clarifications, waiting periods, rework, variation in information, delays in planned activities, interaction between specialists and abnormal wear of equipment.

These classifications (e.g.:(Lee et al., 1999), (Formoso et al., 1999) and (Garas et al., 2001)) are not commonly used by other researchers in identifying and quantifying waste. The main reason for that could be these classifications consist of waste causes as well as waste effects. For an example, ‘unnecessary motion and transportation’ are caused by ‘long distance’ as mentioned by Lee et al. (1999), ‘waiting’ is caused by ‘stoppages’, ‘interaction between various specialists’ and ‘variation in information’ as mentioned by Garas et al. (2001). From a measurement perspective, the desirable types of waste can be easily identified and the wasted time can be quantified. The effects of waste are easier to identify and measure than waste causes.

In addition to the above seven waste effects, Womack and Jones (2003) have identified an eighth category. It is related to underutilisation of people mainly their ideas and creative inputs for improving processes and practices. Macomber and Howell (2004) have suggested ‘not taking advantage of people’s thoughts’ as a similar waste type. According to Mossman (2009a), ‘behavioural waste is waste that does not use people's skills and capabilities' which are relatively close to the waste type defined by Womack and Jones (2003). The eighth category of waste causes the other seven waste types.

Gibbons (2008) noted that the suggested eighth waste is much harder to quantify and requires qualitative understanding. When a lean implementation framework was developed, Gibbons (2008) included this eighth waste since it is a major factor for eliminating the existing waste. In chapter two, it was noted that most alliances consider only part of the value chain. In addition, only a few studies have been devoted to diffusing alliance practices to sub-contractors and workers. This study explores seven types of process waste and behavioural waste in the alliance environment.

3.7.4 Theoretical framework

The eight waste categories were used as a framework (Table 3.8) to identify and eliminate waste in processes of an alliance project.

Table 3.8: Lean construction waste as a theoretical framework

Waste type	Definition
Motion	Waste associated with unnecessary worker/equipment movement around the construction site
Waiting	Time spent waiting for other work crews to finish the conversion process so that the next conversion process may begin. Time spent waiting for crew members of a specific team. Time spent waiting for parts or instructions.
Transport	Wasted effort to transport building components or tools into or out of job trailers or storage between processes.
Extra processing	Waste associated with rework, rehandling or storage caused by defects in design, fabrication or construction activities.
Inventory	Maintaining excess inventory of components, equipment or tools.
Overproduction	Producing too much or too soon, resulting in poor flow of information or goods and excess inventory
Defects	Deficiencies in the finished product that require additional work or rework to correct punch list items.
Behavioural	Losing improvements and learning opportunities by not engaging with or listening to project participants to eliminate the other seven wastes.

Exploring improvements in an alliance through the lean concept is a complex task. The foundation for a lean implementation is to identify waste. Knowledge of waste and its implications for specific settings help to understand the efforts required to improve the system. There is a lack of reference to process improvement methodologies that could assist to eliminate waste successfully in construction. The next section examines the different process improvement methodologies that are available in manufacturing and have also been adopted in construction.

3.7.5 Standard process improvement approaches

Process improvement is a continuous and incremental approach (Macdonald, 1995) to identify, analyse and improve existing processes to create successful results (Bratic, 2011). Shingo and Dillon (1989) have explained that improvements can be achieved through value engineering and manufacturing methodologies in both conversion and flow activities. The most frequently reported methodologies for continuous improvements in processes are Plan-Do-Check-Act (PDCA), Define-Measure-Analyse-Improve-Control (DMAIC) and Look-Ask-Model-Discuss-Act (LAMDA) cycles.

The PDCA is a cycle of iterative activities that continuously seek better ways of doing, removing failure causes without accepting temporary corrective actions (Darrington, 2011). The PDCA cycle is broadly applied in construction to control performance in quality, schedule and safety (Nakagawa & Shimizu, 2004). The DMAIC cycle evolved from the PDCA cycle. It follows a five-step approach to process improvement. Proponents suggest that the DMAIC is systematic and a fact based system. DMAIC can be used with the last planner system to reduce operational defects (Koziołek & Derlukiewicz, 2012). Beary and Abdelhamid (2005) have used DMAIC to develop a production planning process model.

The LAMDA cycle, which is also based on the PDCA cycle gives the most prominence to a situation analysis, ‘Look and Ask’ (Ward, 2007). The LAMDA cycle is a basic learning cycle which mainly used in product and process development process. The major difference to the other two methodologies is the greater focus on the root-cause of problems than on the development of solutions. The LAMDA cycle has rarely been mentioned in construction studies.
All three methodologies share a common history but have some operational differences. Their attributes are compared in Table 3.9. Success in PDCA is reliant on its ‘check phase’ while success in DMAIC and LAMDA is reliant on the initial planning phases when knowledge is gathered about a process. Stewart and Spencer (2006) have suggested that the DMAIC differs in its extensive use of statistical analysis. This may account for the DMAIC being limited to instances of defect reduction (Forbes & Ahmed, 2011).

Table 3.9: Comparison of process improvement methodologies

Attribute	PDCA		DMAIC		LAMDA	
Developed	Shewharts (1939) and Deming (1950)		Deming (1980)		Ward (2007)	
Steps	***Plan***	Detect an abnormality and quickly do root cause analysis	***Define***	Identify and define problem	***Look***	Collect possible information to solve a problem
					Ask	Find reasons for failure
			Measure	Choose indicator	***Model***	Take knowledge from the previous steps and model it
			Analyse	Conduct root-cause analysis	***Discuss***	Discuss the models with relevant parties
	Do	Implement solutions	***Improve***	Brainstorm and identify solution	***Act***	Take action on decision and follow-up on the plan
	Check	Review the results	***Control***	Review results and address the root causes more specifically	***Look***	Review the results and check them against expectations
					Ask	Find answers to why this is not happening
					Model	Re-model the solutions
					Discuss	Discuss the model
	Act	Adjust solutions			***Act***	Implement the solutions
Learning cycle	Single loop learning		Single loop learning		Single loop learning	
Application	Applied in process and product improvements		Applied in process and product improvements		Applied in product design	
Other features	A communication tool		A communication tool		A communication tool	
	Easy and simple		Complex due to statistical usage		Complex due to double PDCA cycles	
	No defined corporate infrastructure		A corporate infrastructure required		No defined corporate infrastructure	

These three methodologies mainly present the detection and correction of the causes of waste in a process within a given set of main variables. They are not linked to radical changes while the governing variables rarely change. Therefore, these methodologies are ‘single loop learning’ cycles and do not seem to emphasise the people side of their implementation, which could be useful for their sustainability.

The success of process improvement depends on organisational features. The next section examines the factors that may influence the implementation of waste elimination and process improvement in construction projects.

3.7.6 Implementation barriers of a process improvement methodology

The implementation of Lean in construction is believed to face vast difficulties (Hook & Stehn, 2008a). So, it is vital to understand and manage the factors that hinder waste minimisation efforts in alliance projects. Since alliance projects are a sub-set of the construction industry, they may also have different barriers to improving processes at the site level.

The barriers to lean implementation in construction have been reviewed by different scholars (e.g: (Alarcon, Diethelm, Rojo, & Calderon, 2005), (Dulaimi & Tanamas, 2001), (Kim & Park, 2006), (Forbes & Ahmed, 2011) and (Alinaitwe, 2009)) for various lean principles and practices (e.g.: quality improvement, just in time (JIT), last planner system, VSM, 5S and BPR). This study particularly focuses on site level continuous improvement through waste elimination. Relevant barriers in implementing a process improvement methodology were identified from two sources namely: (1) literature on barriers in lean construction implementation, (2) studies in manufacturing that have focused on continuous improvement barriers.

Barriers to a continuous improvement culture in construction include lack of time for implementing new practices, lack of performance evaluation of site management and lack of organisational willingness (Alarcon et al., 2005). Dulaimi and Tanamas (2001) noted that construction workers are not well equipped to identify value and to conduct a VSM due to limited education level and skills. Moreover, lack of commitment to change has been denoted as a major barrier in a lean implementation (Dulaimi & Tanamas, 2001). Middle managers play a key role to ensure successful change; hence, their performance measurements must be linked to lean practices (Buch & Sander, 2005). Kim and Park (2006) have pointed out changing behaviour and attitudes of project teams, training and top management commitment as the important criteria for successful lean practices.

Alinaitwe (2009) has mentioned lack of a participative management style for the workforce, lack of project team skills in Lean and lack of reward systems as lean implementation barriers that militate against its extensive usage in construction. Forbes and Ahmed (2011) have noted several prerequisites for successful lean implementation in construction that include willingness to change and commitment to training which are applicable to a process improvement culture as well. Barriers to lean construction include lack of committed leadership, unmotivated employees, negative culture of the organisation and lack of performance based rewards (Alinaitwe, 2009).

Barriers to successful implementation of continuous improvement and associated techniques include lack of focus on people and lack of measurement and feedback systems (Kaye & Anderson, 1999). Moreover, Bhuiyan and Baghel (2005) have identified lack of enabling mechanisms (e.g. training, teamwork), lack of involvement of workers and insufficient integration of continuous improvement activities as barriers for continuous improvement in lean manufacturing. The fundamental challenge for a continuous improvement culture is lack of awareness of Lean, lack of commitment and support from senior management and looking for quick-fixes for existing issues (Antony, Krishan, Cullen, & Kumar, 2012). Oprime, Mendes, and Pimenta (2011) have identified lack of participation of the workers and incentive mechanisms as reasons for failure of continuous improvement initiatives. Moreover, resistance to change, lack of leadership and resources also hinder continuous improvements (De Souza & Pidd, 2011). The identified barriers are summarised in Table 3.10.

The aforementioned process improvements can be achieved in the short term. However, real change and sustainable improvement originate with lean principles that are embedded not only in the processes but also in people and culture of the project organisation. The above waste identification framework was used in the process studies. Poor integration of the lower tier project participants including sub-contractors and site workers was identified as the eighth waste. Lack of project team participation is one of the top barriers to implementing continuous improvement. The next two sections deal with theory around behavioural waste due to lack of integration of site workers and sub-contractors in an alliance.

Table 3.10: Barriers of a process improvement methodology

	Barrier	Cited by
A	High work load and project pressure	(Alarcon et al., 2005)
B	Difficult to change behaviour and attitude	(De Souza & Pidd, 2011) (Forbes & Ahmed, 2011) (Kim & Park, 2006) (Dulaimi & Tanamas, 2001)
C	Schedule and cost being the main priorities	(Alarcon et al., 2005)
D	Lack of perceived need for improvements	(Alinaitwe, 2009) (Dulaimi & Tanamas, 2001)
E	Lack of incentives to encourage process improvements	(Alarcon et al., 2005) (Oprime et al., 2011)
F	Lack of mechanisms for improvement suggestions	(Alarcon et al., 2005) (Forbes & Ahmed, 2011)
G	Lack of evaluations of the middle management based on improvement efforts	(Buch & Sander, 2005) (Forbes & Ahmed, 2011)
H	Lack of education and training to drive the improvement process	(Alarcon et al., 2005) (Antony et al., 2012) (Kim & Park, 2006) (Abdul-Hadi, Al-Sudairi, & Alqahtani, 2005) (Diekmann et al., 2004)
I	Tendency for temporary solutions	(Antony et al., 2012)
J	Lack of leadership	(Alinaitwe, 2009) (Antony et al., 2012) (De Souza & Pidd, 2011) (Kim & Park, 2006) (Abdul-Hadi et al., 2005)
K	Poor engagement of workers	(Oprime et al., 2011) (Abdul-Hadi et al., 2005)
L	Under resourced project team	(De Souza & Pidd, 2011) (Abdul-Hadi et al., 2005)
M	Prevalent command and control structures	(Alinaitwe, 2009) (Abdul-Hadi et al., 2005)
N	Little consultation of project participants	(Oprime et al., 2011) (Abdul-Hadi et al., 2005) (De Souza & Pidd, 2011)

3.8 WORKER PARTICIPATION

The people factor and process improvements are positively related themes as worker participation has significant potential to improve a project (Love, Li, Irani, & Faniran, 2000). Though worker participation has been a well-researched area, its understanding has been limited to project management research especially in construction. Many authors have pointed out the ignorance of the people factor within the construction context. Morton (2002) has stated that the workforce could be a main source of productivity improvement, which could be equally effective as the adoption of new systems. Mossman (2009a) has pointed out that site operatives need to be engaged in site management tasks since they create value for end users. The following sections review the worker participation practices in construction to identify current worker participation practices in the case study project.

3.8.1 What is worker participation?

The worker participation culture was initiated through an employee suggestion system which was started by Eastman Kodak in 1898 (Fairbank & Williams, 2001). At present, different terms are used to explain worker participation since it is constantly being renewed by researchers and practitioners. However, most of the terms refer to similar principles with varying practices. Basically, it is a culture that gives workers the opportunity to participate in substantive decisions, skills to make this participation meaningful, and the incentives to encourage skills acquisition and worker participation (Appelbaum, 2000). A review of previous literature conducted by Doody (2007) has identified common worker participation practices (Appendix D). Worker participation is an important principle of process improvement methodologies. Literature on worker participation practices provides the background for the description of workers' influence on process improvements.

According to Marin-Garcia, Bonavia, and Miralles (2008), four factors of worker participation are information sharing, training, decision making and reward. Worker participation practices listed by Doody (2007) are further classified into four factors provided by Marin-Garcia et al. (2008). Some practices like 'treat the entire workforce as equals' and 'conduct social activities' do not fall under any specific category. Certain practices that not frequently cited as worker participation practices such as hiring and promotion rule, selection process and conflict resolution are eliminated in this study. It can be identified that authors do not usually use the exact terms to describe the same practice. Such practices are combined and renamed. For example, 'problem solving mechanism' and 'quality circle' are combined and noted as 'request for employee ideas and input'. Worker participation practices are revisited and divided into five categories as shown in Table 3.11. The different categories are relationship, knowledge, reward and recognition, information sharing and decision making/power. These categories will be used as a guide for assessing worker participation in alliance projects.

Table 3.11: Categorisation of worker participation practices

Factors	Worker participation practice
Relationship	Treat the entire workforce as equals
	Conduct social activities
	Conduct relationship workshops
Knowledge	Formal appraisal system to assess training needs
	Supervisors trained in people management skills
	Site workers have job training opportunities
Reward and recognition	Regular employee performance appraisal
	Site workers receive performance related rewards
	Work team receive performance related rewards
Information sharing	Management gives project information to employees
	Standard job related induction programme
	Opinion survey of employees by third party
Decision making/ power	'Feedback box' to make suggestions
	Worker involvement in lesson-learnt workshops
	Requests for employees' ideas and input

3.8.2 Worker participation in construction

The workforce at the construction site is one of the most important variables in project performance (Kartam & Kartam, 2001) due to the high labour and knowledge intensive nature of the industry (Pathirage, Amaratunga, & Haigh, 2007). The industry informally relies on the contribution of workers to transfer experience from one project to another. Therefore, workers' input is vital in developing work procedures and quality assurance systems in projects.

3.8.3 Worker participation in alliance projects

In general, alliance projects are adopted for high risk and complex projects. A study conducted by Stringer (2007) has identified that high risk and complex projects with new technology need to adopt a bottom-up approach. According to Mossman (2009c), the bottom-up practices influence a permanent lean change. Continuous improvement through worker participation is a core lean principle (Angelis & Fernandes, 2007) and worker participation positively affects innovation and continuous improvements. Recent alliance projects have also revealed that worker participation practices such as the provision of training and more flexible quality of work-life issues address the needs of both management and workers. However, employee participation practices in alliance projects have not surfaced yet in the scientific literature and these practices are hardly explained in any alliance manual or guidelines. A review of past studies conducted on worker participation practices in construction are summarised in Table 3.12.

Table 3.12: Review of worker participation practices in construction

Factors	Practices	Literature findings
Relationship	Treat the entire workforce as equals	Dibia (2012) shows that worker-management relationships improve project performance
	Conduct social activities	Jefferies et al.(2006) revealed that induction programs and informal social occasions will improve organisational culture.
	Conduct relationship workshops	Cheung and Rowlingson (2005) showed a relationship building workshop for all operational level staff had improved teamwork. Davis & Walker (2009) found training in alliance principles as a success factor
Knowledge	Formal appraisal system to assess training needs	Staff appraisals are important but rarely considered in training decisions (Raiden, Dainty, & Neale, 2004).
	Supervisors trained in people management skills	Supervisory staff lacks worker management skills (Gann & Senker, 1998).
	Site workers have job training opportunities	Growth in sub-contracting has led to a decline in training for workers (MacKenzie, Kilpatrick, & Akintoye, 2000).
Reward and recognition	Regular employee performance appraisal	Weekly workforce performance review based on time, cost, design integrity and quality indicators for the main alliance (Yeung, Chan, & Chan, 2007).
	Site workers receive performance related rewards	Concept of performance based bonus payments improves productivity (Walker et al., 2001a). Less acceptance is given to extrinsic rewards (Holmes, 2011)
	Site workers receive performance related recognition	The lack of recognition for site workers prevails (Ng, Skitmore, Lam, & Poon, 2004); Recognition plans developed by Suzaki (1993) for lean oriented company
Information sharing	Management gives project information to employees	Raiden, Dainty and Neale (2004) claim that team briefings in construction are infrequent and ineffective
	Standard job related induction programme	Jefferies, Brewer, Rowlinson, Cheung and Satchell (2006) revealed that induction programs and informal social occasions would improve organisational culture.
	Opinion survey of employees by third party	Huselid (1995) shows regular opinion surveys will improve the project performance, and other alliance projects in NZ used the 'opinion survey' of workers (Alliancing Association of Australasia, 2011b).
Decision making /power	'Feedback box' to make suggestions	Suggestion box is a famous feedback collecting method in construction (O'Connor, Larimore, & Tucker, 1986)
	Worker involvement in lesson learnt workshops	Worker involvement in solving project-related problems is valued (Mohyin, Dainty, & Carrillo, 2012).
	Requests for employees' ideas and input	Managers think workers could view the consultative style as a management weakness (Greasley et al., 2005).

In summary, worker participation practices are vital in high risk, complex projects with high technology content and there is a trend for their inclusion in construction projects. The Australian National Museum alliance project has used a new organisational framework with solution building teams to encourage suggestions for encountered problems (Hauck et al., 2004). Numerous examples related to worker participation practices have been cited in the wastewater treatment plant alliance project (Cheung & Rowlingson, 2005). Davis and Walker (2009) have found that training and coaching of alliance principles throughout the project lifecycle help maintain a good collaboration among the project participants. Due to the temporary nature of construction projects (Kines et al., 2010), the industry believes that people development and participative approaches are inappropriate (Green, 2002). Therefore, involvement of the wider project team has not been extensively researched especially in relational type construction projects. The next section focuses on barriers to implementing worker participation practices.

3.8.4 Barriers to worker participation in construction

Studies show that there have been numerous examples of successful worker participation, in a variety of forms in other industries, but there have been very few in construction (Gil, Tommelein, Kirkendall, & Ballard, 2000). Green (2002) has noted that participation in problem solving groups could be found only in 21% of workplaces in construction. Furthermore, there is a large volume of published studies (Pasquire, 2012; Raja, Green, Leiringer, Dainty, & Johnstone, 2012), describing the motivation of site workers as minimal.

Construction projects seldom maintain the same team in more than one project (Dubois & Gadde, 2002). Conversely, Diekmann et al. (2004) have pointed out that the high labour turnover in construction is caused by the lack of opportunity for training which ultimately leads to a shortage of labour skills. The temporary organisation culture (Diekmann et al., 2004) and the fragmented nature may weaken the relationship between workers and management which is crucial for a worker participation culture. Consequently, lack of labour skills and high labour turnover are dominant in construction (Department of Building and Housing, 2009). Therefore, the implementation of people development and participative approaches would enhance the ability for organisations to retain employees (Meiling, Backlund, & Johnsson, 2012).

Oreg (2006) has shown that there is a negative attitude from middle managers to worker participation in construction. The support from the management is always a pre-requisite for a successful strategic intervention in construction. Major barriers to achieving team work in construction are a lack of organisational culture for teamwork and inadequate knowledge and skills (Alinaitwe, 2009). In summary, worker participation practices are essential in construction. Yet, the industry has neglected to take advantage of its workforce resulting in a considerable amount of untapped productive potential.

3.9 SUB-CONTRACTOR INTEGRATION

Project alliancing involves an active collaboration of owner and non-owner participants (designers, contractors and suppliers) to deliver the project by sharing risks and rewards. Alliancing connotes integration but in real practice, it fails to create a true alliance since only parts of the value chain are considered for integration. Sub-contractors are very often left out of the main alliance. This study discovers that the alliance needs to work closely with its sub-contractors to develop better relationships to sustain lean principles and to achieve high performance in a project. The following sections deal with sub-contractor management practices in construction and alliance projects.

3.9.1 What is sub-contracting?

The term sub-contracting has ambiguous definitions depending on the industry from which it is viewed and the term sub-contractor and supplier are frequently used interchangeably (Lehtinen, 2001). The term ‘sub-contractor’ instead of ‘supplier’ has tended to be used in operations, which have been considered as a temporary excess production requirement or performed by more than one participant. Traditionally, the term ‘sub-contracting’ is used in construction when there is a main contractor. Another notable difference between the two terms is that sub-contractor products are part of the end product, whereas suppliers’ products are basic inputs for construction. In this study, a sub-contractor is defined as a business entity that has a contract agreement with the main contractor to provide a portion of work, material input, or services on a project that the contractor agrees to perform. Sub-contracting arrangements are mainly categorised based on outsourcing decisions, functional participation, payment methods, mode of entry and capabilities (Figure 3.5).

Sub-contracting based on outsourcing requirements depends on capacity, specialisation and economic justification. Sub-contractors may be nominated, named or domestic sub-contractors depending on their mode of entry into a construction contract. The client selects a nominated sub-contractor while the main contractor selects a domestic sub-contractor. A named sub-contractor is a combination of the nominated and domestic where the client selects the sub-contractor and the main contractor is responsible for the named sub-contractor's work and payments. A ‘special purpose vehicle’ is used to manage third party contracts in alliancing and this method is unique to alliancing (Victorian Government, 2006). The special purpose vehicle is a legally recognised body, which is formed by sub-contractors of an alliance. The scheme envisages a clear legal entity with evidence of prior experience of positive collaboration among its members. Other categorisations of sub-contract works include categorisation by capability profile (Lehtinen, 2001), functional participation (Tam, Shen, & Tam, 2007), methods of payment and nature of work rendered on the project (Ramus, Birchall, & Griffiths, 2006).

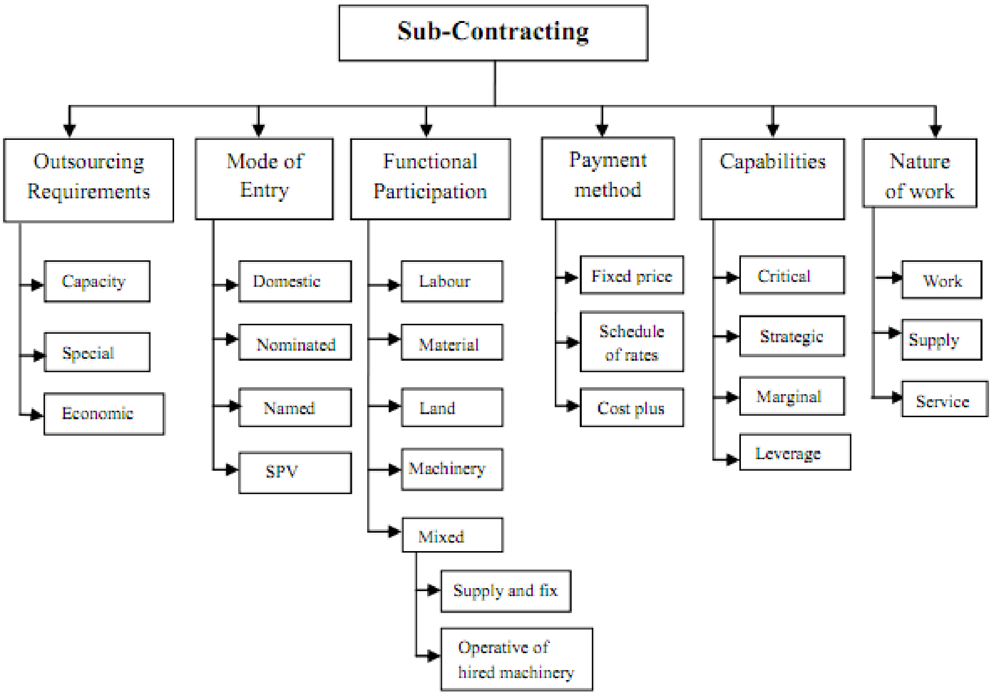


Figure 3.5: Sub-contracting categories

Source: (Vilasini, Neitzert, Rotimi, & Windapo, 2012)

3.9.2 Lean supply principles

Applying lean principles to a supply chain assists to improve performance and to meet customer requirements. Lean principles would not be truly effective unless they focus on the entire supply chain. Applying identified lean supply principles to the supply chain in alliance projects would maximise the project performance. Lean supply principles and practices pooled from literature are listed in Table 3.13. Lean supply principles help the sub-contractors and main contractor to ensure the desired performance of the project. The principles require a high degree of supplier innovation and coordination in both product development and production processes. In fact, the principles suggest collaboration in product development through group-based supplier development tools. Some other suggestions include introduction of production control based techniques such as the just-in-time concept, improved flexibility and synchronisation of supplier-customer capacities and improved inter-organisational relationship to achieve a win-win for all stakeholders.

Table 3.13: Lean supply principles and practices

Sources : (Bozdogan & Horng, 2007; Ma, Wang, & Xu, 2011; Schniederjans, Schniederjans, & Schniederjans, 2010), compiled by author

Factor	Lean supply practices
Nature of competition	Focus on the total competitiveness of a value stream No competition between the members of a supply chain Dependent upon partnerships, trust, openness and profit sharing Number of suppliers are low and very stable
Supply structure	Long term, often lifetime relationships Buying criteria are based on maximum network benefit Early involvement of established supplier in the design process A tiered and defined supply structure
The role of suppliers	A high degree of supplier innovation in both new products and processes The supplier is a leader of technology in the area A high level of supplier coordination at each level of the supply structure
Supplier development	Suppliers within value streams are seen as a group Greater effort made by customers to develop their suppliers Pursue perfection by continually removing waste along value stream. True transparency in costs and capacity
Data interchange and interaction	Detailed, some strategic, within the network Very frequent interaction at operational level, spreading through a network
Production principles	True just-in-time Synchronised capacity The flexibility to operate with fluctuations

3.9.3 Sub-contracting in construction

Sub-contracting in construction projects is a widely used and well-established practice. Irrespective of the categorisation method, sub-contractors are vital in construction projects (Yin, Wang, Yu, Ji, & Ni, 2009) as they perform major aspects of construction project works (Andreas, Florence, & Jane, 2009). With the increasing complexities of construction projects (Ahuja, Dozzi, & Abourizk, 1994) and improved procurement systems, roles of the main contractors have become limited to the management of work interfaces while offering physical execution of construction tasks to sub-contractors (Humphreys, Matthews, & Kumaraswamy, 2003). Sub-contracting is therefore a preferred option for project delivery and sub-contractors' inputs range from about 60-95% in different countries (Lehtonen, 1998; Maturana et al., 2007; Ohnuma, Pereira, & Cardoso, 2000). Informal alliances exist between contractors and sub-contractors, which the industry could benefit from. For example, most sub-contractors consistently work for the same contractor and 94% of sub-contractors in Australia have worked with fewer than three main contractors (Francis & Hoban, 2002). Another survey found that 41% of commercial sub-contractors have maintained steady relationships with their main contractors for an average of nine years (Costantino & Pietroforte, 2002).

Reasons for sub-contracting are cost reduction, shortage of skill and production capacity, organisational and managerial flexibility and risk mitigation (Costantino, Pietroforte, & Hamill, 2001). Although sub-contracting provides these benefits, some disadvantages have also been attributed to it. Usdiken (1988) has argued that increased sub-contracting may reduce the main contractor's control over the construction process and could lead to cost and time overruns. Non-completion of construction projects has also been attributed to sub-contractor delays (Alarcon et al., 2005). Ohnuma et al. (2000) have pointed out that the main focus of the sub-contractor is to complete the work with the least attention to material wastages and work quality. This could be because sub-contractors are paid based on physical production at a fixed price. Therefore, the relationship between the main contractor and the sub-contractor is potentially adversarial and may not augur well on some projects (Wood & Ellis, 2005). Interdependence between the main contractor and the sub-contractors helps maintain a high degree of control over project activities.

The integration of key project participants in the design phase of projects has been recognised in the industry and could reduce perceived rivalry between contractors and sub-contractors (Gadde & Dubois, 2010). Relational based project delivery systems that have been adopted by/in different countries such as ECI in the UK, IPD in the USA and alliancing in the Australasian region describe some form of integration of the supply chain. However, these relational contracts are very often limited to the client, main contractor and designers. An early integration of sub-contractors within projects would provide opportunities for them to offer their expertise to maximise potential cost savings. Sub-contractor integration could also assist timely completion, improved quality, enhanced performance in environmental issues, health and safety and innovation (Miguel, 2008). A common underlying theme of sub-contractor integration is early involvement through value management workshops to gain sub-contractor’s knowledge of construction work to improve project performance. The following section focuses on the roles of sub-contractors in alliance projects.

3.9.4 Sub-contractors' position in alliances

Alliancing has emerged to reduce adversarial contractual relationships and other effects of fragmentation in the construction industry (Davies, 2008).The selection strategy of the alliance team is based on both objective (skills, experience, and track record) and subjective (behaviour and attitude) criteria (Morwood et al., 2008) and is not based on price competition (Davies, 2008). This selection strategy promotes self-awareness, awareness of the other participants, team development and communication as critical success factors in construction projects (Morwood et al., 2008). Alliances provide a transparent legal and commercial framework and offer incentives to the participants through an open book concept but very often such transparency does not extend to sub-contract works (Ross, 2003). Transparency could induce high bargaining power to sub-contractors thus preventing main contractors from realising increased profit margins. Some interface problems could arise from a lack of trust and ineffective communication among project participants if sub-contractors are not integrated into the main alliance (Huang, Huang, Lin, & Ku, 2008).

Alliances involve a gain:pain share regime that maximises KRAs of projects. Thus, payment disputes due to competition could be reduced through this gain:pain share regime (Tang, Duffield, & Young, 2006). Still, this mechanism does not flow on to sub-contractors as they are not a party to the alliance and other activities at the pre-development phase. Sub-contractors are therefore not able to share cost savings with main contractors under alliance agreements. Thus, the motivation for continuous improvement of work processes is reduced. Maximum participation and innovation could only be gained when sub-contractors contribute to the design phase of the project (Ross, 2003) and if they are incentivised (Eriksson, Dickinson, & Khalfan, 2007).

Another limiting factor for the full integration of sub-contractors in an alliance is the fact that the majority of the alliance projects are one-offs (Brown, Ashleigh, Riley, & Shaw, 2001). Therefore, sub-contractors are relegated downstream in the hierarchy of alliances without any mechanism to monitor their relationship and performance. Keeping sub-contractors at arm's length and operating a transactional relationship, which is mainly built on price competition could negatively influence project success. Conversely, both parties can secure the project success through mutual co-operation, which is a prerequisite for lean principles.

3.10 CHAPTER SUMMARY

The purpose of this chapter is to position and examine the research issues highlighted in chapter one and two from a lean perspective. This chapter covered the theory of the lean concept and its applicability in alliance projects. The literature review in chapter two showed that there exists relatively little research on the integration of process improvement approaches in alliance projects. During an exploration of such approaches for relational contracts, Lean was identified as a central organising framework in combination with other similar methodologies. Despite the growing attention of Lean in construction, existent definitions, principles and techniques of Lean in construction are somewhat ambiguous. This chapter summarised lean construction principles listed by other researchers and grouped them accordingly. With a comparison of procurement characteristics, lean thinking was identified as suitable for relational contracts. Through a comparison of lean principles and alliance practices, it was identified that there are limited lean attempts in alliance projects.

The current study recognised that identifying and quantifying the waste in an operation is an essential step of performance improvement initiatives in construction. Therefore, the review has sought to discover how a process management technique like Lean can best be used in alliance in term of

- elimination of process waste through process improvement approach
- elimination of behavioural waste by implementing worker participation practices and sub-contractor management practices

After identifying three areas of lean applications in alliance, the next step is to identify suitable research methodology for the research. This will be focus within the next chapter. The next chapter will discuss the methodological options and the research design use in the current study.

4 RESEARCH METHODOLOGY

4.1 INTRODUCTION

Research is a systematic investigation that looks for relationships, predictions and generalizations. The literature review in chapter two and three is used as the foundation for this investigation to explain the position of the current study within the existing literature. The procedure of selecting appropriate research techniques is an essential step of a systematic investigation. This chapter explores different methodologies used in construction management research and the relevance of certain methodologies to this research.

Creswell (2009) has suggested that a framework of research design consists of three major elements of inquiry and they are a) philosophical assumptions, b) inquiry strategies and c) methods. The first element is the philosophical premises, which explain assumptions on which the research design is based. The second element is the strategy of inquiry such as experiment, survey, action research, ethnography and case study. The third one is the data collection namely questionnaire, interview, document review and observation. This chapter discusses how the above three elements are applicable to this research.

A number of authors have highlighted the criteria and methods for selecting suitable research paradigms, methodologies and techniques for a research problem. Accordingly, an interpretive paradigm was chosen as this research seeks to understand the complex interaction of people, processes and technology in a project. A case study strategy is used to explore how lean thinking can be utilised in alliance projects to improve the alliance project performance. As every data collection approach has its own merits and demerits, this research methodology follows a multiple data collection technique. The study used field observations, documents, interviews and questionnaire as data collection approaches.

This chapter consists of eight sections including this introduction section. The next five sections (4.2-4.6) outline research perceptions and explain which research perceptions are shared by the researcher. Section 4.7 explains the quality criteria of the research. The next section (4.8) discusses limitations of the research methodology. The last section (4.9) summarises the findings of this chapter.

4.2 PHILOSOPHICAL POSITION FOR THE RESEARCH

The exploration of the underlying research philosophy enables the researcher to evaluate different methodologies and methods. There are four philosophical dimensions in a research paradigm which include ontology (realism vs. nominalism), epistemology (positivism vs. anti-positivism), axiology (determinism vs. voluntarism), and methodology (nomothetic vs. ideographic) (Chua, 1986). The ontology includes one's view of the nature of reality while the epistemology addresses how the reality is known and the relationship between the 'knower' and the 'known'. Axiology considers the place of values in one's research. Methodology addresses the question of how we gain knowledge (Morrow, 2007). Guba and Lincoln (1994) have agreed that ontological and epistemological assumptions are the main steps in selecting a methodology. Therefore, the ontological and epistemological position of this research is discussed in the following sub-chapters to determine an appropriate methodology.

4.3 ONTOLOGICAL POSITION

Ontology refers to the nature of social reality (Crotty, 1998). Burrell and Morgan (1979) have suggested two main ontological possibilities that are useful in selecting a research methodology. The first possibility is that there is one reality and it is observable to a researcher who has little impact on the object being observed (Nwokah, Kiabel, & Briggs, 2009). The second possibility is that the reality exists in the product of an individual's mind and the engagement impacts on the observer and the situation being observed (Nwokah et al., 2009). In this context, ontology provides two dimensions, realism and idealism. Collis and Hussey (2009) have emphasised that if the social world is external and real, the researcher can apply experiments and surveys. Conversely, if the social world is subjective and depends on human perception, the researcher can use field research methods such as case study and ethnography.

4.3.1 Ontological position for this research

Ontologically, it is assumed that the success of implementing Lean in an alliance environment will be subjective and depends on the participants of the study. Moreover the research tries to identify improvement opportunities in an alliance project by considering attitudes of project participants and subject matter experts. Therefore, the ontological idealism stance was selected.

Based on the assumptions of ontology, the epistemological stance was identified by using a model developed by Nadim and Goulding (2007) as shown in Figure 4.1. Therefore, this research follows an interpretivist view. Seymour, Crook, and Rooke (1997) have noted that the interpretive approach is valuable for identifying problems in construction as it recognises the respective viewpoints of practitioners. Nevertheless, for clarity and consistency, subsequent sections (4.4 - 4.4.3) explain theory related to the epistemological position and the epistemological position applied in this research.

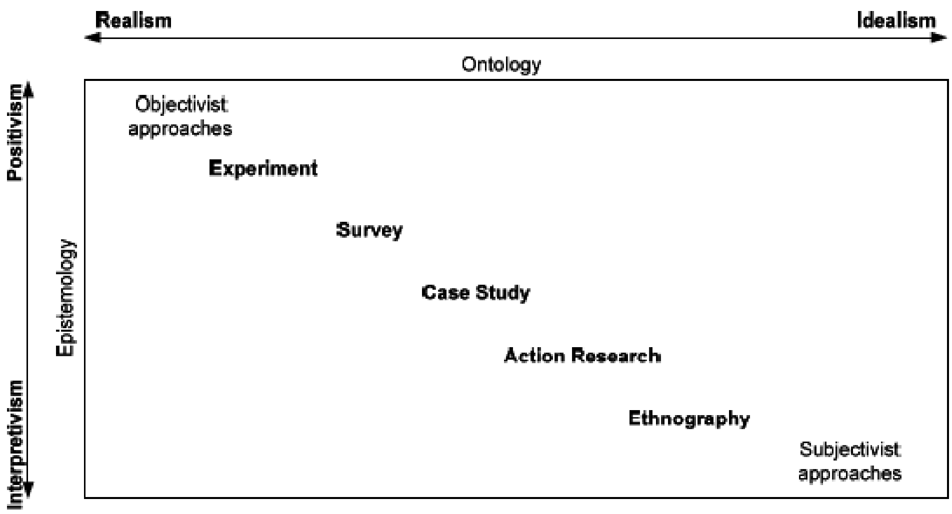


Figure 4.1: Selection of research strategy
Source: (Nadim & Goulding, 2007)

4.4 EPISTEMOLOGICAL POSITION

Ontology embodies understanding of what it is, while epistemology tries to understand what it means (Gray, 2009). Epistemology is the relationship between the knower and what is sought to be known (Love, Holt, & Li, 2002). This relationship can be derived from accepting the fact that knowledge can be either viewed as objectively knowable or in contrast, only subjectively knowable (Burrell & Morgan, 1979). Therefore, two dimensions are identified on the epistemology axis namely positivism and interpretivism. The positivists assume that the reality is objectively given and is measurable using properties which are independent of the researcher and interpretivists use a qualitative and subjective stance (Nwokah et al., 2009).

Construction management research deals with a blend of highly complex technical and social systems as they take place at the connection of natural science and social science. So, both positivism and interpretivism have a role to play in construction management research (Amaratunga, Baldry, Sarshar, & Newton, 2002). Those two paradigms are explained in section 4.4.1 and 4.4.2 while the research paradigm for this study is explained in section 4.4.3.

4.4.1 The positivist paradigm

Positivism assumes that there are universal laws to govern social events and these laws enable scholars to describe, predict and control social phenomena (Kim, 2003). Gray (2009) has defined core arguments of positivism as:

- reality consists of what is available to the senses
- inquiry should be based upon scientific observation and
- natural and human science share common logical and methodological principles, dealing with facts and not with values.

Findings of positivistic studies are based on a large sample of observations, a strict and scientific procedure and they are the highest form of knowledge (Nonaka & Peltokorpi, 2006). From a positivist perspective, the research takes place 'behind the glass', where the researcher observes but does not interfere with a phenomenon (Kock, Gallivan, & DeLuca, 2008). Positivism is used in scientific and applied research (Fellows & Liu, 2008) and relies on quantitative methods (Howe, 2009). Opponents criticise positivism for not being capable of addressing complex social issues (Willits, Bettner, Jensen, & Coyne, 2011) due to the disregard of historical and contextual conditions (Orlikowski & Baroudi, 1991). In contrast, scholars drawing on interpretative philosophies argue that knowledge and social entities cannot be understood as objective things (Nonaka & Peltokorpi, 2006).

4.4.2 The interpretivist paradigm

The interpretive paradigm seeks to understand values, beliefs and meanings of social phenomena, by obtaining a deep understanding of human activities (Kim, 2003). Interpretive studies accept researchers' interaction with subjects and attempt to reflect their biases as integral to the insights derived (Kock et al., 2008). Interpretivism is realistic because facts are not considered independent of the theory or the observer (Meredith, Raturi, Amoako-Gyampah, & Kaplan, 1989). Interpretivism also helps the researcher to grasp why certain characteristics or effects occur or do not occur (Meredith, 1998). The interpretive paradigm is receiving increased attention in social science studies (Orlikowski & Baroudi, 1991). Researchers' assumptions, beliefs, values and interests always intervene with their investigations and they are not entirely homogeneous as is the positivist approach (Orlikowski & Baroudi, 1991). Therefore, they have an impact on the research process and approach. Consequently, the approach to the research is unnecessarily bound to their paradigmatic preferences which reduces the generalizability (Mangan, Lalwani, & Gardner, 2004).

4.4.3 Epistemological position for the research

The positivistic paradigm is the most dominant paradigm in construction management research (Fellows & Liu, 2008). Given the research methodology debates in construction management in the mid-1990s, there is still limited evidence for a paradigmatic change in research methdology (Dainty, 2008). Nevertheless, the interpretivist paradigm is becoming more acceptable in business studies (Collis & Hussey, 2009) due to growing dissatisfaction with the quantitative based positivistic paradigm (Cepeda & Martin, 2005). Apart from debates on the use of paradigms in social sciences, each paradigm has its own merits and demerits depending on the nature of the study. In section 4.3.1, it was noted that the idealism stance of the ontological position directs to an interpretivism stance for this research. In addition, the next paragraphs further justify the relevance of the interpretivism stance in this research.

This research evaluates the effect of the implementation of lean principles and techniques on performance in alliance-type construction projects. In order to achieve this, a base level of 'lean performance' needs to be established. This base level of performance will identify both good lean practices and areas to be improved. Once a base level of understanding has been established, it is then possible to identify lean principles and practices which may reduce or eliminate the observed poor performance. Lean principles and practices exist at the interface of people, processes and technologies (Womack & Jones, 2003). Any research that seeks to identify lean practice must have this observation as its fundamental rationale. So, a particular interest exists in deep understanding of the complex interactions of people, processes and technology embedded in the culture of a construction project team (Morwood et al., 2008).

The understanding of performance issues in an alliance project and the adoption of lean thinking are context dependent. Any research in lean principles and their implementation must establish how and why excellent (and poor) performance occurs. In addition, this research is involved in knowledge transfer, since the lean concept has not been previously used in alliance projects especially in NZ. The construction industry in NZ is relatively small compared to other developed countries. The research is restricted to a limited number of samples due to a lack of alliance projects in NZ.

In summary, the interpretivist paradigm is more suitable due to the context dependent nature of the problem, limited knowledge in Lean and limited alliance projects in NZ. The features of the two perspectives, positivist and interpretivist, are summarised in Table 4.1. The criteria chosen for this study are shaded.

Table 4.1: Features of positivist and interpretivist paradigm

Criteria	Positivism	Interpretivism
Assumptions	Objective world which science can 'mirror' with privileged knowledge	Inter-subjective world which science can represent with concepts or concepts of actors
	Observer is independent	Observer is part of what is observed
	Science is value free	Science is driven by human interests
Emphasis	On measurement and scientifically proven results	Understanding and interpreting meaning, role of language and understanding
Nature of knowledge	Verified hypotheses established as facts or laws	Non-falsified hypotheses that are probable facts or laws
Goal of paradigm	Uncover truth and facts as quantitatively specified relations among variables	Describes meanings, understands members' definitions of the situation, examines how objective realities are produced
Nature of knowledge or form of theory	Verified hypotheses involving valid, reliably and precisely measured variables	Hypothesis generating, Abstract descriptions of meanings and members, definitions of situations produced in natural contexts
Criteria for assessing research	Internal validity, external validity, reliability, dependability	Credibility, transferability, dependability and conformability
Researcher should	Focus on facts Look for causality and fundamental laws Reduce phenomena to simplest elements Formulate hypotheses and then test them	Focus on meanings Look at the totality of each situation Try to understand what is happening Develop ideas through induction from data
Research method characteristics	Taking large samples Largely using quantitative methods Operationalising concepts so that they can be measured	Small samples investigated in depth or over time Largely using qualitative methods Using multiple methods to establish different views
Research method	Experiments, Questionnaire survey, secondary data analysis, quantitatively coded documents	Field studies, participant observation, interviews, case studies,
Type(s) of analysis	Regression, Likert scaling, structural equation modelling	Conversational and textual analysis, expansion analysis, grounded theory development

4.5 RESEARCH STRATEGIES

According to Yin (2003), applying a suitable research strategy for a particular study depends on the research question, the control over the actual behavioural elements and the degree of focus on historical or contemporary events (Table 4.2). The second column of Table 4.2 explains the form of question. These questions can be addressed by most research strategies with varying degrees of efficiency. For example, ‘how’, ‘what’ and ‘where’ questions are well addressed through surveys and historical accounts. Case studies are suitable for ‘how’ and ‘why’ type questions. However, other strategies are also used to investigate ‘how’ and ‘why’ type of research questions. Control over behavioural events and focus on contemporary events offer necessary demarcation. For example, archival analysis is best used where there is no ability to control or focus on contemporary events. In contrast, there is scope for control and to manipulate events in experiments. Nevertheless, Yin’s (2003) classification does not cover all the research strategies such as action research and Delphi study.

Table 4.2: Research strategies and their characteristics

Source: (Yin, 2003)

Strategy	Form of question	Focus on current events	Requires control over behavioural events
Experiments	How, why	Yes	Yes
Survey	How, what, where, how many/much	Yes	No
Archival analysis	How, what, where, how many/much	Yes/No	No
History	How, why	No	No
Case study	How, why	Yes	No

A significant factor of research includes thoroughness and appropriateness of the research strategy. Another approach of identifying the most appropriate research strategy is eliminating the research strategies that are not suitable for the particular study. Many authors have argued that each research strategy has its own pros and cons. Therefore, a number of research strategies are assessed for the aptness to the research objectives. Meredith et al. (1989) have explained a distribution of research strategies, which should be selected in accordance with the nature of the research problem (Table 4.3). The distribution covers most of the available research strategies. An appropriate strategy for the research was selected from the distribution as explained in section 4.5.2.

Table 4.3: Distribution of research strategies

Source: (Meredith et al., 1989)

Research Problem / Research Paradigm	Direct Observation of Object Reality	People's Perception of Object Reality	Artificial Reconstruction of Object Reality
Logical positivistic/ Empiricist	(A) Field studies Field experiments	(C) Structured Interviewing Survey research	(E) Prototyping Physical modelling Experiment Simulation
Interpretive	(B) Action research Case studies	(D) Historical analysis Delphi Expert panels	(F) Conceptual modelling Hermeneutics

The frequently used research strategies in construction research are surveys, cases studies, experiments, action research and ethnography (Fellows & Liu, 2008). The following section describes these different research strategies while section 4.5.2 evaluates the suitable strategies for this research.

4.5.1 Types of research strategies

Experiments

Experiments are best suited to testing theories or theory refinement (Stuart, McCutcheon, Handfield, McLachlin, & Samson, 2002). An experiment strives to discover a phenomenon from its context so that it focuses only on a few variables. Experimental research is divided into true experiments, quasi-experiments and pre-experimental design (Walliman, 2006).

Experiments are extensively used in physical and social sciences. Meredith et al.'s (1989) study showed that 70 % of the peer reviewed journal articles in operational management have used experimental research. This is mainly due to the fact that researchers have established the mentality that a study is of greater quality if it contains experimental design (Ross & Morrison, 2004). However, with realistic operational issues, it is difficult to conduct experiments if organisations, large systems or actual managers are involved.

Action based research

Action research creates an organisational change through process studies while other research methods study organisational phenomena without changing them at the same time (Myers, 2008). This method is widely used as it is grounded in action and aims at solving an immediate problem situation while updating theory (Coughlan & Coghlan, 2002).

There are five phases in action research. They are (1) diagnosing, (2) action planning, (3) action taking, (4) evaluating and (5) specifying learning (Baskerville & Wood-Harper, 1996). Action research is appropriate when the research questions are related to describing a series of actions that are taking place over time in a group or an organisation (Coughlan & Coghlan, 2002). It is strongly oriented towards collaboration and change involving both the researcher and the subjects. Action research is especially powerful as an instrument for researchers who are interested in finding out about the interplay among humans, technology, information and socio-cultural contexts. Action research may include all types of data collection methods but interviews and surveys are the commonly used methods (Coughlan & Coghlan, 2002). The main limitation of this strategy is the difficulty in finding resources and in accessing organisations to conduct the research.

Survey approach

Survey research is typically used to validate models or hypotheses (Kock , McQueen, & Scott, 1997) and it is valid in situations where direct manipulation of variables is either unfeasible or unethical (DeMarrais & Lapan, 2004). Survey research is a way of collecting information from individuals (Forza, 2002). These data are analysed using statistical techniques.

Survey research is a process of collecting sample data from a larger population and making comments about the population based on the sample. Usually, the sample is large enough to allow extensive statistical analyses. Often the survey method offers only a ‘snapshot’ of the situation at a certain point in time, resulting in little information on the underlying phenomena (Gable, 1994). Within survey research a distinction is often made between descriptive, analytical and exploratory survey research (Forza, 2002) and their characteristics are shown in Table 4.4.

Survey research requires rigorous planning because once it is underway it cannot be changed during the process of data gathering. A major criticism of survey research is that survey researchers assume all respondents interpret questions in the same way (DeMarrais & Lapan, 2004). Moreover, some variables of interest to a researcher may not be measurable by this method. Researchers use several techniques to mitigate these limitations such as pre-testing and pilot-testing the questionnaires with selected groups.

Table 4.4: Characteristics of three types of survey research

Source: (Pinsonneault & Kraemer, 1993)

Element	**Exploration**	**Description**	**Analysis**
Research design			
Survey type	Cross sectional	Cross sectional	Cross sectional/ longitudinal
Research method	Multiple methods	Not necessary	Multiple method
Unit(s) of analysis	Clearly defined	Clearly defined and appropriate for the question/hypotheses	Clearly defined and appropriate for the question/hypotheses
Respondents	Representative of the unit of analysis	Representative of the unit of analysis	Representative of the unit of analysis
Research hypothesis	Not necessary	Question/hypotheses clearly stated	Question/hypotheses clearly stated
Design for data analysis	Not necessary	Inclusion of antecedent variables and time order of data	Inclusion of antecedent variables and time order of data
Sampling procedure			
Representativeness of sample frame	Approximation	Explicit, logical argument, reasonable choice among alternatives	Explicit, logical argument, reasonable choice among alternatives
Representativeness of the sample	Not a criterion	Systematic, purposive, random selection	Systematic, purposive, random selection
Sample size	Sufficient to include the range of the phenomena of interest	Sufficient to represent the population of interest and perform statistical tests	Sufficient to test categories in theoretical framework with statistical power
Data collection			
Pre-test of questionnaires	With sub-sample of sample	With sub-sample of sample	With sub-sample of sample
Response rate	No minimum	60-70% of population	60-70% of population
Data collection methods	Multiple methods	Not necessary	Multiple method

Case study research

A case study is used in social science and the management field. Yin (2003) defined a case study as “an empirical inquiry that investigates a contemporary occurrence within real life context, especially when the boundaries between phenomenon and context are not clearly evident". Under this strategy data are collected from a few organisations through observation, questionnaire and interview. Case studies are used to present description, test theory and develop theory from practice (Eisenhardt, 1989). Flyvbjerg (2006) noted that case studies offer depth and richness relating to a given situation. Also, case study research is apt to research a new theory or research problems which are at early stages (Cepeda & Martin, 2005). Eisenhardt (1989) developed a process to conduct an inductive case study approach with eight steps (Table 4.5).

Table 4.5: Process of building theory from case study research

Source: (Eisenhardt, 1989)

Step	Activity	Reason
Getting started	Definition of research question	Focuses efforts
	Possibly a priori constructs	Provides good ground for measuring
	Neither theory nor hypothesis	Retains theoretical flexibility
Selecting cases	Specific population	Sharpens external validity
	Theoretical, not random, sampling	Focuses on theoretically useful cases
Crafting instruments and protocols	Multiple data collection methods	Strengthens grounding of theory by triangulation of evidence.
	Combines qualitative and quantitative data	Synergistic view of evidence
	Multiple investigators	Fosters divergent perspectives
Entering the field	Overlap data collection and analysis, including field notes	Speeds up analysis and reveals adjustment to data collection
	Flexible and opportunistic data collection methods	Allow investigators to take advantage of emergent themes
Analysing data	Within-case analysis	Gains familiarity with initial theory generation
	Cross-case pattern search using divergent techniques	Forced to look beyond initial views and see evidence through multiple lenses
Shaping hypotheses	Iterative tabulation of evidence	Sharpens construct definition/ validity
	Replication, logic across cases	Confirms, extends, and sharpens theory
	Searches evidence for 'why'	Builds internal validity
Enfolding literature	Comparison with conflicting literature	Builds internal validity, raises theoretical level and sharpens construct definitions
	Comparison with similar literature	Improves construct definition, generalizability and theoretical level
Reaching closure	Theoretical saturation when possible	Ends process when marginal improvement becomes small

Case studies can be divided into three types: exploratory, descriptive and explanatory (Table 4.6). An exploratory case study is aimed at defining the questions and hypotheses of the study (Yin, 2003). A descriptive case study offers a complete description of a phenomenon within its context (Yin, 2003). An explanatory case study presents cause and effect relationships of the data and explains how events occurred (Yin, 2003). Case study research can be carried out using a single case or multiple cases. Yin (2003) suggests single case studies are appropriate for the exploratory nature of a problem, whereas multiple case designs are desirable for descriptive or explanatory case studies. One case can also include several sub-cases or embedded cases, which are investigated within a larger case. Benbasat, Goldstein, and Mead (1987) suggest that multiple case designs allow for cross case analysis and the extension of theory. Case studies can be performed in combination with both ethnographic research and action research (Fellows & Liu, 2008) .

Table 4.6: Characteristics of three types of case study research

Sources: (Yin, 1994; Yin, 2003) and (Stake, 1995), compiled by the author

Item	**Case study type**		
	Exploratory	**Descriptive**	**Explanatory**
Approach aim	Defining the issues of sub-sequent study	Complete description of a phenomenon within context	Presenting a causal relationship
Case study selection	Site that represents each important variation	Typical and representative of diversity	Representative of important variations
Theories	Search for causal theories	Requires theory to guide data co-location	Search for explanatory theories
Nature	Intrinsic	Instrumental	Instrumental
Number of cases	Single	Single	Collective
Unit/s of analysis	Holistic unit of analysis	Sub-units/holistic unit of analysis	Sub-units/holistic unit of analysis
Data collection	On-site observation, not to be longitudinal	Published documents and observation	Visual evidence
Data analysis	Closely concurrent with field work	Pattern-matching techniques	Concerned with data quality and meaning
Drawbacks	Extended exploratory phase, poor coverage of diversity, over interest in evaluator's guesses	Failure to take diverse views, competence of all on-site observers may not be high, costly due to study size	Insufficient time on site for in-depth study, inadequately represented situations

Benbasat et al.(1987) identify three strengths of case study research as,

- can learn about the state of the art and generate theories from practice,
- allow the researcher to understand the nature and complexity of the process and
- gain valuable insights into new topics emerging in the rapidly changing field.

Lee (1989) identifies issues with case study research namely a lack of controllability, deductibility, repeatability and generalizability. An often cited weakness of the case study method is the difficulty of generalizing because of inherent subjectivity (Darke, Shanks, & Broadbent, 1998; Flyvbjerg, 2006; Gerring, 2007). This is mainly because case studies are based on qualitative and subjective data i.e. are generalizable only to a particular context. By implementing some research procedures this limitation could be eliminated. These are extending the data gathering time on site, employing a variety of data collection methods, counter checking with the research participants, peer reviews and external audits (Creswell & Miller, 2000).

Ethnography

Ethnography focuses on applying insights from social and cultural anthropology to the direct observations of socio-cultural phenomena (Hammersley & Atkinson, 2007). Therefore, it is a qualitative research approach which is carried out in a natural setting to present the perspectives of participants (LeCompte & Schensul, 1999). The main difference between case study and ethnography approaches is the extent to which the researcher immerses himself or herself in the life of the social group under study (Yin, 2003). In case studies, the primary sources of data are interviews, supplementary documentary evidence such as annual reports and minutes of meetings while in ethnography, the data sources are supplementary data collected through participant observation. The researcher becomes a part of the community during the study and observes the behaviour and participants' statements to understand what, how and why patterns occur (Hammersley & Atkinson, 2007).

Ethnographic studies provide rich information about a culture and insights into its reactions and interactions (Houser, 2007). This is mainly due to its observational nature that allows the researcher to record the behaviour and consequently the findings are more realistic. Generally, this approach takes a longer period to collect data, analyse them and write the final report (Myers, 2008) resulting in possible out-dated findings. Fellows and Liu (2008) mention that the results of this method could be uncertain mainly due to the presence of the researcher. Moreover, the information collected from an ethnographic study is often very difficult to translate into tangible results (Houser, 2007). Another limitation of this research strategy is the difficulty in generalizing the findings as the study is conducted in a specific setting so that the result might not be applicable to other settings (Harvey & Myers, 1995). This limitation could be overcome by using a procedure to enhance the external validity such as conducting multi-site studies and increasing the scope of the study group. Advantages and disadvantages of each research strategy discussed by the above authors are summarised in Table 4.7.

Table 4.7: Advantages and disadvantages of research strategies

Approach	Design	Advantages	Disadvantages
Quantitative	Experiment	Allow researcher to control the situation	Situation is artificial, and results may not generalize
		Permit researcher to identify cause and effect and distinguish experiment and control group effects	Validity issues due to experimenter effects and participant dropouts
		Enable to examine the effects of more than one independent variable on the dependent variable	
Qualitative	Case study	Expand the knowledge in modern phenomena within its real context	Lack of rigor due to researcher bias
		Offer depth and richness information	Provide little basis for statistical generalization
		Can study unusual, unethical or impractical cases	Lack of controllability, deductibility and repeatability
	Action research	Bridging the gap between theory, research and practice	Lack of control for researcher
		Cyclical approach increases the generality of the findings	Lack of rigor due to researcher bias
		Empowerment to all participants	Time consuming and complex
	Survey	Provide a large amount of information	Generalizability dependent on design of the sample
		Expand the knowledge about the effect of specific variables	Responses may be inaccurate
			Low validity in close ended questions
	Ethnography	Provide more complete perspective	Time consuming
		Understand behaviours within their natural environment	Uncertainty and out-dated results Observations may be biased
			Lack of generalizability

4.5.2 Strategy of this research

Based on section 4.5.1, an appropriate research strategy was selected to achieve the objectives of the research. According to the research objectives, the researcher explored reasons for operational deficiencies that exist in alliance projects from a lean perspective. The literature review (section 2.5.4) shows that alliances might not achieve the expected level of performance due to operational level interferences. Still, those interferences were not revealed in previous studies. Therefore, this study begins by exploring the current operational waste in alliances. The main research questions (section 1.5.3) are 'what' and 'how' type questions. The 'what' type of research questions justifies exploratory studies (Levy, 1988). Nevertheless, as an exploratory study, any of the five research methods mentioned in Table 4.2 can be used (Yin, 2009).

From the literature review and initial discussions with subject matter experts and academics, it is understood that the alliance and lean concepts are relatively new to NZ. Due to the limited number of projects a large sample population is not feasible. The second condition in Table 4.2, that was present in the current study, is that the events being examined are contemporary. According to Yin's (2003) classification shown in Table 4.2, survey, archival analysis and history strategies are eliminated for this study.

Further according to Yin's (2003) classification, only case study or experiment strategies are suitable for this study. The main difference between those two strategies depends on the ability to control behaviour. In experiments, an investigator manipulates behaviour directly, precisely, and systematically (Yin, 2009). Moreover, in some case study approaches where participant-observation is used as data collection an informal manipulation can occur (Yin, 2009). In order to conduct a field experiment, the process variables of alliance projects should be under the control of the researcher. In this study, the researcher acted as an observer who was not an employee of the alliance project and only interested in generating a more complete understanding of the different processes of the case study project. Therefore, direct and systematic control would not be within the practical reach of the researcher in terms of either time or more particularly business constraints. Therefore, the choice of an experimental approach was rejected because the nature of the industry and the research questions of this study prevent the use of controlled behavioural events.

Yin's (2003) classification does not cover all research strategies. Therefore, Meredith's et al. (1989) classification (Table 4.3) was also used to identify an apt research strategy for this study. Section 4.4.3 showed that the philosophical position and underpinnings of this research was interpretivistic. Therefore, the research strategies shown in the (A), (C) and (E) cells of Table 4.3 were inappropriate for this research.

The literature review in chapter two demonstrates that alliance contracts are not widely applied in the NZ construction industry. Utilising evidence and data from historical implementation of lean principles and practices would be highly desirable in order to create a 'benchmark' of performance. In the context of alliances using lean principles generally, there is a relatively small group of potential experts worldwide. In the special context of the NZ construction industry there have been only 12 historic alliance projects delivering exclusively road related projects. Consequently, the total available experts to undertake Delphi type research are both minimal and self-referential. With this in mind these techniques were not used due to being problematic and a potential source of bias in the research project. Therefore it was not possible to get valid answers from practitioners; hence the cell (D) of Table 4.3 was also eliminated.

The major demarcation of the remaining cells, (B) and (F), depends on the natural-artificial dimension of the framework for the research. The nature of the research questions required an investigation of the existing operational waste in alliances in terms of Lean. Based on epistemological assumptions, field studies are more appropriate for analysing the nature of alliances because they are more contextually defined and construction management is a practical subject. Therefore, a natural dimension of the research framework was selected and a case study strategy was used for this research.

The selection of a case study methodology was furthermore reinforced by Benbasat et al. (1987), who consider a case study is feasible for research which tries to understand complex processes. Uniqueness of a phenomenon (i.e. alliance projects are complex and Lean and alliances are new to the NZ construction industry) provides a sound basis for choice of the focused, in depth case study approach.

The initial stage of this research paid attention to exploring the issues in an alliance project using the exploratory case study approach. After investigating the issues, the researcher proposed certain changes to merge Lean with alliancing and discussions with management regarding those changes gave new insight in alliance management practices. McCutcheon and Meredith (1993) suggest a case study as a good strategy to study how some of the operational systems interact with each other. Therefore, this study selected the case study approach.

4.5.3 Mixed methods and triangulation

The study comprises both quantitative and qualitative techniques in order to explore and test the applicability of lean concepts in an alliance project. However, within the interpretivist approach and when the research problem has not been studied before, it is suggested that the qualitative technique is more appropriate as the study will expose more realties (Guba & Lincoln, 1994). However, using some quantitative data about a complex problem, allows more robust evidence based implications to be drawn.

In this research study it was identified that using a quantitative method (questionnaire) would overcome the limitation of the qualitative methods (e.g. process study observations and semi structured interviews) in establishing their validity and reliability. Statistical data from the questionnaire in this work could enable the generalisation of certain themes / constructs found in the qualitative materials. On the other hand, qualitative findings would add breadth and depth to the constructions of the reality of the selected case study project. Driven by the above arguments, the study used a model of exploring qualitatively the social construct of the reality of alliance participants' role in lean implementation and then testing them quantitatively by the questionnaire and deductively against the existing literature.

This allows a level of methods triangulation to take place and considering the chronological model of triangulation, the following methods have been used:

- Process study observation at southbound construction phase and informal discussion with site workers
- Documentary review (e.g. method study statement, production schedule meeting minutes)
- Follow up meeting and discussion with site management

- Follow up process study at northbound construction phase
- Interviews with top management
- Questionnaire with middle level management
- Validation interviews with subject matter experts

In order to address the research aim, process study observations and informal discussions were used first at the southbound construction phase. This is in order to inform the development of the interviews and questionnaires with management. Moreover, the key gap in the observation method is that participants could change their behaviour, which is referred to as the "Hawthorne effect" and thus data validity are threatened. Using data from other methods allowed the researcher to verify the credibility of such data.

4.5.4 Selecting a case study

Selecting cases is a difficult process. Stake (1995) claimed that the selection offers the opportunity to maximise what can be learned, knowing that time is limited. Therefore, this research paid attention to selecting the right type of case study. The research aim and questions guided the researcher during the selection of a proper case study research structure as explained in Table 4.8.

Table 4.8: The relationship between research question and case structure
Source: (Stuart et al., 2002)

Purpose	Research question	Research structure
Discovery: uncover areas	What is going on? Is it interesting enough to research?	In-depth case study Longitudinal case study
Description: explore territory	What is happening? What are the key issues?	In-depth case study Longitudinal case study
Mapping: identify critical variables	What are the key variables? What are the key themes or patterns?	Focused case studies In-depth field studies Multi-site case studies
Relationship building: identify linkages between variables	What are the patterns that link the variables? Can an order in the relationships be identified? Why do these relationships exist?	Focused case studies In-depth field studies Multi-site case studies

The initial phase of the research detected and measured the waste in an alliance project. According to Stuart et al.'s (2002) classification, the purpose of this research satisfies the discovery and description characteristics. Therefore, the research structure should be an in-depth and longitudinal case study.

Due to a lack of alliance contracts in NZ particularly in the Auckland region, the researcher selected a longitudinal study of a single project. The nature of the alliance project offered the opportunity to study several contexts within the case study with different project participants. Yin (2003) suggested criteria to justify the use of a single case as:

- the case is rare or extreme and finding other cases is highly unlikely
- the revelatory case provides unusual access for academic research and
- the case is a critical one for confirming, challenging or extending a theory, because it is the only one that meets all the conditions.

Alliance projects are infrequent around the world in general. In NZ, because the economy is very small in comparison with other leading developed countries, this is especially the case. The first alliance project in NZ began only as recently as 2001 in the Grafton Gully motorway extension (Lin, 2005). Since that watershed project, there have been only 13 alliance projects undertaken in NZ (Alliancing Association of Australasia, 2011b) – inclusive of the most recent Water-view connection project announced in 2012. On average only one new alliance project is announced on an annual basis in NZ. Consequently there are significant problems in identifying a suitable alliance project at an appropriate point (i.e. during construction with sufficient scope to demonstrate improvements during the construction process). Considering these aspects it can be reasonably stated that the research fulfilled the first of Yin's (2003) criteria. The case study situation was rare with limited scope for considering alterative data sources.

Over and above the rarity of the specific alliance case, it was possible to negotiate through industry contacts of the university extensive access for the researcher to the critical phases of the construction process. This was historically unique for an academic researcher. No previous researcher (e.g: (Lin, 2005) and (Masurier, Wilkinson, & Shestakova, 2006)) who has published academic work reporting on the functioning of alliance contracts in NZ has been allowed as extensive access as that provided to this study. Consequently it can be stated that the research project fulfilled the second of Yin's (2003) criteria in that the case study provided unusual and revelatory access for the researcher.

Thus the findings had the potential to significantly contribute to the body of knowledge on alliances, particularly within the NZ context.

In addition to the points mentioned above, in order to conduct such work in NZ it was essential to identify an alliance project at an appropriate stage of development. When the research initiated the work, four alliance projects were under development or construction in NZ. All of these projects were based around the Auckland region, which made accessibility significantly easier for the researcher. These projects included:

- Victoria Park Tunnel
- Manukau Harbour Crossing
- Newmarket Viaduct
- Waterview Connection Project

Each of these projects was evaluated by the researcher for its suitability for conducting research. When the project began, both the Victoria Park and the Manukau harbour crossing projects were in the later stages of development, with the vast majority of the construction work having been completed. Consequently both of these projects did not offer reasonable scope to conduct extensive research in lean construction methods. Conversely the Waterview project had been essentially ‘parked’ for a period of time as a result of funding concerns and planning problems (Dearnaley, 2010; New Zealand Press Association, 2010). Indeed the final go-ahead for the project was not given until the later part of 2011 (New Zealand Press Association, 2011). As a result the Waterview project was similarly deemed to be non-feasible for the conduct of extensive research. The only alliance project under development within the window of opportunity for the conduct of this research project was the Newmarket Viaduct project that started in 2009. It was considered therefore that the project would provide a unique opportunity to evaluate current NZ capability in the delivery of alliance projects. Notwithstanding the problems of a lack of generalizability from any results obtained, the opportunity was critical to extending current knowledge of the NZ alliance contracting ability. This in turn considered as essential since alliancing (in the form of PPPs) has been so frequently cited as offering the opportunity for the country to upgrade its deteriorating infrastructure in the most resource efficient manner (Ross, 2003;

Walker et al., 2002) Therefore all three criteria mentioned by Yin (2003) are met in the current study.

Single case study research has limitations. The first is the limit of the generalizability of conclusions, models or theory developed from one case study (Kennedy, 1979). The second one includes the risks of misjudging a single event, and of overstating easily available data (Voss, Tsikriktsis, & Frohlich, 2002). In order to reduce those limitations the researcher conducted five process studies with diverse characteristics (Section 5.4) and used different data collection tools. Furthermore, the conclusions made from the case study were validated by considering experts views to improve external validity.

4.5.5 Unit of analysis

The unit of analysis is a critical factor in a case study. The research purpose, questions, propositions and theoretical context determines the unit of analysis (Rowley, 2002). The research questions of this study (section 1.5.3) are directed towards improving alliance performance through a case study. Therefore the project site becomes central to this research as being the unit of observation and the main unit of analysis. This study contains multiple units of analysis since the research was conducted in a longitudinal manner by observing different sub-processes over time. Sub-processes included in this study are pre-cast segment production, parapet construction, column deconstruction, deck deconstruction and deck construction. These sub-processes become smaller units of analysis embedded into the main unit of analysis.

4.6 RESEARCH APPROACHES

Once the research strategy is chosen, it is appropriate to select the techniques for data collection. A wide variety of data collection methods is available under the case study approach. Yin (2003) identifies six sources of evidence in case studies namely documents, archival records, interviews, direct observation, participant-observation and physical artefacts. Yin (2003) further states that a major strength of a case study data collection is the opportunity to use many different sources of evidence. In order to increase the quality and the validity of the case study research Johnston, Leach, and Liu (1999) suggest using more than one data collection method.

4.6.1 Combining the research approaches

Selfe (1985) argues that a combination of several such methods should be used to gather data in case studies since the indirect observation provides only an incomplete reflection of the complex set of processes. Kaplan and Duchon (1988) note a variety of data collection methods that can be applied to case study research namely questionnaire, interview and observation. This approach is known as triangulation and it has been commented on by a number of authors (e.g.: (Saunders, Lewis, & Thornhill, 2009; Stake, 1995; Travers, 2001; Yin, 1994)). This multi-method approach to data collection is also supported by Mathison (1988) stating the flaws of one method are often the strengths of another (Table 4.9).

The combined advice of these authors was pursued in the selection of the data collection methods for this research, which included participant observation, interviews, questionnaire and project related documents (e.g.: method statements, project schedule and project performance). Each data collection methods used in this research (section 4.6.3) could be considered as a part of the overall approach to improving the quality and validity of the research.

4.6.2 Types of research approaches

Participant observation

Marshall and Rossman (2010) defined observation as the systematic recording of events, behaviours and artefacts in a social setting. The data gathering tools under observation are natural conversations, interviews, checklists and questionnaires (DeWalt & DeWalt, 2002). Observation methods are useful to researchers in a variety of ways. Jorgensen (1989) notes that observation methods provide researchers to check for nonverbal expression of feelings of participants, determine who interacts with whom, grasp how participants communicate with each other and check for how much time is spent on various activities. As a result, it allows detail descriptions of natural settings and it provides opportunities for viewing unscheduled events. Waddington (2004) identifies ethical problems and participant distraction as disadvantages of this method. Jorgensen (1989) notes access difficulties and being time consuming as limitations of observation approach.

Document analysis

Document analysis is a way of collecting data by reviewing existing documents. Document review can be used to collect background information like history and operation of the organisation under study. Documents include reports, program logs, performance ratings, meeting minutes and newsletters in electronic or hard form. Bowen (2009) identified document analysis as an efficient and cost effective method because document analysis does not depend on the availability or participation of certain groups of people. Insufficient details, low retrievability and biased selectivity are identified limitations of this method (Bowen, 2009).

Semi- structured interview

Interviews provide the researcher with information from a variety of perspectives (Patricia, 2004). There are different kinds of interviews, which can be identified in the literature namely structured, semi-structured and un-structured (Fellows & Liu, 2008). The more structured the interview, the easier is the analysis. Semi-structured interviews allow participants to express their views in their own terms. Creswell (2009) Identified limitations of this method as being time consuming and not very reliable due to the small sample size and analysis difficulties of qualitative information. Yin (1994) suggest improving the skill of the interviewer because the quality of results depends on it. Seidman (2012) provided a detailed guide for conducting interviews as a data collection technique and it covers preparation, interview execution, recording and analysis stages.

Questionnaire

The observation findings influence the development of questionnaires. Bogdan and Biklen (1982) define a questionnaire as a list of questions sent to a number of persons to answer. Questionnaires include the types and number of variables that can be studied, require minimal investment to develop and administer and are relatively easy for making generalizations (Glasow, 2005). Therefore, questionnaires are cost effective when compared to other data collection methods as they cover a wider geographical area. A questionnaire needs to be designed in such a way that ideas are easily conveyed to the respondent. By incorporating scales in a questionnaire, the analysis becomes more structured.

Table 4.9 summarises the merits and demerits of different data collection approaches.

Table 4.9: Merits and demerits of different data collection approaches

Approach	Merits	Demerits
Observation	Covers events in real time	Time consuming and expensive
	Covers context of event	Event may proceed differently when it is being observed
	Useful in exploring uncomfortable topics	Bias due to investigator's manipulation
	Provides detail assessment of activities	Not appropriate for all situations
	Provides information previously unknown to researcher that is crucial for research	Hard to obtain access
		Relies on memory, personal discipline and diligence of researcher
Questionnaire	Good for measuring attitudes and eliciting other content from participants	Time consuming to analyse open ended questions
	Can conduct statistics	Low response rate for long and poorly designed questionnaires
	Inexpensive	Might have missing data
	Quick turnaround	Possible reactive effects
	Can be directed at groups	Non response to certain items
	Perceived anonymity by respondents possibly high	Response rate possibly low for mail questionnaire
	High measurement validity for well-structured and well tested questionnaires	Open ended items possibly resulting in vague answers
	High response rate for close ended questionnaires	Open ended items possibly reflecting differences and may be unclear
	Easy to analyse close ended questions	Needs validation
Interview	Focuses directly on case study topic	Bias due to poorly constructed questions
	Provides perceived causal inferences	Response bias due to interviewer presence
	Informants can provide historical information	Provides indirect information
		Inaccurate due to poor recall
	Allows researcher control over the line of questioning	Not all people are equally articulate
		Limited reflexivity
Documents	Can be reviewed repeatedly	Irretrievability
	Unobtrusive, broad coverage	Access may be deliberately blocked
	Saves time and expense of transcribing	Interpretive validity possibly low
	Contains exact details of an event	Materials may be incomplete
	Ease of data analysis	Biased selectivity, if collection is incomplete

4.6.3 Data collection for this study

Data collection is a vital phase of research. Therefore, in this study a detailed plan of data collection methods was prepared. Since case study research generates a large amount of data from multiple sources, systematic organisation of the data is assured. Selected main data collection tools included participant observation, document analysis, questionnaire and semi- structured interviews.

Participant observation

Observation was chosen as an initial method of data collection to explore the existing deficiencies in alliancing (research question 1). The researcher acted as an observer who is not an employee of the alliance project and is only interested in generating a more complete understanding of the different processes of the case study project. Informal conversations and interactions with members of the study population were also important components of this method. The observation tool is used to measure activity composition and causes for waste in each process. There are several steps involved in this method and further details are explained under section 5.3**.** During the data collection stage, every process was observed at least three times and the sample size was determined by using Equation 4-1.

$$\sigma_p = \sqrt{\frac{pq}{n}} \qquad \textbf{Equation 4-1}$$

Where, $\sigma_{p=}$Standard error of proportion

p= Percentage of occurrence

q= Percentage of non-occurrence

n= Number of observations or sample size

A preliminary study was carried out to determine the percentage of occurrence of an event. At a 95% confidence level with a 10% margin of error, σ_p was obtained from statistical tables. The required number of observations was obtained from the above equation. The accuracy level of each observation was validated by using a nomogram (Appendix L) method provided by Kanawaty (1992). For every process the accuracy level was determined. This methodical triangulation of expert opinion, statistical approach and nomogram method, improved the generalization.

Participant observation was designed to gain more details about the deficiencies existing in each process and causes of those deficiencies. For each process study, all the process steps were observed and activities categorised based on the rule developed in Figure 5.4. The work study techniques used as a main tool for time measurements in quantifying process waste in an alliance project and the full description of data collection are explained in section 5.3.

The observation method covered the five main processes, namely pre-cast segment production, parapet construction process, deconstruction of the deck, pier and column deconstruction and deck construction (Table 5.3). The processes are selected based on process characteristics, process performance, project programme and safety restrictions. The process and the process practices were observed for a period of approximately 650 hours on site to identify improvement opportunities and follow-up meetings were conducted with process owners.

At the beginning of each process study, information about current work practices was gathered through discussions with project team members. Daily pre-start meetings and weekly look-ahead meetings were observed to get an insight of current practices and issues. Furthermore, a few lesson-learnt workshops and one team session were also observed to understand the actual problem solving sessions. Field notes were used as an on-going commentary to record what was happening in the project. All possible information was recorded without attempting to judge the importance of events at the time of recording, as it is difficult to know what may or may not be important in the future. Additional data were collected through emails with many informants, but predominantly from site engineers after site visits.

Documents analysis

In order to conduct a document analysis, project method statements, the training register, pre-start and lesson-learnt workshop meeting minutes were used. The project method statements and relevant meeting minutes were obtained from the relevant site engineer of the process. The training register was obtained from the construction manager. The method statements were used to collect background information of five processes under study. Documentary evidence was combined with data from interviews and observations to minimise bias and establish credibility.

Semi-structured interviews

The semi-structured interview method was selected to elicit details of issues identified in the process study observations and to identify current practices in the case study project. The interviews were conducted in two stages. In the first stage, the interviews were conducted with the particular alliance ALT members and the results from these interviews were used to design a questionnaire to be distributed among the middle level management of the project. In the second stage, the validation interviews were conducted with subject matter experts to confirm the findings of the study. All two types of interviews followed the detail guide in conducting interviews prepared by Seidman (2012).

In the initial interview stage, two separate types of interviews were conducted to identify project practices relating to worker participation and sub-contractor management practices. These interviews allowed free responses to specific questions, as the researcher needs to understand the perception of the participants. The potential respondents were selected based on:

- relevant experience in construction and alliance projects
- their involvement in a specific part of the alliance project and
- their relevant experience in the subject matter discussed in the interview.

In interviews, the interview guides (Appendix U, Appendix V and Appendix W) were prepared to improve ease of use. All remedial measures followed the interview guide design by incorporating open ended, clearly worded and neutral questions. Before each interview, interviewees were sent an e-mail describing the objectives of the interview along with the participant information sheet.

Initial interviews were conducted with nine ALT members of the case study project. A variety of questioning techniques were employed including the use of open questions to allow participants to define and describe a situation, closed questions to obtain information or to confirm a fact, or opinion and searching questions to explore responses (Saunders et al., 2009). Each interview lasted around 40-60 minutes. Interviews were conducted at mutually agreed places and were mostly held away from the participants' office to protect the privacy of the participants.

In some cases, the participant was interviewed multiple times for further clarifications and all interviews were digitally voice recorded. The voice recordings and notes were used in the analysis stage. After the interview, a transcribed interview report was prepared based on digital voice recordings and given to the participants to check for factual errors. This served four purposes, namely to gain agreement that the data captured reflected the interview held, to give an opportunity for further comments based on the feedback provided, to encourage on-going participation in the research and as a courtesy to the participants concerned to thank them for their role in the project. The feedback happened via two mechanisms namely an individual e-mail to the participant and face to face at a meeting arranged to suit the research participants. In all the interviews, the informants reviewed and approved the interview reports.

Questionnaire

A questionnaire was used to get a view of the middle level management relating to the identified process waste and behavioural waste in an alliance. The main reason for the selection of a questionnaire as a data collection tool was to get a true picture of the issues from the middle managers' point of view. The questionnaire was directed at all the middle level managers of the particular alliance project. Middle managers were selected for the following reasons:

- Middle managers interact with diverse workers and top management
- Middle managers make changes to the strategic and organisational systems
- Top managers in contrast are isolated from actual day-to-day activities and
- Little construction management research has been undertaken to find middle managers' perceptions.

The questionnaire was designed around the research objectives and developed in consultation with the research supervisors and relevant academics. The questionnaire consisted of five sections namely process improvement initiatives, employee participative culture, sub-contractor management practices, improvements in alliance projects and participants' information (Appendix E).

All possible remedial measures were followed in the questionnaire design; for example questionnaire wording (use simple wording, avoid ambiguous words, avoiding biased wording and double barrelled questions), incorporating close ended questions and question sequence. The demographic data of respondents were added at the end of the questionnaire to obtain a higher response rate as recommended by Dykema, Elver, Schaeffer, and Stevenson (2004).

The researcher also took a number of steps to encourage a high response rate namely focusing on readability, validity and reliability. Readability was obtained from the Microsoft Word readability statistics facility and obtained the standard limit of readiness scores (Appendix F). The reliability and validity of the survey were checked and improved by using the survey quality predictor (1.0) software recommended by Saris and Gallhofer (2007).

In order to ensure the clarity of the instructions and questionnaire items, the questionnaire was pre-tested with construction practitioners (four) and academics (two). Their feedback was solicited and questions were updated accordingly (Appendix G). In expectation of the busy schedule of the participants, the questionnaire was designed to take roughly 30-40 minutes to complete.

The questionnaire was administered online in an anonymous survey. Based on Gordon and McNew's (2008) study, an evaluation of possible online survey systems was conducted. Depending on survey requirements and based on flexible functionalities of survey design, distribution and analysis, the package SurveyMonkey (2012) was selected. Respondents were briefed about the nature of the study at their weekly meeting and were assured confidentiality and privacy of the information before asking for their responses.

The initial survey was open for two weeks. After that a follow-up e-mail was sent to increase the response rate. The questionnaire was sent out to 31 respondents, mainly engineers and supervisors for the case study project. Each of the participants was followed-up by e-mail to ensure a good response rate. A total of 27 responses were returned which represented an average response rate of approximately 87%. On completion of the questionnaire, a thank-you note was emailed to all participants.

All techniques, questionnaire and interviews obtained ethical approval from the university ethics committee (AUTEC) to assure an ethical conduct of this study. It is an important ethical consideration that participants should be informed about the aim of the research before the study commences through a participant information sheet (Appendix H and Appendix I). The sequence of data collection involved in the current study is shown in Appendix J.

The data analysis procedure for this study is discussed in the next section.

4.6.4 Data analysis techniques for this study

After all data had been gathered, it was analysed. The analysis procedure for each data collection tool is explained below.

Participant observation

After each process study, the data were analysed at process, activity and worker levels with the aim of identifying waste activities and their causes. The time study data were then entered into Microsoft Excel for ease of statistical and other calculations that are required to generate patterns. The analysis at this level of detail helps to provide a better understanding of the construction processes and areas where improvement efforts need to be focused. The causes for these activities were analysed with the use of lean tools. The activity composition of each process study was compared within and across process studies. The consolidated figures were obtained by a following meta-analysis procedure designed by Horman and Kenley (2005). The detail description for the data analysis of the process studies is explained in section 5.3.5.

After each process study observation, follow-up meetings were conducted with the purpose of validating study findings with process owners and testing the feasibility of process study recommendations. Five case reports were presented to the site management. This was done in order to further increase the researcher's insights and analyse the improvement prospects in the referred case study. The goal of this kind of discussion was to make everyone aware of process changes. The discussions of the process study findings have therefore been a critical step in the validation of the study results and their application to the case study project. During the follow-up meeting suggestions for improvement areas were identified by using the 'plus-delta' analysis, of which an example is contained in Appendix Q. Agreed suggestions were transferred to lesson learnt registers. Based on that, 'to-be' process performance parameters (Table 5.11) were calculated. A follow-up process study was conducted for all five processes of the study. During follow-up process studies implemented suggestions and other process changes were observed. Based on those observations 'after' process parameters were calculated (Table 5.12).

Documents analysis

After getting permission for access to required project documents, a thorough document analysis was conducted. Method statements for each process were accessed to get a general idea of the process activity breakdown and to analyse the differences between standard operational procedures and the actual working procedure at the site. Past pre-start and lesson-learnt workshop meeting minutes for five processes under study were used to identify participants in those meetings and matters discussed during the meeting. The training register (from 2010-2011) was used to identify training programme coverage for different worker levels. These meeting minutes and a training register were used to verify the observations made at the site during process studies.

Semi structured interviews

Qualitative data gathered through interviews can be analysed by using thematic, discourse and content analysis (Miles & Huberman, 1999). Thematic and content analysis are two commonly used approaches in data analysis of social science research (Vaismoradi, Turunen, & Bondas, 2013). Thematic analysis involves identifying themes and categorising the emerged data. The content analysis involves measuring the frequency of different categories and themes. Thematic analysis is highly qualitative and forms a basis for other qualitative analysis methods (Braun & Clarke, 2006). Thematic analysis is known as a flexible method compared to the other two methods as it does not fall into any extreme epistemological position (Braun & Clarke, 2006). In the current study, thematic analysis was used to analyse the interviews.

The interviews were transcribed by using transcription software, transcriptionf4. The transcription was convenient with this software due to its features like adjustable playback speed, automatic brief interval rewind and time stamps (Dresing, Dresing, & Schmieder, 2012). Data from the transcribed interviews were analysed to establish common themes or ideas that can inform a deeper understanding of the current practices in the alliance and their peculiar issues.

Questionnaire

For the questionnaire, the responses were transferred to a statistical software package for in-depth analysis. ‘SurveyMonkey’ automatically downloaded the data into an Excel file and these were used for analyses by Statistical Package for Social Sciences (SPSS) version18 (University of Central Florida, 2009). SPSS is one of the most widely used statistical software programmes for statistical analysis in social science research. Using SPSS 18 made quantitative analysis easy and more convenient.

Descriptive statistics were calculated and data relationships were analysed. Questionnaire results were measured by respondent category. Item analysis was conducted to determine the internal consistency and reliability of each individual item as well as each sub-scale. Cronbach's Alpha test was also used to test internal reliability. Mean, standard deviation and frequencies were used to identify agreements of views. Nonparametric tests were used to test the significance of the differences between the perceptions of the participant categories. Microsoft Excel was used to process the data into charts.

4.7 QUALITY CRITERIA FOR RESEARCH DESIGN

A certain amount of criticism exists of the quality of case study research. Guba (1981) proposes four scientific measurements to test the research quality namely credibility, transferability, dependability and conformability. Yin (2003) explains another four tests related to case studies as internal validity, external validity, reliability and objectivity and all four measurements are equivalent to Guba's measurement framework.

4.7.1 Reliability / dependability

Reliability concerns consistency of measures (Fellows & Liu, 2008) which contains external reliability and internal reliability. External reliability concerns the repeatability of the research. External reliability is most commonly used in the data collection of quantitative research (Yin, 2003). Internal reliability deals with the internal consistency of the research design. If the research is repeatable and produces the same results each time, this suggests that researchers have been able to detach themselves from the object of their research. Yin (2003) defines a case study protocol to improve the reliability of case study research. Shenton (2004) addresses the dependability issue by explaining the research design and its implementation as well as the operational detail of data gathering in the project. Furthermore, triangulation of various data collection methods also improves the reliability of research.

4.7.2 Validity

The validity refers to how well a researcher's ideas about reality 'fits' with actual reality (De Vaus, 2001). Subsequently, how well the validity is measured relies on how well the conceptual and operational definitions of variables mesh with each other. Yin (2003) defines three validity measures applicable for a case study research as construct validity, internal validity and external validity.

4.7.3 Construct validity / conformability

Construct validity considers whether the concepts and measures applied for studying phenomena measure what they are intended to measure. The main critique of the case study approach is a lack of construct validity due to subjective judgement used for data collection (Yin, 2003). Therefore, appropriate steps must be taken to ensure the elimination of researcher bias. Using multiple sources, establishing a chain of evidence and reviewing draft case study reports by key informants are ways to eliminate the researcher bias of a case study (Yin, 2003). Shenton (2004) also lists possible provisions that may be used by a researcher in order to improve conformability of research. They are admissions of the researcher's beliefs and assumptions, recognition of shortcomings of study methods and their potential effects and in-depth methodological description to allow integrity of research results. Strategies for enhancing conformability include searching for negative cases that run contrary to most findings and conducting a data audit to pinpoint potential areas of bias (Shenton, 2004).

4.7.4 Internal validity / credibility

Internal validity concerns the approximate truth about inferences regarding cause-effect or causal relationships. This could be achieved at the data analysis stage by using pattern matching, explanation building, addressing rival explanations and logical models (Yin, 2003). The researcher can improve the research credibility by adopting appropriate research methods, early familiarity with the culture of participating organisations, negative case analysis and the examination of previous research (Shenton, 2004). At the data collection stage, the research credibility could be improved by introducing different provisions such as random sampling of participants, debriefing sessions to the project organisation and triangulation of different types of informants and different sites (Shenton, 2004). Also, Shenton (2004) explains different provisions to improve credibility and those include use of reflective commentary, peer scrutiny of projects and comparison with previous research findings.

4.7.5 External validity / transferability

External validity refers to the generalizability of the study findings to other case studies (Yin, 2003). Single case studies have high internal validity with lack of external validity. Since the findings of a case study project are specific to a particular setting and participants, it is impossible to explain that the results are valid in other situations. According to Yin (2003), case studies rely on analytical generalization rather than statistical generalization. Collection of data in multiple case studies is also another technique to improve the external validity. This criterion is an assessment of the believability or credibility of the research findings from the perspective of the study participants. The inclusion of member checking into the findings, that is, gaining feedback on results from the participants, is one method of increasing generalizability.

4.7.6 How this research achieves quality criteria

The following measures were followed to ensure the quality of the research design. These measures were taken in three different phases of the study namely ‘define and design’, ‘collect and analyse’ and ‘conclude and present’.

Define and design

A number of steps were taken to ensure the quality of this research at this stage. Initially, as explained in previous sections (4.5.2 and 4.6.3) an appropriate research strategy and data collection techniques were used to improve the credibility of the research. At this point, the researcher already identified and stated the assumptions made in selecting methods and the reasons for favouring one approach over others. This approach will help the researcher to assess whether proper research practices have been followed. It will also ensure the conformability and dependability criteria of the research. Furthermore, this study followed the protocol for case study research developed by Yin (2003) which helps to improve the reliability of research.

Collect and analyse

At the data collection stage, the triangulation technique was used to reduce the effect of the investigator bias. Before conducting interviews and questionnaire data collection, the researcher conducted process studies, which provided a rich and grounded context for questioning current practices and beliefs. The reliability and validity of data were improved by following best practices during the questionnaire (SurveyMonkey, 2012) data collection stage. The questionnaire was pre-tested to ensure that the language was both appropriate and easy to understand. Different techniques were used (section 4.6.3) to improve the reliability and validity of the questionnaire.

Interviewees were sent an e-mail describing the objectives of the interview before each interview. A variety of questioning techniques were employed including open, closed and searching questions that add credibility to the research. In some cases, the participant was interviewed multiple times for further clarification and all interviews were digitally voice recorded. All interview transcripts were sent back to the participants to check for factual errors. All collected non-confidential data including site log books will be kept for six years which allows other researchers to examine and possibly replicate. The reliability of findings is enhanced by conducting discussions with subject matter experts.

Conclude and present

After analysing each process study observation, the findings were debriefed to the project participants through presentations and reports. This process enhances the validity and reliability of the research. Opportunities for feedback by colleagues, peers and academics were welcomed. The feedback at conferences, journals and fellow student meetings were taken into account to improve the research quality. This feedback enabled the researcher to refine research methods and strengthen the arguments. In order to improve credibility in the study results, a process of triangulation with techniques specified by O’Cathain, Murphy, and Nicholl (2010), was used. Table 4.10 summarises Yin’s (2003) recommended tactics covering four research quality criteria and also indicates the ways in which this case study responded to these recommendations.

Table 4.10: Case study tactics and responses

Source: (Yin, 2003), complied by author

Tests	**Case study tactic**	**Research phase**	**Action taken in this research**
Construct validity	Use multiple sources of evidence	Data collection	Use of process studies, interviews and questionnaire
	Establish chain of evidence		Maintain research notebook and customised database; Interview data both taped and transcribe
	Have key informants review draft report	Composition	Conduct follow-up meeting after process studies, Publications based on case study project reviewed by key informants before publication
Internal validity	Do pattern matching	Data analysis	Patterns identified across process studies
	Do explanation building		Use triangulation
	Do time series analysis		Not performed in this research, but under consideration as part of follow-up work
	Do logic models		Not performed - requires time series data
External validity	Use rival theories within single cases	Research design	Not used because of exploratory nature of the research
	Use replication logic in multiple-case studies		Multiple process studies conducted
Reliability	Use case study protocol	Data collection	Same data collection procedure followed for each process study; Consistent set of initial questions used in each interview
	Develop case study database		Interview transcripts, field study notes and questionnaire responses entered into database

4.8 LIMITATIONS OF THIS RESEARCH METHODOLOGY

This study is primarily based on a single case study of alliance practices in an alliance construction project in NZ. The main limitations of this study are lack of generalization of the findings beyond the domain of the case study. The statistical generalization can be improved by a critical case. A critical case is a case in which a theoretical proposition is expected to be extremely likely to be confirmed or not to be confirmed. However, to follow that approach a researcher requires having prior knowledge about whether a case is critical. Due to a lack of accessibility of alliance projects in NZ, this research study did not aim at identifying a critical case. However, the decision to use a single organisation avoids contradictory results that might arise from an inter-company study. Another expected limitation of this study approach relates to the usefulness of NZ based findings to the international community. The organisational features and practices from a small sample of NZ alliance participants may not have generalizability to the international community.

Another limitation has to do with the sample investigated. The small sample size and the organisational identity of the sample population may have influenced some conclusions. The sample size was limited in terms of the number and type of participants, which may influence generalizability. In accordance with Yin (2003), the view taken here is that generalizing the empirical findings of a case study relates to an analytical generalization, not to a statistical generalization. The concepts and perhaps even the causalities identified in this case study framework cover good practices and improvement opportunities in an alliance contract project and the applicability of a lean methodology in an alliance. Certain improvement suggestions can apply to construction projects irrespective of the procurement type. Therefore, there is an opportunity for generalizations of a theoretical framework in further empirical studies.

4.9 CHAPTER SUMMARY

This chapter clarified the logic behind the selection of the paradigm, approach, strategy and methods utilised in this research. The research method and techniques were chosen based on appropriateness, i.e. to answer the research questions and to meet the objectives of the research. The overall methodology followed the interpretivist stance and Table 4.11 highlights the major research design decisions in this research work. It employed the case study method as the primary research strategy to match research objectives, research questions and research conditions. The study used observation, document analysis, interviews and questionnaire as the main data collection methods. Quantitative or qualitative data analysis was performed depending on the data forms. The various limitations of the research methodology are discussed including details of the ethical concerns associated with the research. The next chapter reveals the findings of process study observations, as this approach has been the primary data collection method of this research.

Table 4.11: Overview of the research methodology

Philosophical position	
Research paradigm	Interpretivism
Theoretical base	Lean theory, alliance contracts
Research design	
Research strategy	Case study
Case study	Single and longitudinal
Research type	Applied, qualitative and exploratory
Data collection	
Selection of processes and participants	Purposive sampling
Observation	Five process studies
Interviews	Nine pilot interviews and five validation interviews
Questionnaire - Pre- test	Four construction practitioners and two academics
- Administered	27 middle level managers
Data analysis and interpretation	
Observation	Meta-analysis
Interviews	Thematic analysis
Questionnaire	Statistical analysis
Quality criteria for the study	
Credibility, transferability, dependability, conformability	
Ethical consideration	
Confidentiality, anonymity and trust, sensitive information treated as confidential	

5 PROCESS WASTE ANALYSIS

5.1 INTRODUCTION

Having discussed the theoretical issues of alliances and the suitability of Lean, this section explores improvement opportunities in a real alliance project. This chapter describes process improvement studies and their outcomes in the alliance project under study. The purpose of the process studies is to explore the level of process waste in an alliance project site at macro, micro and sub-micro level and the project participants' reactions to lean applications.

This chapter mainly focuses on 'process waste', which is the core of lean thinking. The data gathered across five processes are analysed to identify similarities and differences in the level of waste. One of the common lean tools called VSM was used in targeted processes. VSM is used to identify major sources of NVA time in the process and help to envision an improved future status by developing applicable lean practices. Work measurement techniques were used to quantify the process waste and to show the improvement potential with the application of Lean in an alliance project. Causes for these waste streams were analysed with the use of lean tools. After analysing the causes, various improvements strategies were developed with the collaboration of the site management.

Initial process studies were conducted at the southbound construction phase of the viaduct (Figure 5.1 (b) and (c)). After completion of each process study, the process study findings were validated through process study reports and presentations at follow-up meetings. The participants of the follow-up meetings were the construction manager, project engineers, site engineers and supervisors. After initial process studies, separate study visits were conducted to study the improvements achieved, the problems faced during implementation and the reasons for precluded improvements. These follow-up studies were conducted at the northbound construction phase (Figure 5.1 (d) and (e)).

As a research outcome, the five process studies have led to the development of a process improvement framework and guidelines for 'good practices' in implementing process improvement systems in alliance projects. The process improvement framework was developed by combining lean techniques and traditional industrial engineering tools such as method study and work measurement techniques. Barriers to implement and sustain such process improvement methodology in alliance projects were identified through a questionnaire. Participants for the questionnaire were the middle management of the selected case study. The research flow in Table 5.1 encapsulates the work undertaken related to the process waste analysis, methods used and the relevant section of this research investigation.

Table 5.1: Research flow in analysing process waste in an alliance project

Research steps	Methods	Section
Identify suitable five processes in southbound phase	Process selection was based on repetitiveness and criticality of the process	Section 5.4.1
Identify process waste	VSM process	Section 5.5
Quantify process waste	Work measurement techniques	Section 5.5
Eliminate/reduce process waste	Lean tools and techniques	Section 5.6
Identify lean strategies	Follow up meeting with alliance management	Section 5.8
Conduct follow-up process studies in northbound phase	Participant observation and lessons-learnt registers	Section 5.9
Get middle management views	Questionnaire with 27 middle managers	Section 5.10
Final findings and conclusions	Triangulation	Section 7.3

This chapter is structured as follows. The section 5.2 following this introduction section gives an overview of the case study project. After presenting the process improvement framework adopted for this study in section 5.3, section 5.4 reviews the processes of the main study. The next section (5.5) explains the value stream analysis conducted at process (macro), activity (micro) and sub-task/worker (sub-micro) level with appropriate examples. Section 5.6 explains how process waste is identified through lean tools as well as through case study examples. Section 5.7 follows with a succinct report of adoption of new initiatives and their effect on processes. In section 5.8, the study findings of the follow-up meetings are reported. In section 5.9, the effectiveness of improvement activities within processes is discussed. The next section (5.10) explains additional observations by triangulating observations, questionnaire and follow-up meetings. Section 5.11 provides a summary of the chapter.

5.2 DESCRIPTION OF THE CASE STUDY PROJECT

The selected alliance project was undertaken to reduce traffic congestion on an existing motorway. Moreover, some of the features of the existing structure do not meet modern design standards. For these reasons, it has been decided to replace the existing viaduct with a new viaduct at the same location.

The existing viaduct consists of two connected bridges (Figure 5.1 (a)). The owner of the project was proposed to build a new viaduct on the eastern side of the existing viaduct (Figure 5.1 (b)). The existing southbound viaduct was then dismantled (Figure 5.1 (c)) and a new northbound viaduct was built at the same place as the old southbound one (Figure 5.1 (d)). Finally, the existing northbound bridge was dismantled (Figure 5.1 (e)). The total construction period was 49 months, starting in 2009. Due to project complexity and uncertainty, the project was delivered by an alliance of eight participant organisations.

(a) (b) (c) (d) (e)

Figure 5.1: Project stages of the viaduct replacement project

5.3 ROLE OF THE RESEARCHER IN THE PROCESS STUDIES

In the literature, the process waste on a construction site is often seen as substantial. However, only a few studies have concluded with a complete methodology for the elimination of waste beyond such detection. By considering all the pros and cons of the previous studies (section 3.7.2) and standard methodologies of process improvement (section 3.7.5), this study used a structured process improvement methodology to increase site performance in an alliance project. This framework was implemented according to a nine-step procedure for five distinct processes (Figure 5.2).

The main phases used for the process improvement methodology adapted the general problem solving approach used in available process improvement methodologies explained in literature (section 3.7.5). Each phases was expanded into process steps by combining lean techniques and industrial engineering tools. After identifying main phases and relevant process steps, the methodology was applied repetitively to five process studies (section 5.4.2). The methodology offers several lessons learned that become an important source of information for the final version of the process improvement methodology (Figure 8.3). The main modification from the initial version (Figure 5.2) and the final version (Figure 8.3) is the addition of a new phase called 'recognition'. During the application of the methodology to the selected case study it was identified that to obtain positive results it is crucial to develop a synergistic relationship with site management and workers of the construction project. In order to develop an effective relationship with site management and workers it is required to provide recognition for all levels of the project team and therefore the 'recognition' element was added to the developed methodology.

In this study, the researcher was involved in process mapping and finding improvement opportunities. The researcher was also responsible for cross-examining the findings with site management. Finally, a representative from the site management was assigned to each process study to verify the findings and improvement plans.

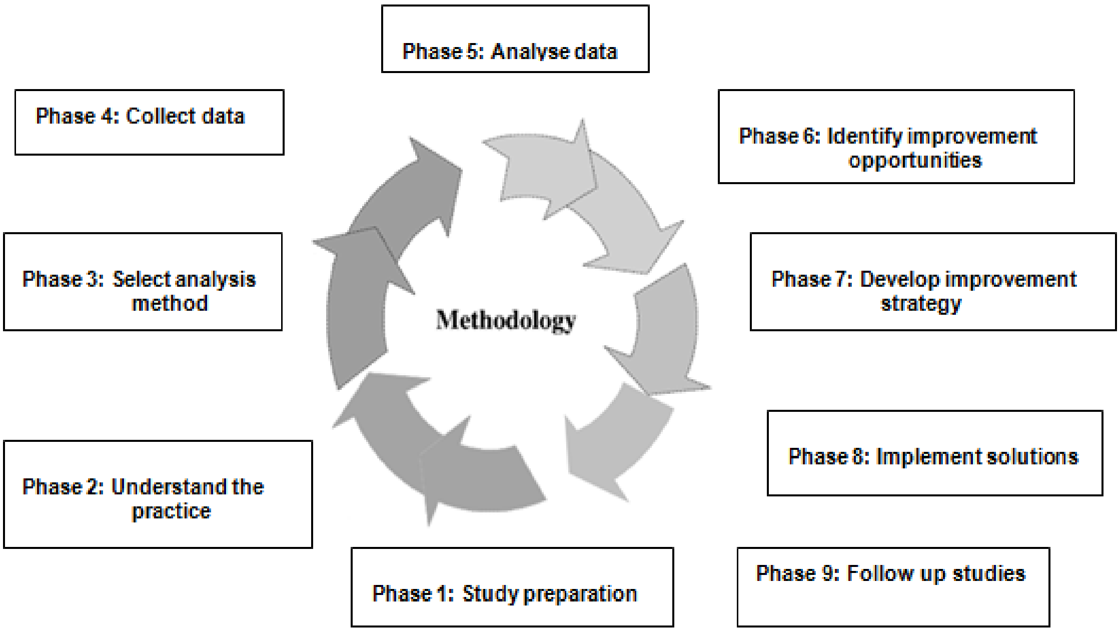


Figure 5.2: Systematic methodology for process study

Different research stages of process improvement methodology and relevant sections in this thesis are summarised in following Figure 5.3.

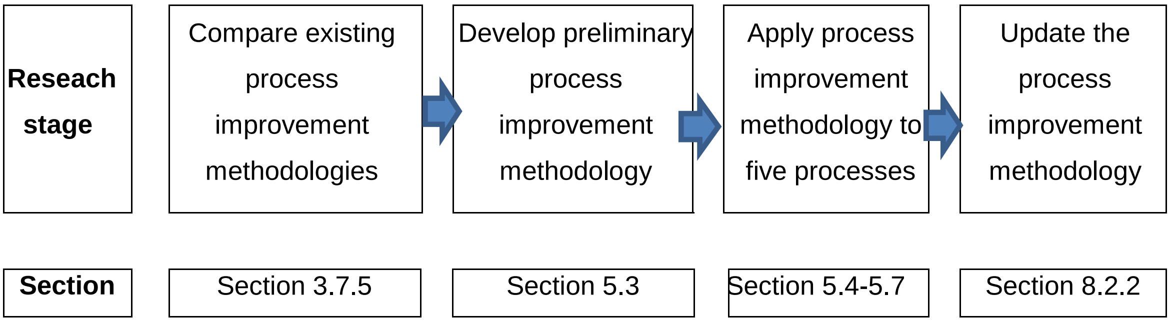


Figure 5.3: Research stages of process improvement methodology

5.3.1 Phase 1: Process study preparation

Following Rother and Shook's (1998) VSM methodology, a quick walk-through along the entire process was done to get a sense of process flow. A general template (Appendix K) was used for every process, which includes a series of questions to gain more detailed information about the process with regard to its suppliers, customers and operational steps. General information such as working days, working hours, workforce and production data were collected from informal discussions and project reports. After the walk-through visit, the process boundaries of the selected processes were determined.

5.3.2 Phase 2: Understanding the practice

At this stage, all the process steps were observed to identify and categorise VA, NVAN and NVAU activities. Standard operating procedures for each process (method statements) were used to understand the standard practice to be performed at the site. In this alliance project, the initial method statements were prepared by the site engineer and the project engineer with the collaboration of supervisors. The construction manager and the safety manager reviewed and approved the finalised method statements. After the approval, the method statements were explained to the site workers.

The activity classification rules are developed by considering video records made of different process steps in process study A and the classifications used in past research. Once the classification was developed, the applicability of the proposed classification was tested on recurrent process studies. A videotape of a process step was used to analyse activities in detail and for each activity the object handled, action performed on the object and resources used were recorded. After the activity analysis, the developed activity classification rules were applied to each activity manually and the activities were classified into VA, NVAN and NVAU activities.

The rules used in the activity classification are explained in Figure 5.4. The flowchart has six decision nodes. The following section explains each decision rule.

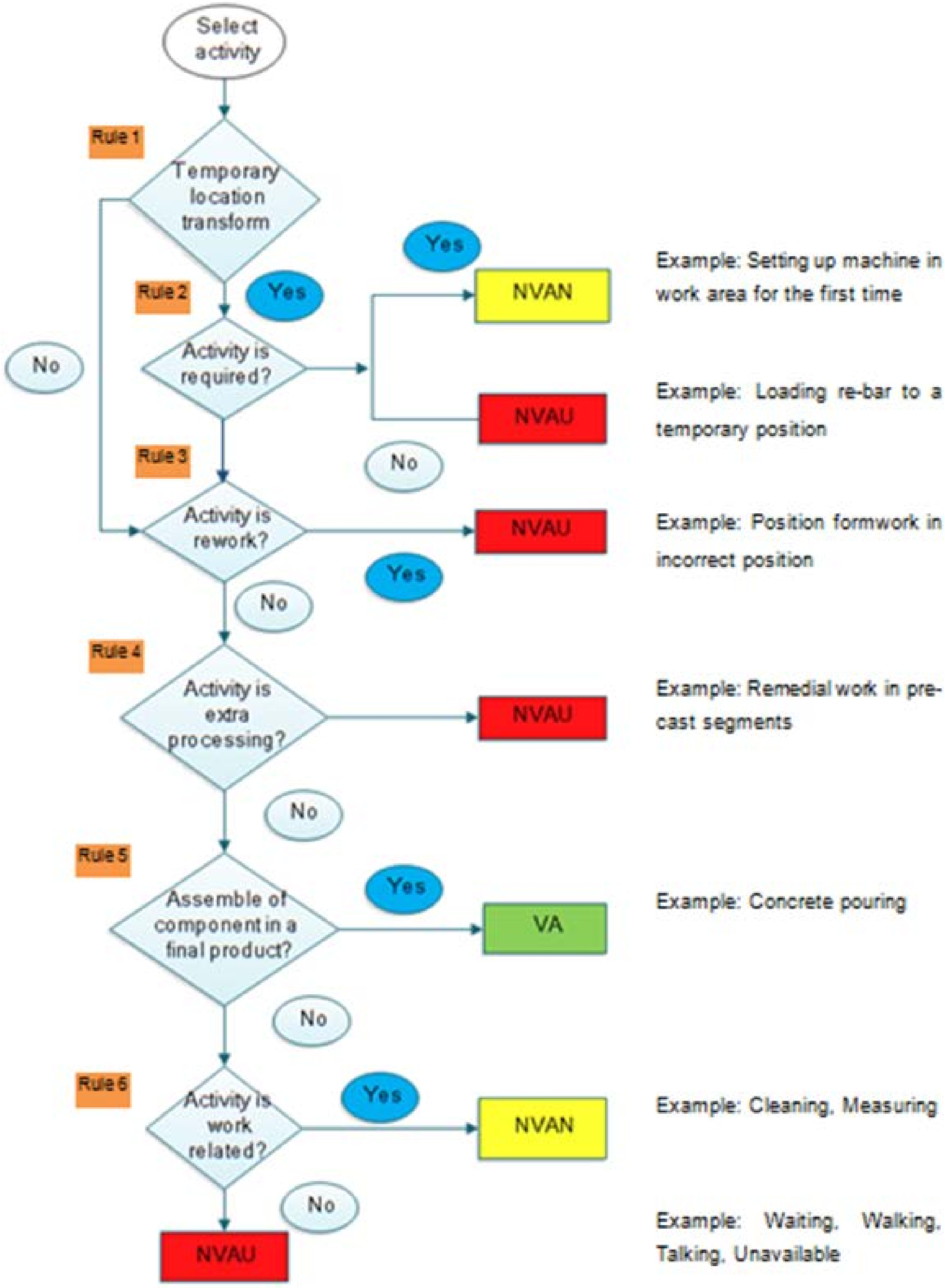


Figure 5.4: Activity classification rules

Rule 1: Does the task permanently change the sub-assembly position?

The activities that change material, sub-assemblies or the final product in a permanent position are considered as VA activities. However, in order to categorise an activity into VA, rules 3, 4, and 5 should be satisfied.

Rule 2: Is the location transformation task mentioned in the method statement?

Certain sub-assemblies or resources positioned in a work area are categorised as NVAN activity. A transformation of location that causes more than one handling is categorised as a NVAU activity.

Rule 3: Is the task done right at the first time?

Even if the activity transforms input materials into a permanent position, the activity could still be a rework due to errors. Such rework activities are grouped as NVAU activities.

Rule 4: Is the task required?

Certain activities are changing the physical appearance or measurements but these activities result from the imperfection of the previous task.

Rule 5: Does the task assemble sub-assemblies into a final product?

If a task combines sub-assemblies into a final product and they remain in the final product, it is known as a VA activity. If the sub-assembly is a temporary component in the final product and such activity is mentioned in the method statement, the activity is known as NVAN activity.

Rule 6: Is the activity a work related activity?

Tasks, which are not mentioned in the method statements, are known as NVAU activities. Examples are waiting, walking and extended breaks.

This classification method was used to assess the value-added components of individual activities of the five process studies. Therefore, the activity classification methodology improves the consistency of activity classification across all process studies. The worker composition and their job descriptions were also obtained at this stage. Following Rother and Shook’s (1998) VSM methodology, a ‘30s exercise’ was conducted with the supervisors to identify the process steps before starting each process. This exercise has provided the process study background and ensured understanding of the right level of detail required from the site participants.

5.3.3 Phase 3: Selection of data collection and analysis methods

The only way to obtain the maximum from any process improvement methodology is to rely on accurate measurement techniques that quantify the exact impact of the initiative (Bishop, 2001). In the absence of any scientific measurement, these improvement studies simply become extremely biased (Bishop, 2001). Under such situations, the outcome is unreliable and often leads to the implementation of solutions with no real payback. Therefore, in this study, time study and activity sampling techniques were used to quantify the process waste and to show the improvement potential with the application of lean thinking in alliance process.

There was no rigid system in place to get the exact time durations for activities of the five processes. However, the majority of the site supervisors were able to provide average durations of some activities but not for all activity steps. Therefore, real time data collection was carried out for all five processes. Depending on the nature of the activity, different data collection and analysis methods were selected (Table 5.2).

Table 5.2: Analysis and data collection method
Source: (Kaye & Anderson, 1999), compiled by author

Activity	Objective of study	Data collection tool
Process task	Eliminate or combine steps, shorten transport distance, identify delays	Process map
Worker working with machine	Minimise idle time,	Multiple activity charts
Workers working as a team	Simplify method, minimise motions and idle time	Time study and activity sampling
Worker/ supervisor working with document	Eliminate or combine steps	Time study and information flow map

Time measurements were taken on the spot without influencing their working pattern while workers were engaged in their normal work duties. The elapsed time for each task was recorded with the judgment of whether the task was VA, NVAN or NVAU based on activity classification rules shown in Figure 5.4. An activity sampling technique was used when several operators were engaged in one task. Whenever a specific waste activity was identified, the waste was quantified by using a suitable data collection tool. For example, the unnecessary transportation time and distance were measured through a movement study with the help of a spaghetti diagram. During the data collection stage, every process was observed at least three times.

5.3.4 Phase 4: Collection of data

Work-study techniques were used as the primary tool for estimating operational waste in each process. The time study technique was used to measure cycle time. On site time studies were conducted without disturbing the normal working pattern while workers were engaged in their work. Activity sampling technique was used to measure the NVAA time in non-repetitive type jobs. Lean practices were used for identified work centres to evaluate the effectiveness of the current work methods and to propose improvements for those work methods.

A research notebook was kept during the study period to record observations. The notebook consists of two columns, where the left column was for time study data (the facts) and the right column was for researcher's thoughts (the reflection). Interaction with site workers during normal work activities and during non-study related activities was recorded. This is similar to the method followed by Gong, Borcherding, and Caldas (2011). Different data collection sheets were used depending on the situation. A set of generic forms (Appendix M, Appendix N, Appendix O and Appendix P) was used for data collection and the raw data were entered into Microsoft Excel.

5.3.5 Phase 5: Process study data analysis

After collecting the necessary information, data was analysed at process, activity and worker levels with the aim of identifying waste activities and their causes. Time study data was then entered into Microsoft Excel for the ease of statistical and other calculations that are required to generate patterns to answer research questions. The analysis at this level of detail helped provide a better understanding of the construction processes and areas where improvement efforts need to be focused. The current state VSM was first established through observations and then refined and validated through discussions with the participants at the follow-up meetings. The participants included project superintendents, engineers and foremen because they are aware of the whole processes studied.

5.3.6 Phase 6: Identifying opportunities for improvement

NVAU activities were selected as the first candidate for improving process performance. The main sub-categories of NVAU activity time were analysed. Furthermore, the causes for these activities were analysed with the use of lean tools like cause and effect analysis, five why analysis and crew balance chart. All waste activities are summarised into waste record forms (Appendix O) and categorised according to lean terminology. Waste activities were prioritised for improvement depending on the level of significance of the activity, easiness of correction and impact on the process in terms of safety, quality or cycle time.

5.3.7 Phase 7: Development of improvement strategy

After analysing the existing wastes in the processes, various strategies for improvements were developed with consultation of the process owners. Lean tools, ECRS (eliminate, combine, rearrange, simplify) and 4W, 1H (what, who, why, where and how) were used to develop improvement strategies for the identified issues. Suggestions for improvement areas were discussed, by using the ‘plus-delta’ analysis (Appendix Q) at the follow-up meetings. This provided the opportunity for brainstorming among all the members resulting in feasible solutions for each waste activity. The study then focused on the future state of the VSM which resulted in streamlined work processes.

5.3.8 Phase 8: Implementation of solutions

Having developed the strategies to eliminate existing waste and future state VSM, the proposed changes in the current process were outlined. The study analysed each case (waste and proposal for reduction) and determined the impact of each change on process measurements which is described in section 5.7. Once feasible solutions were identified, the site management executed and completed the required tasks by deadlines. The identified issues and solutions were recorded in lessons-learnt registers for future reference.

5.3.9 Phase 9: Collecting follow-up data

During this phase, it was expected to conclude the process improvements by using selected performance measures namely process efficiency (PE), cycle time (CT) and labour utilisation (LU). The PE and LU ratios were calculated by using Equation 5-1 and Equation 5-2. PE and LU parameters were used in past productivity studies (Bai, Huan, & Kim, 2011; Oglesby, Parker, & Howell, 1989; Salem et al., 2005) as a guide to determine the efficiency of work. These parameters could be used to make comparisons among projects or crews or to detect changes on a single project (Oglesby et al., 1989).

$$\text{Process efficiency} = \frac{\text{Value adding time}}{\text{Total cycle time}} \quad \textbf{Equation 5-1}$$

$$\text{Labour utilisation ratio} = \frac{\text{VA time} + \frac{1}{4}\text{NVAN time}}{\text{Total cycle time}} \quad \textbf{Equation 5-2}$$

The design of the project allowed for an easy follow-up action. The researcher was able to do the initial study at the southbound motorway while the follow-up study was done at the northbound motorway. After initial process studies, separate site visits were made to study the improvements, the problems faced during implementation and the reasons for precluded improvements.

This concludes the description of the general process study approach, which is common to all five-process studies. The next sections (5.4-5.10) explain the findings of the field study conducted in the participating project organisation.

5.4 PROCESSES INCLUDED IN THIS STUDY

According to Flyvbjerg (2006), the generalizability of case study findings can be increased by selecting the cases and/or sub-units strategically. Eisenhardt (1989) highlighted that between four and ten case studies are adequate to draw robust cross case deductions. Furthermore, in Eisenhardt's study (1989) it is mentioned that the empirical grounding of the research is expected to be weak with less than four case studies or with more than ten cases, it can be challenging to manage the volume and complexity of data. Typically, case study and/or sub-unit selection was made by purposive sampling rather than probability sampling as case studies were not intended to generate statistical generalizations (Yin, 2003).

5.4.1 Selection of processes

The current study contains multiple units of analysis in a single case study. A sample of five studies was selected in a purposive manner to represent major differences in an alliance project context. The process study selection critera was based on:

- process complexity, repetitive nature, procurement method and project participants

- project programme restrictions (e.g. the pier construction process overlaps with the pre-cast segment production process)
- safety restrictions (e.g. gantry operation was excluded because no safety permission provided for visitors)
- critical processes based on managemenet viewpoint and
- processes with performance issues (e.g. variation in time, cost and quality)

Processes, which are on-going in the southbound construction phase and repeating in the northbound construction phase, were selected for the study. The process study framework (Figure 5.2) acted as a theoretical foundation for investigating process waste and improvement prospects of the five processes. The time taken for the primary data collection was approximately 650 hours at the site. Table 5.3 summarises the features of process studies used in the main study. The selected process studies provide a good picture of the diversity within the referred case study project. The five units of analysis (process studies) are explained in section 5.4.2.

Table 5.3: Process study characteristics

Process	Pre-cast segment production	Parapet construction	Column deconstruction	Deck deconstruction	Bridge construction
Code	Process A	Process B	Process C	Process D	Process E
Process type	Labour intensive	Labour intensive	Machine intensive	Machine intensive	Labour intensive
Start task	Re-bar fabrication	Load out parapet	Deconstruction of pier	Installing gantry	Air testing
End task	Transport pre-cast segment	Parapet finishes	Deconstruction of column	Load out cut segment	Anchorage stressing
Number of process steps	10	4	17	4	4
Cycle time (min)	2940	445	3506	1219	528
Target time	19 months	2 months	4 months	4 months	7 months
Procurement type	Mainly alliance Re-bar cage fabrication sub-contract at fixed price	Labour sub-contract	Labour sub-contract	Labour sub-contract	Main alliance
Number of workers	80	8-10	10-12	10-12	8-10
Number of supervisors	3	1	1	1	1
Day/night shift*	2 shifts	2 shifts	2 shifts	2 shifts	2 shifts
Number of visits	18	7	19	8	8
Demand variability**	3	2	2	3	2
Task variability**	4	5	5	4	6

'*' Day shift from 0700 am to 1730 pm; Night shift from 1800 pm to 0430 am

'**'Variability calculations according to Lander (2011) and for more detail with regards to the calculation refer to Appendix R

5.4.2 General process descriptions

Process study A: Pre-cast segment production

This process study involved the production of pre-cast concrete segments required for the bridge replacements. The entire pre-cast concrete segment fabrication process consisted of fabrication of the rebar cage, mould set up, concrete pouring and remedial works. Total of 468 concrete segments were made in a yard by employing 80 workers. Altogether, 18 visits were made to the site, which included one process familiarisations visit, 15 data collection visits, one progress summary meeting and a workshop visit.

Process study B: Parapet construction

This process study focused on the parapet construction of the viaduct. The process consists of installation of pre-cast concrete elements, parapet formwork installation, concrete pour and formwork removal. This entire process was sub-contracted on a labour only basis. On average, there were eight to ten workers in each day/shift. The duration of the whole process was approximately 122 days (18 weeks). Total of seven visits were made to the site, which included one process familiarisation visit and five data collection visits including one night shift visit, and a progress summary meeting visit.

Process study C: Column and pier deconstruction

This process study focused on the column deconstruction of the viaduct. The process covered installation and removal of temporary works, wire sawing, pier segment removal, column removal and transportation of deconstructed sections. This entire process was sub-contracted on a labour only basis. The pier segment and column deconstruction crew consisted of one leading hand, six workers and a crane operator. Altogether 19 visits were made to the site, which included one process familiarisation visit, and 16 data collection visits including one night shift visit and two progress summary meeting visits.

Process study D: Deck deconstruction

This process study focused on the deconstruction of the existing viaduct. The bridge contained two individual structures and it facilitated the staged construction / deconstruction process. Deck segments were removed from the existing structure in a balanced cantilever sequence by using an overhead-launching gantry. After attaching a deconstruction-lifting beam to the leading segment, the segment was sawn by using a wire-cutting machine. The cut pieces were loaded and tied down to a multi axle trailer and removed from the site. Total of eight visits were made to the site, which included one process familiarisation visit, six data collection visits and a progress meeting visit.

Process study E: Bridge construction

This process study investigated the construction of the deck, which includes installation of continuity tendon, post tensioning, stressing and grouting process. To complete a span, the ends of two adjacent cantilevers were connected by an in-place cast closure at or near the mid-span of the bridge. Longitudinal post tensioning (continuity) tendons were installed, tensioned and grouted once the cast concrete attained sufficient strength. The continuity tendon installation and stressing process were observed due to the high repetition compared to a cantilever tendon process. The grouting operation involved leak testing of tendons, mixing and pumping of the grout. Altogether eight visits were made to the site, which included one process familiarisation visit, six data collection visits including a night shift visit and a progress meeting visit.

5.4.3 Comparison of process studies: variability perspective

The variability classification developed by Lander (2007) was used to compare the process studies with respect to their process variability (Appendix R). Task variability and demand variability were used to measure process variability. Task variability was present due to internal factors and was determined through processing and route variability. Demand variability occurred due to external factors. Demand variability was measured through product volume and product mix variability. The variability levels of the five process studies are shown in Figure 5.5.

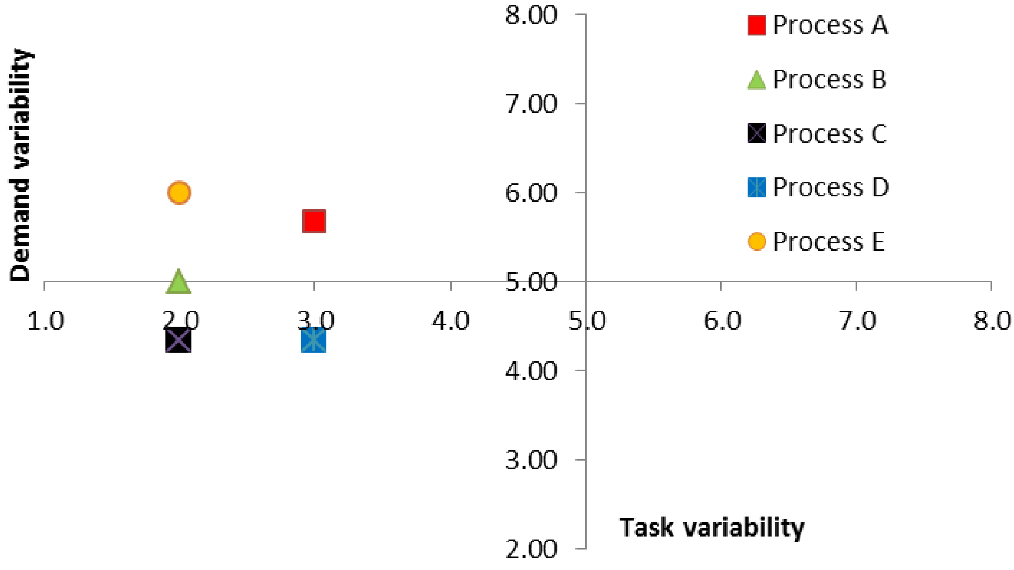


Figure 5.5: Classification matrix for task variability and demand variability

Volume variability was obtained from the project schedule and it was almost constant over the period. There was not much demand variability in the selected processes since all the processes were in the category of 'assembled to order'. The product mix varied only in process A and D where pier and normal segments were involved. Processing and route variability was identified from the process maps. Processes C and D were machine intensive processes with low task variability. The other three processes were labour intensive with medium task variability. It was noted that the selected processes were not too divergent. The next section describes the VSM analysis.

5.5 VALUE STREAM MAP ANALYSIS

Different tools can be adopted to identify existing waste and VSM is one of those tools. VSM helps lean practitioners to apply a complete lean thinking approach instead of using discrete lean techniques. VSM enables a company to see the entire process in both its current and desired future state, and to develop the road map that prioritises the projects or tasks to bridge the gap between the current state and the future state.

In this study, VSM was used to map the processes in an alliance project, which was analysed to identify waste and to improve the workflow. As a lean tool, VSM uses real time data to depict the current process map and to determine the future process map. Work measurement techniques and observations were the common data collection methods used to observe the actual material and information flow (Table 3.7). However, complexities of the construction process and lengthy construction tasks cause most researchers ((e.g.: (Al-Najem, Dhakal, & Bennett, 2012; Kalsaas, 2010)) to rely on second-hand data. In order to eliminate the limitations of second-hand data, this study used real time data through work measurement techniques.

Work measurement is a mechanism that was added to VSM to measure the waste level. After quantifying the waste, causes for waste were identified with the use of lean analysis tools and causes were removed through lean techniques. The symbolic relationship between lean principles, practices and work measurement techniques is depicted below (Figure 5.6).

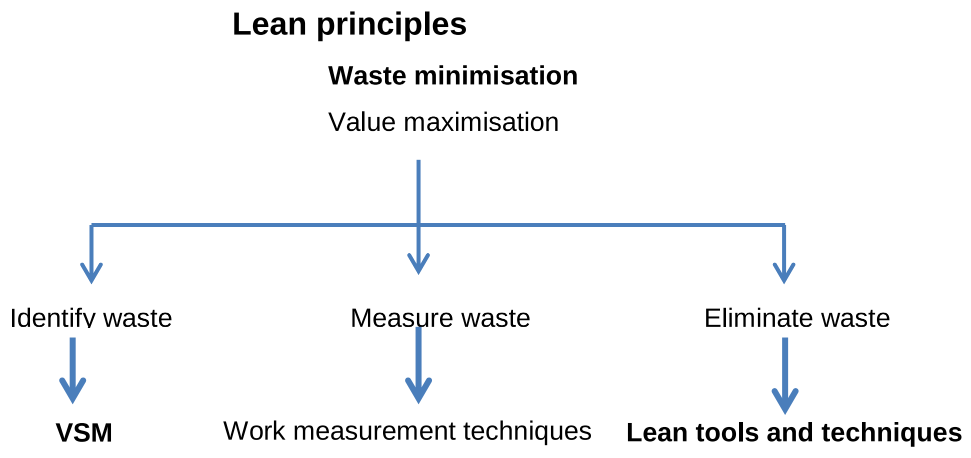


Figure 5.6: Relationship between tools applied

The level of mapping needs to be considered next in a VSM. In manufacturing, mapping generally begins at the level of the production process, with an activity box indicating each process step. Some construction research utilised VSM either at the macro process level, such as supply chain (Al-Najem et al., 2012; Alves, Tommelein, & Ballard, 2005; Arbulu, Tommelein, Walsh, & Hershauer, 2003), project delivery processes (Mohyin et al., 2012), for an operation (Dulaimi & Tanamas, 2001) and components manufacturing (Al-Najem et al., 2012; Ballard, Harper, & Zabelle, 2003). There is a lack of studies that used VSM in a long-term project in a longitudinal manner.

Due to the complexity of certain construction processes, VSM was developed with three levels, specifically process (macro), activity (micro) and worker (sub-micro) level. The current VSM contains three layers as communication, process and timeline. Each layer is further divided into three levels as mentioned above. In construction, activity time is usually measured in days or weeks while in manufacturing, activity time is measured in minutes or hours. This study follows a detailed real time data collection to identify and categorise waste. Therefore, minute is used as the time measurement unit.

5.5.1 Level one – process (macro) level analysis

Level one is the macro level. The boundary of this level was a work cell or a process. This level of the process map helped identify all process steps, potential bottlenecks and critical work centres. It was assumed that the observations were representative of the work distribution values for the activities in each process. Figure 5.7 shows a typical process level summary of a work centre.

Rebar fabrication process

Number of workers	9
Cycle time	540 min
VA time	45%
NVAN time	23%
NVAU time	32%

Figure 5.7: Results for rebar cage fabrication process

The current VSM (Figure 5.8) contains three layers communication, process and time line. A few issues were identified by analysing the current state of communication layer in process A. They are:

- No input from sub-contractors when preparing initial layout and schedule
- Incorrect and partial information from re-bar suppliers to re-bar fabrication section
- Infrequent and inefficient pre-start meeting at the mould set up section
- Incomplete information in production programme
- High WIP in finishing section due to lack of final designer's visits
- Lack of communication between site and ready-mix concrete supplier

The production process of the entire pre-cast segment can be divided into four main process stages: re-bar fabrication, segment casting, remedial works and supporting activities. Different sub-processes were identified under each process stage. Each sub-process was observed at least for three cycles and these observations tracked waste associated with worker and material flow as the process proceeds through the various construction stages. The timeline at the bottom of the current state map contains two components namely waiting time and processing time. The waiting time data was collected during a walk-through and informal discussions with foremen and operators at each workstation. The processing and set-up times were based on the work measurement data. A well-developed value stream map at this level can be used to identify how much waiting occurs between construction activities, the amount of transport required for materials around the job site and the proportion of rework. The current state VSM is identical to a VSM of traditional manufacturing. Based on the waste analysis presented in section 5.5.4, the site management and researcher discussed and defined improvement opportunities for eliminating or reducing these wastes, as indicated with kaizen bursts shown in Figure 5.8

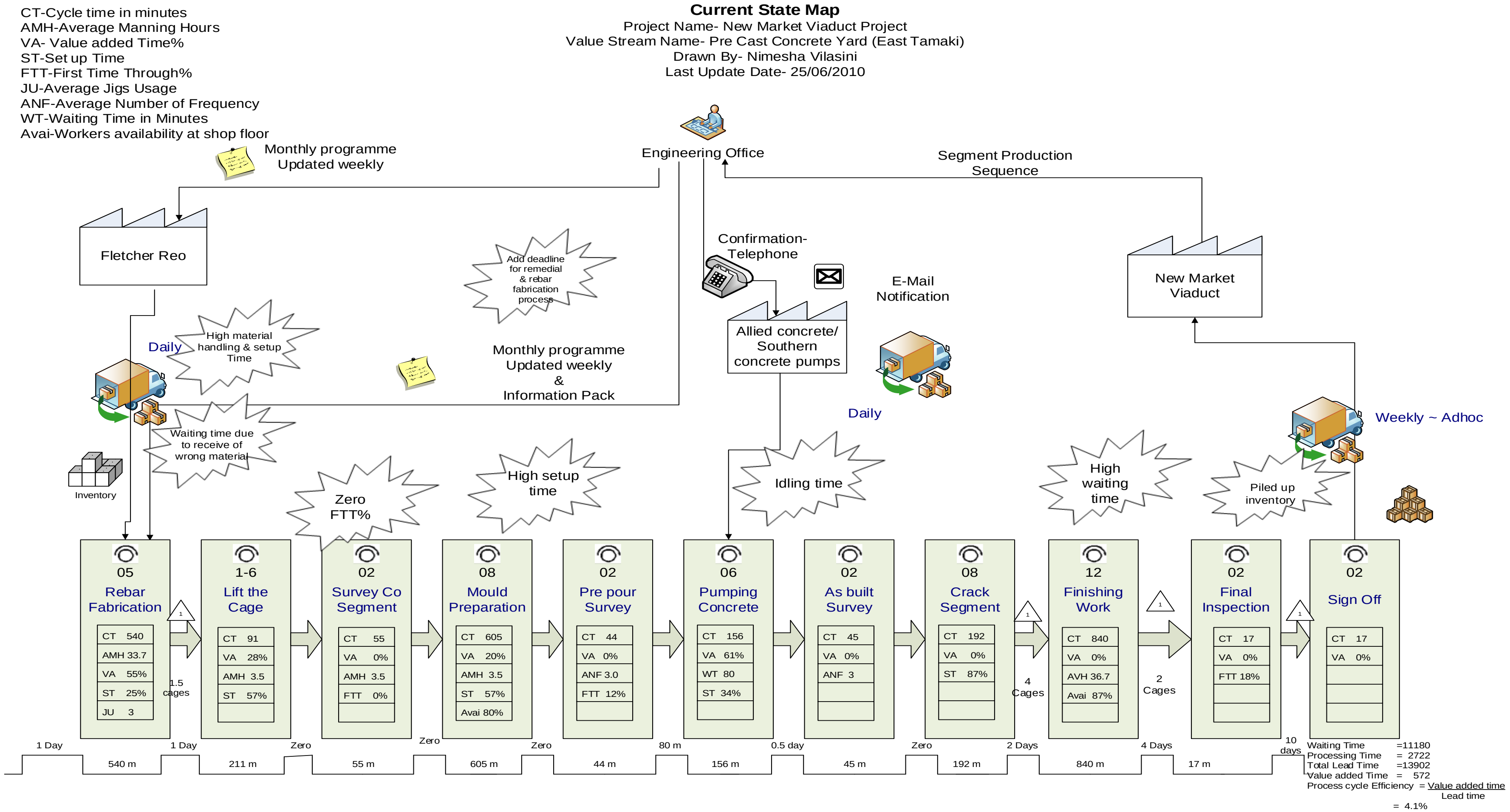


Figure 5.8: Level one VSM

5.5.2 Level two – activity (micro) level analysis

When different teams conduct different processes simultaneously, and a high complexity of processes exists, the process steps need to be sub-divided into activities. Figure 5.9 shows the activities of the rebar fabrication-processing centre. This process consisted of four activities where the first three activities were conducted sequentially and the last activity was conducted simultaneously with the second and third activities. This level two map helped track waste associated with activities as the process proceeds through different construction stages. The activity breakdown was achieved from the weighted average values of the entire crew. The weighting factor was calculated based on man-hour contributions.

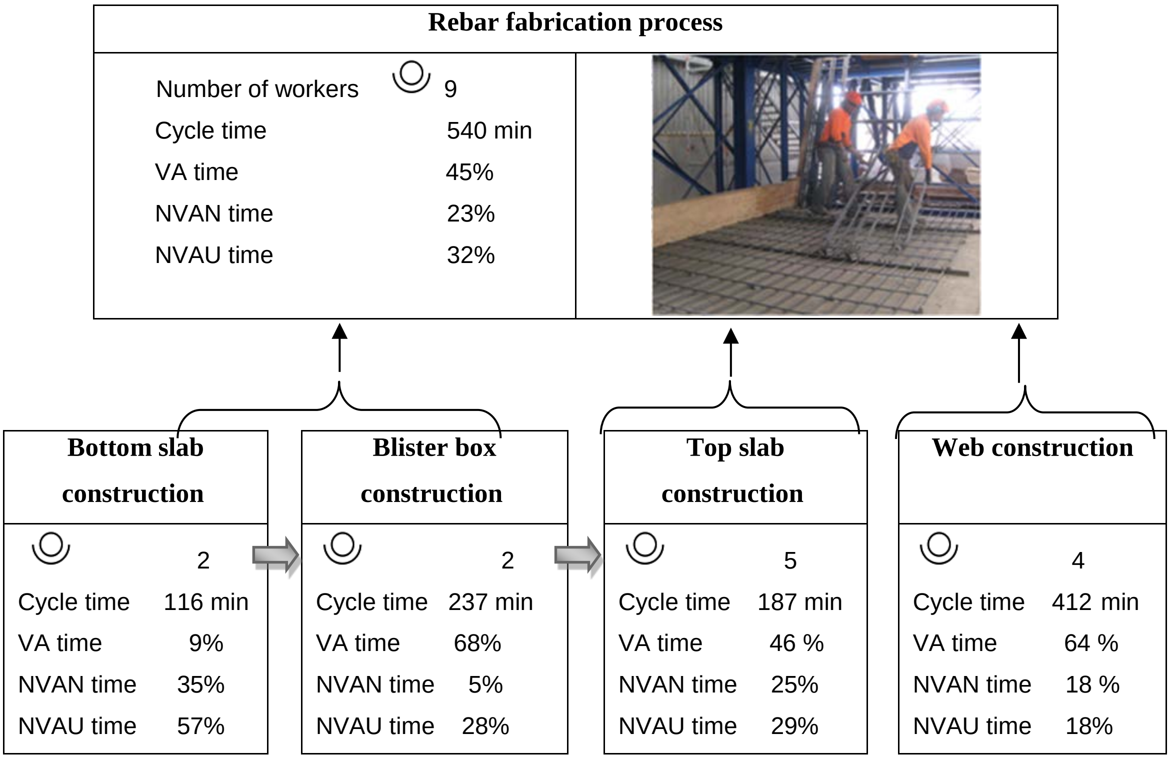
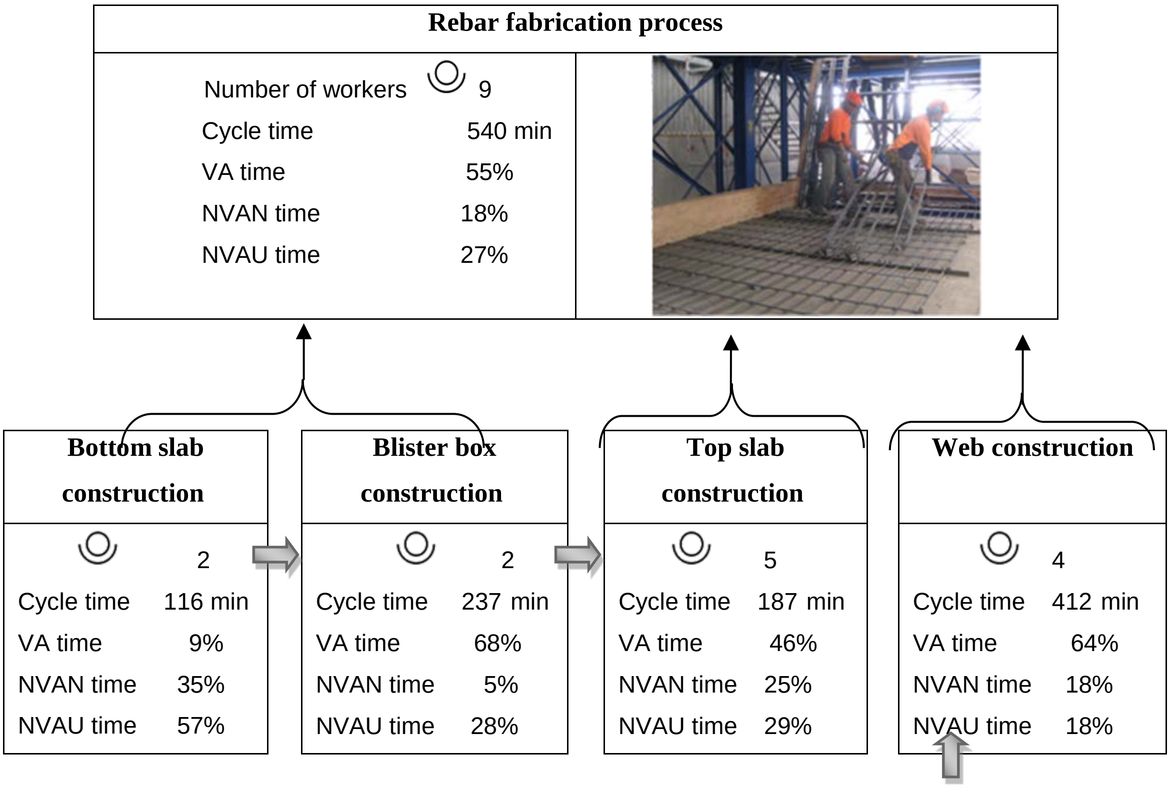


Figure 5.9: Level two VSM

5.5.3 Level three – worker (sub-micro) level analysis

In the sub-micro level analysis, the individual worker contributions to the different processes were evaluated and activities were classified as a VA, NVAN and NVAU. Figure 5.10 shows a typical result of a level-three analysis of individual workers and selected activities. Percentages shown for each worker are based on the total time that each crewmember has contributed to the cycle. This was required as different workers had spent different lengths of time in a cycle. Columns two to four of Figure 5.10 present the percentages of the total time an individual worker was spent on each work category (i.e. VA, NVAN and NVAU). The other columns are associated with further activity breakdowns of NVAN and NVAU categories.



Worker identification number	VA	NAAN	NVAU	NVAN activity breakdown					NVAU activity breakdown					
				Setup	Cleaning	In-process inspection	Measuring	Temporary work	Waiting	Rework	Motion	Transport	Extra processing	Not available
1	83%	7%	10%	0%	0 %	3%	4%	0%	7%	0%	3%	0%	0%	0%
2	79%	7%	14%	4%	0%	0%	3%	0%	7%	0%	4%	3%	0%	0%
3	48%	36%	16%	12%	16%	0%	8%	0%	0%	0%	4%	0%	8%	4%
4	46%	23%	31%	8%	0%	7%	8%	0%	8%	0%	0%	0%	15%	8%

Figure 5.10: Level three VSM for web construction of the rebar fabrication

The third level of the analysis helped determine the correct crew size and work balance. The initial VSM was drawn separately for five process studies to represent each process flow.

5.5.4 Presentation of value streams analysis results

Table 5.4 represents a summary of the work categories obtained for each process study from VSMs. The worker activity breakdown and cycle times were obtained from time studies. In order to conduct the activity level analysis, activity breakdown results of each worker were aggregated based on the total time that each worker contributed to the activity cycle. Finally, the process time breakdown was calculated using weighted averages of activity times (based on man-hours required for each activity).

Table 5.4: Value stream analysis results of five process studies

Process study	Cycle time	Lead time	VAA*	NVAN*	NVAU*	NVAU activity breakdown						Total manning hours
						Waiting	Rework	Motion	Transport	Extra processing	Not available	
A	2940	14100	21%	24%	55%	8%	29%	10%	1%	2%	5%	246.1
B	445	646	6%	48%	46%	19%	6%	12%	1%	2%	6%	32.7
C	3506	3506	13%	34%	53%	37%	5%	4%	1%	4%	3%	204.5
D	1219	1819	6%	37%	47%	26%	6%	3%	0%	6%	7%	84.4
E	528	528	11%	27%	62%	19%	4%	4%	3%	9%	23%	88.0
Aggregate value			11%	36%	53%	22%	11%	6%	1%	4%	9%	-
Aggregate standard deviation			1.2%	10.2%	11.3%	9.54%	9.53%	3.7%	0.99%	2.66%	7.22%	-

Note: * VA NVAN, and NVAU percentages calculated based on total man minutes

All five processes in this study contained NVAU work percentages between 46% - 62%. The largest VA (21%) was found in process study A and the smallest (6%) in process studies B and D. The largest NVAN (48%) was found in the process study B and the smallest (24%) in the process study A. The largest NVAU (62%) was found in the process study E and the smallest (46%) in the process study B.

The analysis shows that the process study results represent only five of the seven types of process waste. Waiting, rework and unavailability are the major contributors to NVAU activities. It was observed that the worker unavailability on site was mainly a result of extended personal breaks. Since worker unavailability was a major contributor to the non-working time, it was recorded separately.

The descriptive statistics provide estimates of the statistical nature of the variables of interest. However, integrating and accumulating the findings of individual studies would provide a more authoritative position regarding the issues under investigation. In order to obtain aggregate figures of five process studies, the meta-analytic aggregation procedure by Horman and Kenley (2005) was adopted for this study.

Aggregate findings show that the proportion of available time used in VA activities was 11% with a standard deviation of 1.2%. When starting with a typical product development process, the VA time is also a small percentage of the whole process time, typically less than 10 % (Garcia & Drogosz, 2006). Moreover, the results of this study show that on average, workers spent 36% of their time in NVAN work while 53% of their time is NVAU work. A further breakdown of these major waste categories indicates that on average, workers spent 21% of their time waiting, 9% of their time unavailable on site and 10% of their time on rework.

Although the NVAU results differ from some published studies like (Josephson & Saukkoriipi, 2007) and (Horner, Talhouni, & Whitehead, 1987), the NVAU results are consistent with Thomas's (1991) and Salim's (1994) studies. Specifically, the current study findings are in line with more than 36% of previous time utilisation studies listed in section 3.7.2. However, from the identified studies in the literature (section 3.7.2), 28% of the studies have reported higher figures than the waste reported in this study and 36% of the studies have reported less waste. The difference in results could be due to the different categorisation of the activities used by researchers, which stem from different views of VA vs NVA and NVAN vs NVAU.

The detailed, real time data analysis explains the current state of the processes and highlights the improvement opportunities. For example, higher unavailability of workers is associated with poor layout arrangements and lack of supervision. Common forms of waste are assessed against lean principles once they are identified. The process studies in the Appendix S provide detailed process improvements identified for each sub-process. The next section will discuss techniques used for identifying problems and implementing improved methods.

5.6 IDENTIFYING IMPROVEMENT OPPORTUNITIES

After finding waste in a process, it is useful to establish the root cause of the waste, which helps reduce or eliminate it. In this phase, the current state VSM was investigated systematically to identify opportunities to increase process flow and to eliminate waste. The NVAU activities were selected as the first set of candidates for improvement efforts. At first, the sub-categories of NVAU activities were analysed. Furthermore, causes for these activities were analysed with the use of lean tools. A number of areas such as crew work distribution, material delivery and storage, transport arrangement, machinery maintenance and work place arrangement were identified as possible areas for improvement. The rest of this section illustrates how lean tools were applied in the case study to detect the causes and implications of waste activities. These improvement opportunities were identified and the validity of results was crosschecked with the site management in the follow-up meetings.

5.6.1 Example 1: Spaghetti diagram for unnecessary transportation

Unnecessary movements (material and workers) are measured using a floor plan for the rebar cage fabrication of the process study A. Most of the time, the rebar cage placement to the mould and the truck arrival happened at the same time. As a result the rebar cage lifting process was distracted due to lack of space and unavailability of the gantry crane. Consequently, workers of the mould section had to stop their work and wait for the truck to finish. The foreman and a worker unloaded all the material to a temporary location by using the gantry crane. After unloading the rebar load at a temporary location, it was transferred to a permanent storage area (Figure 5.11).

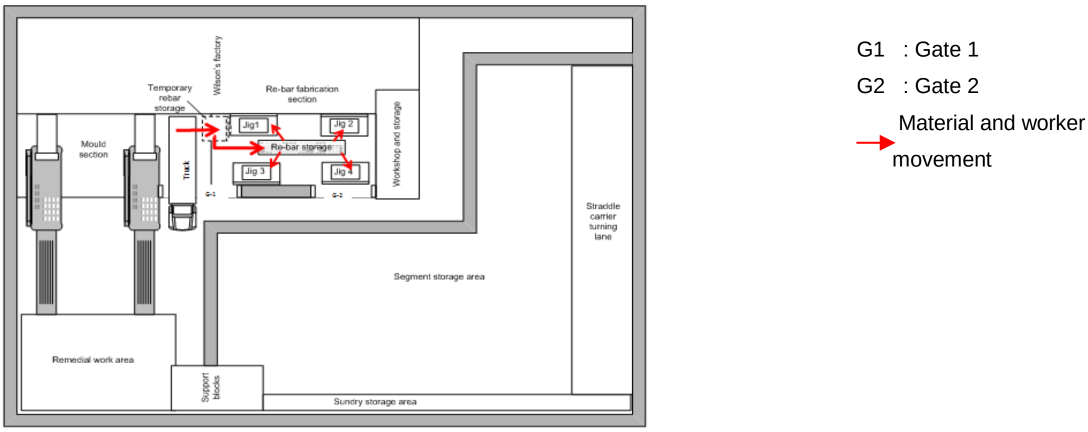


Figure 5.11: Pre-cast yard layout plan

This practice was a double handling of materials from one location to another obstructing the smooth flow of work traffic across the site. Due to space constraints, the steel bars were stacked on top of each other which resulted an extra time to pick the required steel bars. This second rebar placement was conducted manually due to the unavailability of the gantry crane. Once the foreman of the rebar section received the information pack, the foreman and another worker had to relocate necessary steel components to a designated jig area. The pieces were picked one at a time. This resulted in a longer material transportation time. From a spaghetti diagram (Figure 5.12), it can be identified that there are 12 and 28 movements per truckload from the truck to the temporary location and from the temporary location to a permanent location respectively. It was observed that inappropriate rebar storage in the permanent storage bay causes unnecessary movements of workers.

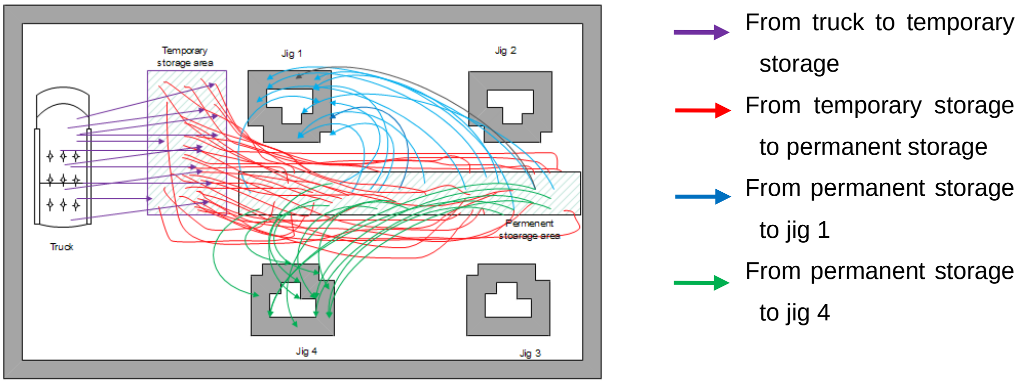


Figure 5.12: Spaghetti diagram for rebar fabrication section

5.6.2 Example 2: Fishbone diagram for unnecessary waiting

The grouting operation of the bridge construction process has taken approximately five hours to complete one cycle with 20% of the average cycle time being spent for unnecessary waiting. The fishbone diagram, another lean tool, was used in this study to visually demonstrate the potential root causes of a given waste event. As illustrated in Figure 5.13, causes of waiting are arranged into four groups as man, material, machine and method. The classification shows that human factors play a significant role in the causes of waiting.

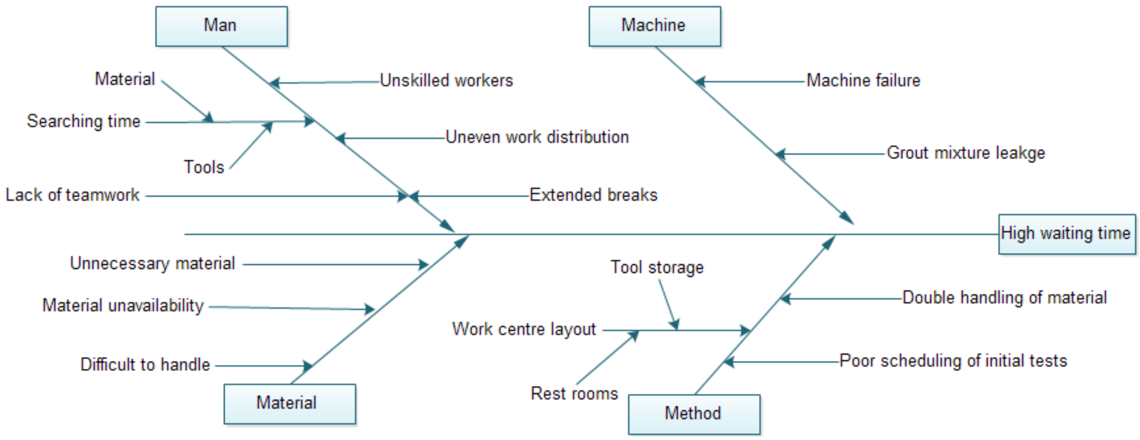


Figure 5.13: Cause and effect diagram to identify factors of waiting time

5.6.3 Example 3: Work place arrangement for motion and extra processing

Most of the time, waste of motion and extra processing of work were happening because of required items not being in the appropriate location. For example in process study B, while a new parapet formwork was connected to deck and barrier, the worker was spending time on searching connecting screws and bolts which were removed from the previous parapet formwork. The activity breakdown of the worker reveals that 20% of the cycle time was wasted in looking for these items (Figure 5.14). Therefore, the author suggested implementing 5S on site level. A few introductory presentations to 5S were conducted with the site management.

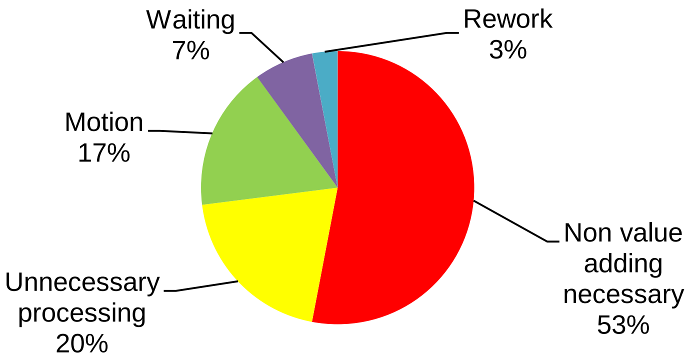


Figure 5.14: Formwork connecting work activity breakdown

5.6.4 Example 4: Five whys for high variability in cycle time

This study used the 'five whys' tool for different processes to identify root causes of a problem and to develop countermeasures. The 'five whys' is a tool used to determine the root cause of a problem by asking 'why' until the root cause is identified. In the process study C, there was a delay in the cutting process. The site management and the researcher conducted a lessons learnt workshop to discuss the reasons for high cycle time. Specific problems were identified and quantified. The investigation of root causes through a five whys method is shown in Table 5.5.

Table 5.5: Five whys application to column cutting operation

Issue	Why	Why	Why	Why	Why	Countermeasure
Varied cycle time	Cutting process interrupted	Slow cutting process	Wire jammed in the cut	Wrong wire used	No system to identify the wire	Introduce a tagging system and share this control mechanism with workers.
		Frequent wire breakdown	Overused wire	Cannot trace the wire usage life	-	Use wire lifecycle tag system

5.6.5 Example 5: Overall equipment effectiveness (OEE) for extra processing

The TPM concept addresses the major ‘losses’ for a machine intensive operation and this concept can be used to achieve higher OEE. The OEE measure was used in the column deconstruction process which is process study C. Due to various operational, managerial and breakdown losses, the total available time for the cutting operation was not effectively used. The average operational, managerial and breakdown losses related to the cutting machine were estimated based on observational data (Table 5.6). These losses were examined and classified into three categories namely recoverable, reducible and irrecoverable losses. This provides the management an insight for further improvement of the work centre performance.

Table 5.6: Generic loss structure for selected work centre

Description	Category (Min)				Total time	Remarks	
	Available		Losses				
Theoretical cutting cycle time (a)	720		0		720	3hrs/cut*4 cuts*60 min	
Equipment related losses	**Cut line**					**Reasons for losses**	**Action**
	3	**4**	**5**	**6**			
Breakdown losses	80	80	0	0	160	Power pack, wire failure	Reducible
Changeover losses	40	60	40	53	193	Set up wire cut machine	Reducible
Minor stoppage losses	12	0	0	0	12	Wire cut machine failure	Reducible
Man related losses							
Management losses	30	30	0	0	60	Waiting for sign off sheet	Recoverable
Measurements & adjustment. losses	10	12	23	17	62	Fixing the water line	Reducible
Logistics losses	8	0	0	0	8	Waiting for wire/ machine	Reducible
Operational motion losses	5	5	5	5	20	Worker movement	Irrecoverable
Line organisation losses	0	0	0	4	4	Personnel break	Irrecoverable
Total losses (b)	185	187	68	79	**519 min**		
Effective cutting time (c)	144	205	152	172	**673 min**		
Recoverable losses	**60 min**	**Irrecoverable losses**		**24 min**		**Reducible losses**	**435 min**
OEE (c/(b+c))			**56.46%**		**Process efficiency (a/(b+c))**		**60.40%**
Overall worker utilisation		Worker-1 (cutter)		65%	Worker-2 (helper)		9%

5.6.6 Example 6: Pareto chart for rework at rebar fabrication

A high rework time was detected during the three observation cycles of the rebar fabrication process (process study A). An error was identified during the final cage inspection, which had been conducted by the site engineer. It required two additional workers to correct the defect. Any minor rework incident that was identified before the final inspection was corrected at the point of source. From past records of cage inspection checklists, the study was able to identify that major corrections of the rebar cage had not been a frequent problem. However, the total elimination would impact on process performance. In order to conclude the criticality of the rebar cage rework, one of the basic quality control tools, a Pareto chart, was used (Figure 5.15).

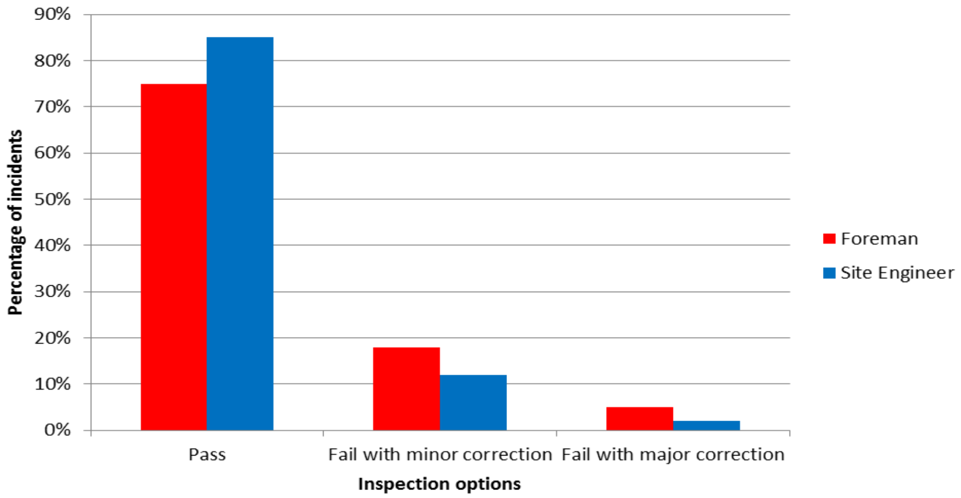


Figure 5.15: Analysis of rebar cage inspection

5.6.7 Example 7: Poka-Yoke tool for rework

Fayek, Dissanayake, and Campero (2003) have identified "human resource capability" as the second highest cause of rework in construction. A Poka-Yoke tool is used to guarantee the in-built quality of a process. In process study E, extra processing of the cutting machine had to be done due to improper placement of the machine at the segment near the pier. General practice was for surveyors to survey the segments and mark the 'line of cut' on the segment. However, the pier contains steel tendons, which increase the cutting time. During the pier cutting cycle workers were advised to set the cutting machine 20 cm away from the marked positions. The workers set up the machine on the markings but the mistake was realised only during the cutting operation. Therefore, the machine had to be set up again at the correct position. This caused a 30% increase in average cycle time. This was due to confusions of surveyors' markings and forgetfulness of workers. In order to prevent this type of mistakes, a Poka-yoke tool can be used. Surveyors were asked to mark an arrow away from the pier for pier segments and use red colour paint for the markings. Meantime, they were advised to use yellow for the rest of the segments.

5.6.8 Example 8: Crew balance chart for waiting time

The crew balance chart was used to optimise performance through the right labour composition. The labour utilisation rates and high waiting time of upstream processes show that there has been an uneven worker distribution in certain work centres. The following example was extracted from the process study C. The activity compositions for a load test at six positions are shown in Table 5.7. The second worker was waiting 76% of the average activity cycle time. The first worker was waiting during the machine operation time, which was about 45% of the average activity cycle time. Crew balance charts were used to analyse work restructuring. Two alternatives were identified namely, utilise two load-testing machines simultaneously by two workers or utilise two load testing machines by one worker. The study identified that there was a lack of skilled workers to operate the load testing operation.

Table 5.7: Activity composition of load test for two workers

<table>
<tr><th>Time (hr: min)</th><th>Operator 1</th><th>Operator 2</th><th>Machine</th></tr>
<tr><td>9:16</td><td>Fixing the machine</td><td rowspan="8">Waiting</td><td>Waiting</td></tr>
<tr><td>9:17</td><td rowspan="4">Waiting</td><td rowspan="4">Operation</td></tr>
<tr><td>9:18</td></tr>
<tr><td>9:19</td></tr>
<tr><td>9:20</td></tr>
<tr><td>9:21</td><td>Removing arrangements</td><td rowspan="6">Waiting</td></tr>
<tr><td>9:22</td><td>Measuring and marking</td></tr>
<tr><td>9:23</td><td>Weld cut</td></tr>
<tr><td>9:24</td><td rowspan="8">Waiting</td><td rowspan="3">Fixed to the next position</td></tr>
<tr><td>9:25</td></tr>
<tr><td>9:26</td></tr>
<tr><td>9:27</td><td rowspan="9">Waiting</td><td rowspan="5">Operation</td></tr>
<tr><td>9:28</td></tr>
<tr><td>9:29</td></tr>
<tr><td>9:30</td></tr>
<tr><td>9:31</td></tr>
<tr><td>9:32</td><td rowspan="2">Removing arrangements</td><td rowspan="4">Waiting</td></tr>
<tr><td>9:33</td></tr>
<tr><td>9:34</td><td>Measuring and marking</td></tr>
<tr><td>9:35</td><td>Weld cut</td></tr>
</table>

5.6.9 Example 9: Failure mode and effect analysis (FMEA) for extra processing

FMEA is a structured analysis method to identify failure modes and it is used as a risk assessment tool to identify potential risks their root-causes. The frequent breakdown of the cutting machine in the deck deconstruction process in process study E has caused 16% of unnecessary setup time and 28% of waiting time. Through the past records, failure causes were identified and an FMEA was conducted for the issue (Table 5.8).

Table 5.8: Failure mode and effect analysis sheet for wire cutting operation

Potential failure		SEV	Potential causes	OCC	How to eliminate	DET	RPN	Rank	Current process controls
Element	Effects								
Wire	One-sided bearing wear	5	Low twisting of the wire, strong tension on wire, little coolant supply, short distance between drive wheel and wire entry	5	Increased twisting or frequently changing, reduce feed pressure, increase coolant supply, increase distance	3	**75**	**2**	Prepare standard operating procedure for wire usage and update workers
Wire	Too high wear	3	Abrasive material, wire speed too low, Contact lengths very short, coolant quantity too low	5	More wear resistant type, increase wire speed, reduce feed pressure, increase coolant supply and optimise	3	**45**	**3**	Select and use appropriate wire type, speed and coolant supply.
Wire	Wire not cutting	4	Life span over, very hard aggregates, very long contact lengths, wire speed too high, concrete very heavily reinforced	5	Identify optimum life span, sharpen if abrasive material, reduce contact length, reduce wire speed, set deflection rollers	5	**100**	**1**	Tag system to mark cutting time, trace out optimum contact length and set the deflection rollers
Wire	Failure	5	Too strong tension, sharp edges, narrow arc of contact radius, stronger wire vibrations, great wear on the connection due to wrong assembly, wrong wire usage	4	Reduce feed pressure, break edges, set deflection rollers, pay attention to short, free wire lengths, assemble connection according to instructions	5	**100**	**1**	Tag system to mark cutting time
Wire joint	Connection pull out	5	Wire cut with cable scissors, wrong pressing, tension on wire, sharp edges, jamming, narrow arc of contact radius	3	Wire cut with cut-off wheel , pressing according to regulations, reduce feed pressure, , set deflection rollers	5	**75**	**2**	Update workers about technical details via training
Wire	Displacement of the beads	5	Too strong tension on the wire, too little water, overheating, slipping of wire on drive wheel, overheating, sudden jamming	4	Reduce feed pressure, More water, several nozzles, More wire tension, wedge material	5	**100**	**1**	Update workers about technical details via training
Wire	Wire not starting	4	Too strong tension, sharp edges, very different wire diameter new wire in old, narrow cut, too long arc of contact	5	Reduce feed pressure, deflection rollers, use wire with same diameter, additional bore or set deflection rollers	5	**100**	**1**	Update workers about technical details via training

Key: SEV = How severe is effect on schedule? (1: less severe-5: very severe)

OCC = How frequent will incident occur? (1- less frequent- 5: very frequent)

DET = How probable will incident be detected? (1- less probable- 5: highly probable)

RPN = Risk priority number in order to rank concerns; calculated as SEV x OCC x DET

5.6.10 Example 10: Visual management for unnecessary motion

Visual management helps eliminate waste, improve productivity and improve team member involvement with improved morale. In process study B, the storeroom was located at a fixed position and workers had to travel a longer distance to access equipment as the work points were moving away from the store when the bridge construction progressed. The study revealed that there have been at least 12 visits per day to the stores and the average time taken per visit was ten minutes. It was observed that unavailability of materials or tools has caused idling of the other workers. Therefore, the researcher developed a material/equipment checklist and displayed it in the stores. Workers were advised to bring necessary, routine material in advance with the help of the material/ equipment checklist (Figure 5.16).

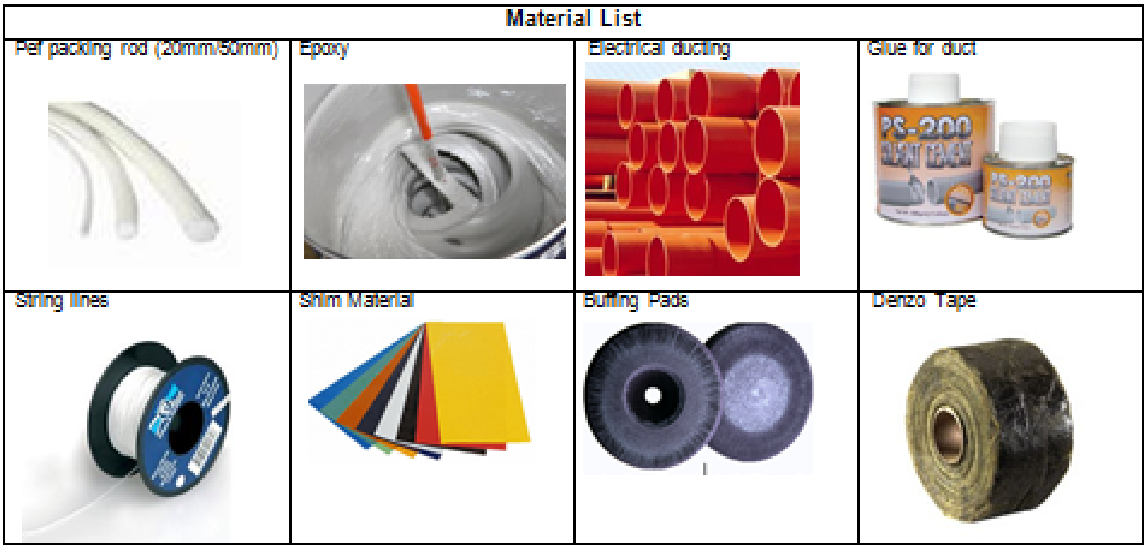


Figure 5.16: Material checklist prepared for the process B

Above examples show how lean tools can be applied in different settings in an alliance project to identify waste and their causes. The target areas for improvement and improvement strategies were developed and they are explained in the next section.

5.7 DEVELOPMENT OF IMPROVEMENT STRATEGIES

The results of the study presented in section 5.5.4 show that waste is extensive in the range of 46 - 62% of the process time. The largest proportion of waste is hidden to most of the project team members. It is essential to identify the potential improvements as discussed in this section. The process improvements in the alliance project mainly focused on eliminating process waste. Depending on the effect of the activity and easiness of the correction, the waste activities were prioritised for improvements. The ‘ECRS’ method and various lean tools were used as guidelines in developing process improvements. Possible solutions for identified improvement areas were discussed with the management. All process owners were brought together to determine the feasibility of suggested improvements through the ‘plus-delta’ analysis (Appendix Q). Comments from process owners were gathered and changes were made to reflect suggestions.

Some of the suggested strategies were implemented during the initial study while the other suggestions were considered in the later northbound construction phase. The summary of suggestions with relevant management actions for process study A is shown in Table 5.9. The improvement suggestions of the remaining process studies are documented in Appendix S.

Table 5.9: Improvement suggestions summary of process study A

Section	Objective	Recommendation	Accepted by management: Accept	Partially accept	Reject	Comment made by management	Action taken by management
Rebar cage fabrication section	Reduce temporary material storage	Change truck arrival time	√	-	-	This obstructs the rebar cage lifting process	Change truck arrival time
		Use alternative gate	-	-	√		
	Improve material traceability	Use pre-coloured tag system to differentiate two orders	-	-	√	Out of scope	No change
		Separate rebar bundles for two orders	-	-	√		
	Eliminate waiting due to material unavailability	Supplier ensure correct material	-	-	√		
		Use bar code system for material identification	-	-	√		
	Reduce material handling time	Stack rebar in the order of usage	-	-	√		
		Directly loaded to near jig area by crane	-	-	√		
	Reduce rework	Successive check by worker	-	-	√		
Rebar lifting	Reduce waiting time	Change truck arrival time	√	-	√	Gate change requires major changes	Change truck arrival time
		Use alternative gate	-	-	√		Change truck arrival time
	Improve process traceability	Frequent process monitoring	√	-	-	Cannot attach cement blocks at rebar jig	Assign rebar workers to attach the blocks
Survey	Reduce setup/rework time	Improve the sensitivity of equipment or introduce visual gauge system	-	-	√	Difficult to do such changes to pneumatically controlled machine	No action

Mould preparation	Eliminate searching for work	Improve leadership skills of charge-hand	-	√	-	Selects best worker as a charge-hand and no reference is made tc people skills.	No change
	Eliminate searching for material	Worksite standardisation (5S implementation)	-	-	√	To realise gain it takes time	No change
	Reduce motion and transportation time	Worksite standardisation	√	-	-	-	Bring necessary material from store to the site
	Reduce setup time	Prior pocket preparation	√	-	-	-	Add pocket change item to the schedule
	Enhance worker involvement	Effective pre-start meeting	-	√	-	Involved with worker at celebrations	Share production results with workers
Remedial work	Eliminate waiting time	Reduce saddler movement	-	√	-	-	Changes to production schedule
		Underground power supply	√	-	-	This was discussed in early project	Underground power supply
	Reduce rework and motion	Work standardisation	√	-	-	-	Educate workers on quality attributes request by designers
	Reduce segments double handling	Reduce waiting time for the final inspection	√	-	-	-	Increase the designer inspection frequency
Concrete pouring	Eliminate waiting time	Concrete truck and pump arriva time	-	√	-	-	Pour time outside of rush hours
		Prepare work backlog to crew members	-	-	√	Crew members are specialised in concrete operation	No action
	Reduce setup time	Discharge two trucks simultaneously	-	-	√	Second truck arrive when the concrete pump operator is busy with pumping	No action

The suggestions were grouped into themes based on waste types identified in the study. The incidence and the implication of each reported suggestion are presented in Table 5.10.

Table 5.10: Improvement suggestions and effect on man-hours

Process study		Suggestion themes						Man-hours	
		Waiting	Rework	Motion	Transport	Extra processing	Unavailable	Saving	Improvement
A	Time (min)	444	185	167	145	22	409	1372	9%
	Frequency	12	3	7	5	6	4	-	-
B	Time (min)	126	120	54	4	7	174	485	25%
	Frequency	6	3	3	1	0	3	-	-
C	Time (min)	1066	147	89	10	150	80	1542	12%
	Frequency	9	4	4	1	6	3	-	-
D	Time (min)	304	62	16	0	77	79	538	11%
	Frequency	11	3	2	0	5	4	-	-
E	Time (min)	229	32	156	26	78	429	950	18%
	Frequency	8	2	3	2	5	3	-	-
∑	Time (min)	2169	546	482	185	334	1171	4887	16%
	Frequency	46	15	19	9	22	17	-	-

The study focused on the most observed types of waste mainly waiting, rework, unnecessary motion and unavailability of workers. It was identified that most of the time, one unnecessary action causes more than one waste. For example, during construction, workers identified unavailability of necessary materials on the floor. One worker was going to get those materials and it causes motions as well as unavailability on site while other crew members are waiting for material. Therefore, tackling the root cause of unnecessary action will reduce other waste as well.

The study has discovered 124 suggestions and predicted improvements in man-hours in the range of 9-30% with overall improvement of 16%. Kuprenas and Fakhouri's (2001) have found that on average, 15-20% man-hour savings can be achieved through work performance improvement studies. Watson and Gryna's (2002) study shows that process improvement programmes in construction increase productivity by 16–40 % and the lead time decreases by 25%. Improvement results in the current study are consistent with the past studies that were conducted in different project settings. Mohamed and Tucker (1996) have shown that 25% time saving is feasible in a construction work without increasing resources. Ballard (1999) showed that a 30% improvement in productivity is possible with the implementation of Lean. Based on the improvement alternatives recognised from the initial study, three process study parameters namely PE, CT and LU are calculated as shown in Table 5.11.

Table 5.11: Analysis of ‘as is’ and ‘to be’ process parameters

Process study	‘As- is’ process			‘To- be’ process			Expected improvement %		
	CT (min)	**PE**	**LU**	**CT (min)**	**PE**	**LU**	**CT (min)**	**PE**	**LU**
A	2940	21%	27%	2675	23%	30%	9%	10%	10%
B	445	6%	18%	334	8%	24%	25%	33%	33%
C	3506	13%	22%	3085	15%	25%	13%	14%	14%
D	1219	6%	15%	1085	8%	19%	11%	26%	13%
E	528	11%	18%	433	13%	22%	18%	22%	22%
Consolidated improvement (%)							12%	16%	14%

Projected improvements in CT, LU and PE are 12 %, 16%, and 14% respectively. There are major gains to be made by implementing those suggestions, which have been derived from lean principles.

The future state map was developed after identifying the areas where improvements could be implemented. The future map (Figure 5.17) shows the desired status of each activity and offers direction for kaizen events (Table 5.9) that are intended to improve the current process map.

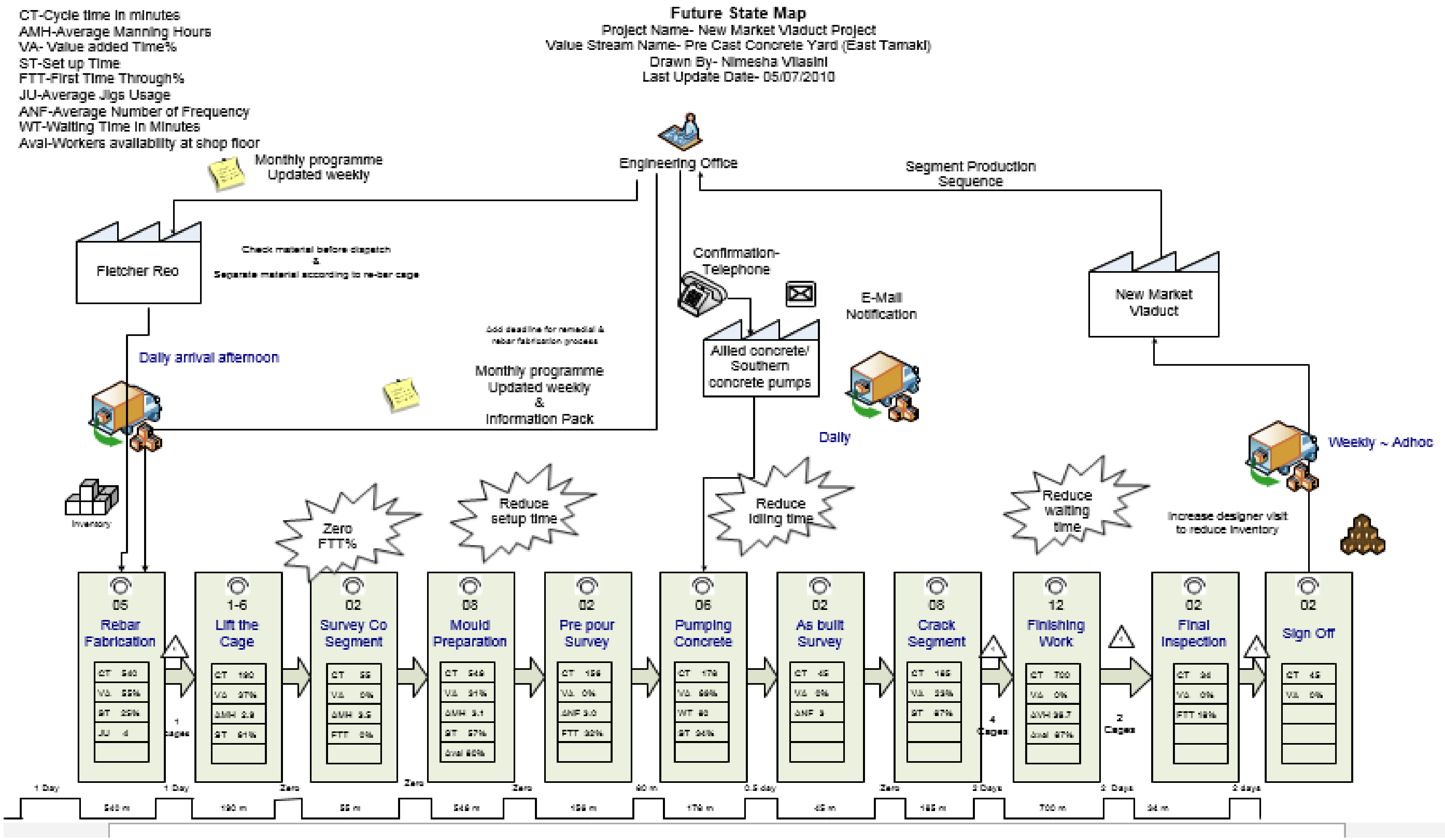


Figure 5.17: Future state map for the process study A

5.8 SUMMARY OF FEEDBACK DURING FOLLOW-UP MEETINGS

After completion of each process study, follow-up meetings with process owners were conducted to validate study findings and to test the feasibility of lean principles and practices. Process study reports and presentations were presented to the site management. The participants of the follow-up meetings were the construction manager, project engineers, site engineers, the superintendent and supervisors.

5.8.1 Process study A

In the follow-up meeting of the process study A, it was identified that the project engineer and construction manager were highly involved in method statement preparation for the pre-cast concrete yard. During that time, the project team spent time on discussing the layout and required resources. However, due to time pressure, lack of information on sub-contractor's process (re-bar fabrication) and lack of understanding of the actual work sequence at the site, these process wastes were not identified in advance. The project engineer identified that follow-up after implementation was poor due to preoccupation with daily work. However, the construction manager noted that innovation and continuous improvement are KRAs in this alliance project. The site management agreed to implement most of the suggestions (13 out of 18). Suggestions for the sub-contracting operation were among the exclusions.

5.8.2 Process study B

Material transportation and worker motion time were identified as major waste streams. Study findings created an environment to show the actual picture of the site. All the participants agreed that middle level managers were heavily engaged with the project documentation work restricting them to see the current status of the site. The construction manager stressed that day to day management of the project should be done by a seamless integrated project team through daily site visits and effective pre-start meetings. During a follow-up meeting, site engineers and project engineers discussed certain improvement opportunities identified in the current study. This meeting created a brainstorming session, which was not seen in the on-going alliance project. It enhanced the communication and sharing of knowledge between process owners. The study generated 21 suggestions while 15 of them were transferred to the lessons-learnt registers.

5.8.3 Process study C

Waiting time due to machine breakdown was mainly highlighted in the meeting. The discussion at the follow-up meeting realised overarching issues to be addressed as:

- Operator competency training in use of the machines considering pre start checks and machines set-up/start-up, machine performance during operation, shut down steps, post operations maintenance. A continuous training mechanism is required due to high worker turnover and absenteeism in the project.
- User performance and contractual arrangement for external/sub-contract labour or work packages, and
- Issues in regular machine services and maintenance regimes and manufacturer's warranty on purchased equipment.

Process study findings surfaced some high issues where the senior management involvement is necessary. 20 out of 25 recommendations realised from the study were transferred to lessons-learnt registers. Finally, a separate lessons-learnt workshop was conducted for site workers. This example shows that the alliance management put an effort in breaking down the barriers with workers and everyone involved in the process and promoting communication across all players.

5.8.4 Process study D

This process study discussed waiting time due to equipment set up time. All participants saw this activity as a bottleneck operation. The construction manager explained the first run studies conducted in major project activities like deconstruction and asked middle management to conduct such first run studies for sub-processes like grouting-mix preparation. The project engineer noted that the identified improvement opportunities from the current study were understandable. However, these were not identified and applied at the site. The construction superintendent explained the 'open door policy' in making suggestions in an alliance. Further discussions identified that these improvements were still not realised at site level especially from site workers due to:

- low educational level of site workers
- no motivation for improvements
- belief that there is no more room for improvement and
- poor supervision

The participant group recognised the failures in identifying improvement opportunities in the alliance rather than putting the blame on workers. This proves that the ‘no blame’ culture prevails in the operation level as well. 21 out of 39 recommendations were transferred to lessons-learnt registers.

5.8.5 Process study E

This process study mainly highlighted high waiting time due to machine failure and high setup time. Participants analysed different causes and came up with different solutions. The follow-up session was a brainstorming session to identify solutions. The alliance project management continuously challenged everyone to make decisions in alignment with the agreed principles and objectives and to find better ways of working. This kind of forum helped the project team to admit mistakes and to improve the process continuously. However, in this meeting, particpants highlighted the need of revision of certain process changes in method statements. These changes required acceptance by ALT members which may be challenging in an alliance project. Consequently, the implementation of ideas may be slow and this could affect the enthusiasm around the proposed changes. In this process study, 10 out of 15 recommendations were transferred to lessons-learnt registers.

In general, the participants gave a positive feedback for the process studies during follow-up meetings. The construction manager considered the implementation of such process improvements as ‘very valuable’ and they could save ‘significant amounts of construction time’. The project engineer in process B frequently requested the researcher to generate process checklists and visual management tools. These tools allowed workers to find required items in a shorter time, i.e. saving search times.

According to the site management, there was no firm system to identify the actual cycle time for scheduling purposes and assessing the performance of individual workers to encourage more productive activities. Indeed, these managers were repeatedly requested to expand the process study to other processes and to share the real time data for schedule updates. All the process study presentations were circulated among project team members and suggestions were recorded in the lessons-learnt registers. This observation showed that project participants were willing to share ideas and opinions, opportunities for innovation and improvement among the project team. This is a perfect fit of alliance principles and open communication with lean implementation initiatives at the operational level.

Even though previous researchers for example (Gransberg, Scheepbouwer, & Tighe, 2010; Rowley, 2002; Song, Liang, & Javkhedkar, 2007) have stated that there are resistances to lean implementations and process changes in construction, in general, the team members were interested in making changes and willing to extend their joint effort. In addition, brainstorming sessions were conducted to document current issues and explore possible areas of improvement. The study findings show that 66% of suggestions of the process studies were transferred to lessons-learnt registers.

The relevant site engineer was responsible for process changes but all the participants at follow-up meetings worked together on defining possible solutions for the identified issues. This observation shows the collaborative decision-making at the alliance operational level. This could be due to the alliance project nature, which promotes improvements via the gain:pain mechanism.

In summary, most of the participants agreed upon advantages of process improvement tools. However, they did not believe that site workers were committed to such improvements due to lack of motivation and knowledge. Most participants felt that the project failed at sharing best practices throughout. All five follow-up meetings conducted in the study idenified unanimous decesion making among the middle level management with respect to process changes.

5.9 FOLLOW-UP STUDY

There was an existing process of the lessons-learnt programme in the selected alliance project. Project engineers keep updating lessons-learnt registers and site engineers support implementation of lessons-learnt at the site. Lessons are recorded in a Microsoft Excel spreadsheet but there were no strict guidelines to describe what constitutes a valid lesson learnt. Identified leasons were reviewed at the lessons-learnt workshop with the particpation of relevent site management. The solutions were identified and all leasons-learnt workshop minutes were distributed to the site management.

The lessons-learnt derived from the current study also included the existing lessons-learnt programme in the selected case study. After discussing the suggestions with the management, suggestions were recorded in lessons-learnt registers. Study suggestions were revisited with the site management before starting the same process in the northbound construction phase. However, the researcher was not fully involved in the implementation. A site engineer was appointed to explore the implementation of the recommendations. This study only focused on establishing a system that enables project team members to identify and act on waste on a continuous basis.

Reactions to the initial study findings were evaluated through follow-up visits. From the follow-up visits, it was identified, that only a few of the suggestions from the initial study were implemented and sustained in some processes. During the follow-up studies, the reasons for failures were identified as:

- Uncommitted members: A few process owners who had agreed on process changes during the follow-up meeting have not implemented certain recommendations. This seemed mainly due to lack of trust in lean success in processes of a short term nature. Those assigned to work on an alliance project must be carefully selected on a 'best for project' basis.
- Poor reference to lesson-learnt registers
  The study identified that the lessons-learnt registers were not greatly used by the middle management. The following issues were identified as reasons for not properly using the lesson-learnt registers.
  - evidences (e.g: photographs and reports) were not embedded with the identified issue so that it is difficult to recall the issue
  - no clear guidelines to explain what constitutes a valid lesson learnt
  - searching within the lessons-learnt register was not efficient and

- only final decisions on improvements were captured in the documentation and no alternative approaches were discussed during the workshops
- Lack of awareness of lessons-learnt registers
  Due to the long-term nature of the project, there was a high middle management turnover. New site engineers and supervisors were not aware of the lessons-learnt registers.

The multi-year construction schedules in alliance projects allow the project team to develop process improvement practices. Based on actual improvements, changes to the initial performance measurements were calculated as shown in Table 5.12. In addition to the researcher’s suggestions, teams have implemented a few more improvements without proper knowledge sharing practices. Nevertheless, the study shows that construction work in an alliance project can be improved substantially by eliminating waste factors.

The follow-up study results show that not all the processes reached their full improvement targets. All the processes except the pre-cast concrete segment production were observed repeatedly over a period of two-years. During that time, most of the workers including the site management left the project. New employees had limited or no understanding of lessons learnt.

Table 5.12: Before / after process comparison

Process study	‘Before’ process			‘After’ process		
	Man-hours	**PE**	**LU**	**Man-hours**	**PE**	**LU**
A	246.1	21%	27%	196.0	26%	34%
B	32.7	6%	18%	37.7	5%	16%
C	204.5	13%	22%	204.5	13%	22%
D	84.4	6%	15%	60.1	8%	21%
E	88.0	11%	18%	67.8	14%	23%

Supplementary to the aforementioned results and analysis, the next section presents a summary of additional observations and limitations of the process studies.

5.10 ADDITIONAL OBSERVATIONS

The lessons-learnt from the process improvements of this particular alliance project would be generalized for other alliance projects that operate over a long time scale. The following section presents the implications of data triangulation from periodic observations and a questionnaire. A questionnaire was used to get the view of the middle level management relating to the identified process waste in an alliance. The questionnaire was sent out to 31 participants, mainly engineers and supervisors of the case study project. A total of 27 responses were returned resulting approximately 87% of average response rate.

5.10.1 Demographic respondent profile

The questionnaire gathered job title, experience in construction and alliance from the middle management of the project under study. The question related to the participant's job title (Question 15, that is shown in Appendix E), was kept as an option due to the ethics precepts. The participants were briefed about the questionnaire during their weekly meeting and explained the research purpose, questionnaire instructions and confidentiality of the study.

In this study, 25% of the respondents skipped this question (Question 15). Respondents were made up of project engineers (15%), site engineers (26%), supervisors (26%) and foremen (8%). The majority of them represent the upper middle management (Figure 5.18). The average work experience of the respondents in construction was 9.7 years. The average experience of the respondents in previous alliances was 3.5 years and 56% of respondents experienced more than one alliance project. This shows that participants are demonstrating a good spread of experience.

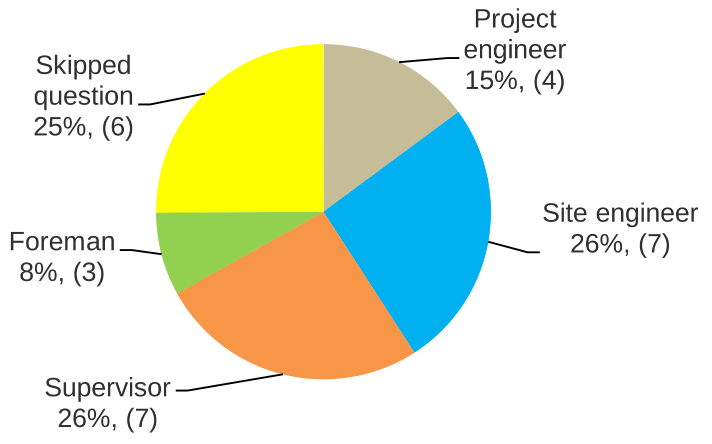


Figure 5.18: Analysis of respondents' profile

Descriptive analysis of response pattern

The response pattern was analysed based on Bosnjak and Tuten's (2001) definition as shown in Table 5.13. In this study, 71% of the participants were complete respondents and 7% were unit non-respondents. 3% were lurkers while 19% were item non-respondents. Early responses are defined as completing the questionnaire before the final notification (Lindner, Murphy, & Briers, 2001). The late respondents can be marked as non-respondents as they would not have responded if there had been no follow-up. In line with past studies (example: (Lindner et al., 2001)), this study received 72% of responses before the final reminder. Since no-response is a threat to external validity of a study, the non-response bias was assessed by comparing responses of early and late respondents. In order to evaluate the consistency and reliability of the scales, Cronbach's alpha coefficient was calculated for all questions.

Table 5.13: Response types of web surveys

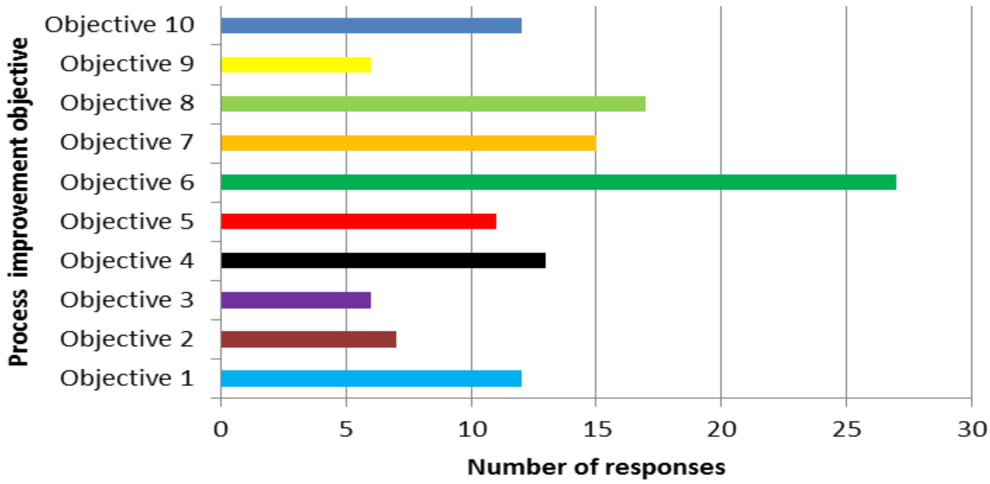
Response types	**Number of responders**	**Percentage of responders**
Complete responders (who view and answer all questions)	22	71%
Item non-responders (who view the whole questionnaire, but answer some of the questions)	6	19%
Unit non-responders (who do not participate)	2	7%
Lukers (who view all of the questions, but do not answer any of them)	1	3%

5.10.2 Objectives of the process improvements

Several waste activities can appear due to the dynamic and complex nature of processes as explained in section 5.5.4. Considering the above fact, it could be concluded that the implementation of lean techniques is appropriate and advantageous with relevant customisations to the context. In this study, the VSM process served as a guide and satisfied the desired objectives. It can be seen from the study that the traditional VSM tool is not suitable to identify improvement opportunities at micro level. Detailed VSMs were developed to understand the locations of waste and to provide the foundation for improvements. Although Picard (2002) has stated that improvements at sub-activity level do not have a great impact on performance, the current study shows that there are potential improvement opportunities at activity and sub-activity levels. Site management holds the same viewpoint possibly due to the unawareness of waste as a quantitative figure.

The evidence from the study suggested that a micro view on observations and improvements can help identify waste present in a process while opening up more existing issues. Individual results showed that waste in the alliance seems to be negligible but if all these waste streams are added up, in the long run, it would be substantial. During process studies, it was observed that the focus for process improvements was limited. Site management views on objectives of process improvements in alliance projects were gathered (question two in Appendix E).

The responses to the question on objectives of process improvements in the alliance project site were dominated by two objectives. They were to ‘provide a safe work environment’ and to ‘develop crews with multi-skills’. These options received 27 and 17 selection votes respectively out of 27 selection votes[1]. These two objectives are consistent with alliance KRAs (safe environment and employee development). Frequencies for other objectives are shown in Figure 5.19 and each of them received 15 or less selection votes. This analysis shows that there is a lack of focus on eliminating process waste from unnecessary motion, transportation, waiting and rework in the alliance project site.



	Objective		Objective
1	Eliminate duplication of material handling	6	Provide a safe work environment
2	Minimise travel distances	7	Maintain equipment for zero downtime
3	Minimise the storage of materials	8	Develop crews with multi-skills
4	Provide a uniform flow of resources	9	Minimise redundant inspections
5	Eliminate material wastage and theft	10	Break the chain of repeated rework

Figure 5.19: Objectives of the process improvement activities

[1] This question was coded to allow for multiple selection choices.

5.10.3 No formal data collection to identify waste

Work measurement and process analysis techniques were used to quantify and identify waste systematically in the processes. The work study concept has been widely accepted in manufacturing compared to construction (Peer, 1986). Such acceptance is paired with the implementation of productivity improvement programmes (Gong et al., 2011). Consequently, the emergence of lean thinking in construction might increase work-study applications. However, the process study observations showed that there are different ways of determining process improvements in an alliance.

Six ways of process improvements identification used in construction projects were identified and respondents were asked to mark relevant identification methods for process improvement in an alliance project (Question one[2] in Appendix E). Through analysis of the questionnaire, it was discovered that the frequently applied process improvement identification methods are discussed with peers (90%), from worker suggestions (80%) and through lessons-learnt workshops (75%). This ensures the existence of open communication between site management and site workers and seamlessly integrated project environment. The least applied methods are from variation of the expected outcome (38%), through periodic site visits (38%) and complaints made by other parties (32%) (Figure 5.20). Furthermore, it was realised that most of the process improvements are identified through informal ways while solutions are developed based on experience of site management. The existing problem solving approach used by the site management often omits the root causes of the problem due to lack of understanding of the current situation.

[2] This question was coded to allow for multiple selection choices

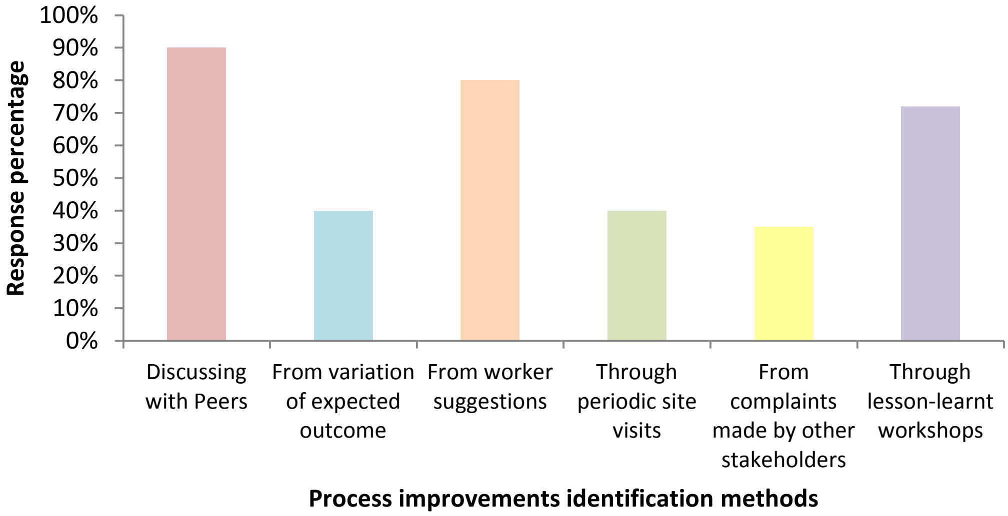


Figure 5.20: Process improvements identification methods

Appropriate data collection and data analysis techniques are required for process improvement study. Supervisors are usually not aware of data collection and analysis methods. Worker training programmes are not normally concerned about those concepts. However, supervisors with work-study training are able to achieve better productivity at the site. Training is required to sustain the suggested process improvement system. The researcher conducted training sessions (during the follow-up meeting) for the project team on data collection and analysis tools that were used in this study. Project team members highlighted the requirement of additional manpower as a major issue. Additional people would be required for collecting and managing real time data collection.

5.10.4 Level of worker participation

Figure 5.20 (Question one in questionnaire) revealed that the second most frequent method of identifying process improvement initiatives is through worker suggestions. However, process study observations showed that there is little worker participation in process study improvements especially little active participation in the pre-start meetings and lessons-learnt workshops. This observation was confirmed by the middle management response to Question four[3] (Appendix E). Respondents were asked to determine the involvement of different groups in process improvement initiatives. In terms of this, out of 27 respondents:

[3] This is a matrix type (with one answer allowed) question.

- 15 respondents considered that involvement of site engineers was very high
- 12 respondents considered that involvement of supervisors was very high
- 11 respondents believed that involvement of project engineers was very high
- Eight respondents believed that involvement of ALT members involvement was very rare
- The majority of the respondents noted that involvement of site workers and sub-concentrators was very low

The frequency of involvement of each group in process improvement initiatives is shown in Figure 5.21.

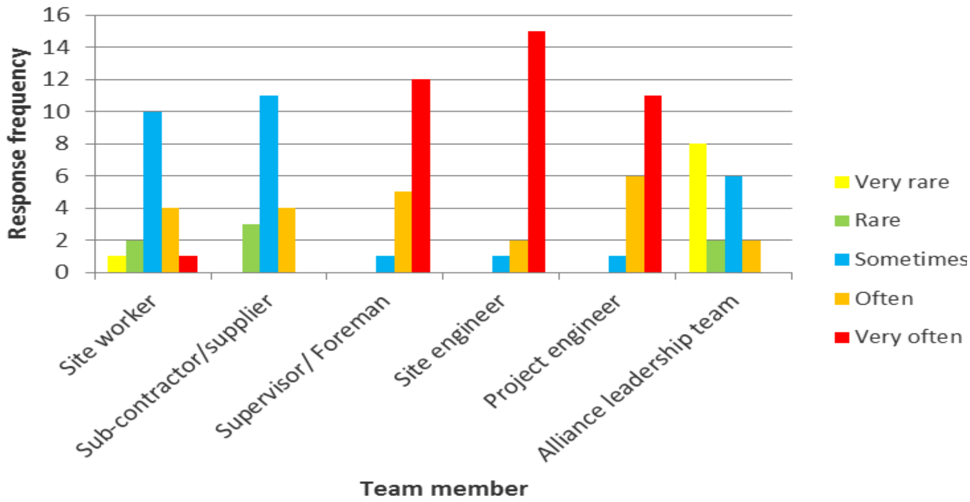


Figure 5.21: Process improvement involvement by job title

In the selected case study, it was observed that the only active forum to gather suggestions from site workers was pre-start meetings. The researcher attended (at least five) pre-start meetings of each process study and gathered minutes of the past pre-start meeting (20 meeting minutes per process). During the participation observation at pre-start meetings, it was observed that there were low interactions between site workers and site management. Discussion points in pre-start meetings of each process study were analysed to identify the focus of process improvements and involvement of site workers. Few key issue categories were selected to assess the effectiveness of the meetings. The selected categories were quality, schedule, workers' voice, worker training, planning and safety. Statistics of the meetings are shown in Figure 5.22 and Appendix T. Overall focus on pre-start meetings in the selected alliance project was:

- 31% weightage on project schedule related issues
- 32% weightage on day to day planning discussions
- 16% weightage on safety related issues
- 15% weightage on quality related issues
- only 6% weightage on worker related issues

Observations showed that there was a high focus on schedule and daily planning in the pre-start meeting’s agenda but less focus on people issues (Figure 5.22).

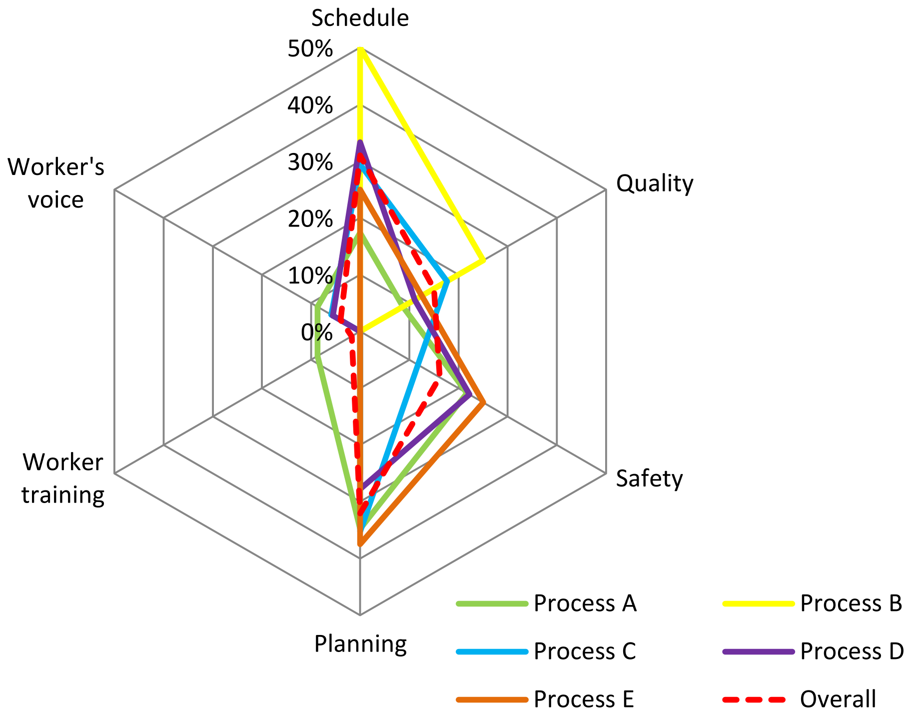


Figure 5.22: Pre-start meeting discussion points assessments

Meantime, input from workers was low during these discussions. The main challenge for implementing an effective pre-start meeting was the communication between site management and workers throughout the day. Most of the supervisors mentioned that they talked to their crew members during the operation on the job site. Consequently, there is little room for discussions on new issues during daily meetings. Hence, pre-start meetings with repetitive agendas lead workers to provide less feedback.

Not using worker creativity was identified as another waste in the project and this is further analysed in section 6.2.

5.10.5 Sub- contractor management strategies

Certain processes of the case study project were sub–contracted through different schemes. For example, the rebar cage fabrication of the pre-cast segment production (process A) was sub-contracted at a fixed price rate and process B was sub-contracted on labour only basis. The sub-contractors were not within the main alliance and were not part of the design team at the design development phase. During the construction stage, the involvement of sub-contractors in process improvements was minimal (Figure 5.21).

During process study A, it was found that 45% of the cycle time of the rebar cage fabrication was on waste activities. Improvement opportunities around rebar steel handling, site layout and process delays were mainly due to material and equipment unavailability. Moreover, the process study found that there were aspects of the sub-process, which the main contractor was engaged in, but they were specifically sub-contractor's responsibilities and the sub-contractors were paid for that. These improvement opportunities were discussed with the alliance management, but these could not be directly implemented due to the accountabilities for sub-contractor's processes, which were out of the alliance management control. There was also little incentive to influence any change in sub-contractor's activities because the contract was awarded at a fixed price.

It is apparent that the benefits of teamwork among upper tier parties were not transmitted down the supply chain. In addition, sub-contractors were not able to visualise how marginal improvements could benefit the entire project. The study revealed that project participants in alliance contracts very often keep sub-contracting firms at arm's length and such a condition acted as another cause for unused project participants' creativity. Identifying and maximising these additional opportunities would improve the project performance. A study was carried out to confirm the findings of the process studies and is reported in section 6.3.

5.10.6 Barriers to implementation and sustainability

During the follow-up meetings, process owners raised difficulties in implementing the suggested process improvement framework. Therefore, in the questionnaire, respondents were asked to rank the identified barriers with regard to their influence on process improvements and the difficulty level in overcoming them. The barriers were ranked from the strongest (most influential) to the weakest and the difficulty level in overcoming these barriers were ranked using their respective co-efficient of variation (COV) (Table 5.14).

The use of COV in ranking is considered more reliable than the mean because it considers both E(X) and V(X) (Abdul - Hadi, Al -Sudairi, & Alqahtani, 2005). Alinaitwe (2009) has used the COV to determine the strength and the ease of lean implementation barriers. The same method was adopted in this study. The five scale responses have been converted into expected values, variance and COV as shown in Equation 5-3, Equation 5-4 and Equation 5-5, respectively.

$$E(X) = \sum_{i=1}^{n} (X_i \, . \, p(X_i)$$ **Equation 5-3**

$$V(X) = E(X - \mu)^2 = \sum_{i=1}^{n} (X_i - \mu)^2 \, . \, p(X_i)$$ **Equation 5-4**

$$COV(X) = \frac{\sqrt{V(X)}}{E(X)}$$ **Equation 5-5**

Where,E(x) the expected value of a discrete random variable X
X the value of the random variable
p(X) the probability distribution
μ the average
V(X) the variance of a random variable X
COV(X) the coefficient of variation

There are five strong barriers that influenced the success of process improvements in the alliance project. These barriers were:

- lack of leadership
- difficult to change behaviour and attitude
- tendency for temporary solutions
- high workload and project pressure
- lack of education and training to drive the improvement process

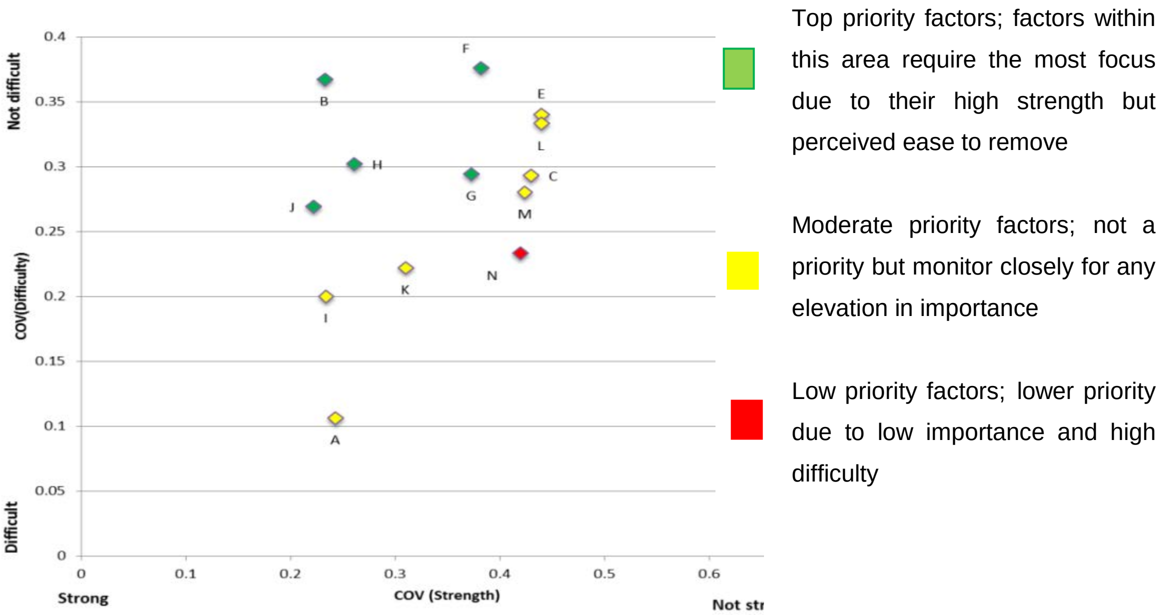
All of the above factors recorded mean scores of greater than 3.0 and the least COV. The barriers that were regarded as difficult to overcome were high workload and project pressure, tendency for temporary solutions and lack of perceived need for improvements.

Table 5.14: Prioritising barriers of process improvement initiatives

	Barriers to implementing process improvements	Influence on process improvements				Difficulty of overcoming barriers			
		Mean	V(X)	COV	Rank	Mean	V(X)	COV	Rank
A	High workload and project pressure	4.00	0.97	0.243	4	4.26	0.45	0.106	1
B	Difficult to change behaviour and attitude	3.55	0.83	0.233	2	4.00	1.47	0.367	14
C	Schedule and cost being the main priorities	3.60	1.55	0.430	11	3.63	1.07	0.293	8
D	Lack of perceived need for improvements	2.35	1.50	0.637	14	3.56	0.83	0.234	5
E	Lack of incentives to encourage process improvements	2.50	1.10	0.440	13	2.63	0.9	0.340	12
F	Lack of mechanisms for operational improvement suggestions	2.70	1.03	0.382	8	2.84	1.07	0.376	13
G	Lack of evaluations of the site management built on improvement effort	2.58	0.96	0.373	7	2.74	0.81	0.294	9
H	Lack of education and training to drive the improvement process	3.11	0.81	0.261	5	2.90	0.88	0.302	10
I	Tendency for temporary solutions	3.90	0.91	0.234	3	3.26	0.65	0.200	2
J	Lack of leadership	3.21	0.71	0.222	1	4.26	1.15	0.269	6
K	Poor engagement of workers	2.48	0.77	0.310	6	2.35	0.52	0.222	3
L	Under-resourced project team	3.75	1.65	0.440	12	2.53	0.84	0.333	11
M	Prevalent command and control structures	3.75	1.59	0.424	9	2.50	0.7	0.280	7
N	Little consultation of project participants	3.80	1.60	0.420	10	3.21	0.75	0.233	4

Figure 5.23 shows the factors ‘difficult to change behaviour of site workers’,’ lack of leadership’ and ‘lack of education and training to drive the improvement process’ as being the strongest to overcome. Additionally, barriers that fell in the marginal area such as ‘lack of evaluation of the site management for process improvements’ and ‘lack of mechanism for improvement suggestions’ can be added to the this category. It was identified that barriers such as ‘little consultation of project participants’ and ‘lack of perceived need for improvements’ were not the major barriers when process improvement initiatives in alliance projects were considered. They could not be easily eliminated. The remaining barriers were moderate: either influential but difficult to overcome, or not influential but easy to overcome. This analysis will assist alliance management to identify barriers and their difficulty of overcoming in

order to minimise waste at sites.



A High work load and project pressure
B Difficult to change behaviour and attitude
C Schedule and cost being the main priorities
D Lack of perceived need for improvements
E Lack of incentives to encourage improvements
F Lack of mechanisms for suggestions
G Lack of evaluations of the site management
H Lack of education and training
I Tendency for temporary solutions
J Lack of leadership
K Poor engagement of workers
L Under resourced project team
M Prevalent command and control structures
N Little consultation of project participants

Figure 5.23: Prioritising process improvement barriers

Besides these observations and lessons-learnt, the following limitations, which add up to the future research study's recommendations, were identified.

5.10.7 Limitations of the process studies

Like all other forms of research designs, a process study has strengths and weaknesses. The major strength of process research is identifying the real and dynamic nature of the project organisation and embedding those dynamics over the time in the case study research context. The longitudinal and contextual information of the case was taken into account to enhance the study validity. A longitudinal case study design was used for better understanding of how lean concept can be used to improve alliance performance. Operational level deficiencies were identified in the southbound construction phase and improvements made through lean techniques were measured during northbound construction phase. Detailed process studies were conducted at the project site. These process studies provided in-depth contextual information on processes, site workers and outcomes of lean applications. This research focused on five processes of the project due to project schedule and safety restrictions of the selected case study. However, these processes covered a wide scope of the selected project and the selection was based on process characteristics and procurement routes.

Participant observation technique was used as data collection in assessing process waste in the alliance project. Consequently, there is big scope for observer bias. Observer bias refers to the ways in which errors may consciously or unconsciously occur when gathering and analysing observational data. In this study, only one observer was involved in process studies and that assures the consistency of the data collected. This study used standard data collection protocols (Appendix M- Appendix P and Figure 5.4), which helped improve the reliability of the study. These protocols were designed to be as objective as possible to minimise observer bias.

As presented in section 5.5.4, the data of each process study was analysed independently and results were aggregated to facilitate drawing conclusions. The degree of divergence of processes caused a comparability issue in the process study findings. Regardless of these differences, the similarity of research designs, procedures, and the observer and process variability (section 5.4.3) make such a result aggregation appropriate and reasonable. Bartunek, Crosta, Dame, and LeLacheur (2000) have noted that the role of the researcher can be limited especially when implementing potential improvement changes in case study organisation. As the author was not part of the alliance project, Bartunek et al. (2000), concerns might be relevant in this case. However, due to continuous improvement and innovation culture in alliance projects, most of the suggested improvements were absorbed by the selected alliance project.

A limitation of the proposed process improvement framework is that each individual worker needs to be trained in Lean related waste categorisation and supervisors need to be knowledgeable in data collection and analysis procedures. The availability of a pre-trained workforce in lean concept is desirable for implementation in a construction site. As the researcher of the study conducted the present work in order to sustain a developed framework such a training process is essential for site management. Understanding both advantages and limitations of the process study puts the researcher in a better position to develop distinctive recommendations from the study.

5.11 CHAPTER SUMMARY

This chapter presented the process study findings in the alliance case study. While innovative procurement systems allow realisation of value, it can be noted that the operational level potential improvements in alliance can easily be identified through lean thinking. The study defined necessary steps for initiating improvements of processes. The results showed that the most problematic wastes were waiting, rework and unavailability of workers. The VSM results in the alliance project are as follows (Table 5.11):

- NVA time decreased by 16% after applying lean tools
- Lean tools resulted in a 12% reduction of the cycle time and
- LU changed to 14% by eliminating waste.

Suggestions for process improvements were proposed for on-site activities. The application of lean tools uncovered significant opportunities for process improvements. The method was very effective and the results clearly show that there is room for improvement in the alliance project activities at the site level. The elimination of waste is important to all project participants of the alliance project. Potential process improvements would improve the performance of the project. The lean concept was identified as an appropriate tool for improving productivity at the operational level, and evidence of applying lean principles to the alliance suggests that benefits can be achieved. Another interesting aspect of this study is the identification of barriers for implementing a process improvement methodology in an alliance from a site management perspective. This analysis enables construction professionals to understand major barriers that could hinder the execution of process improvements and better chances of overcoming these barriers in alliance.

It was noted that alliance projects contain systems for improving the construction project at a high level (strategic/project level) but less practices at site level. The process studies show that lean tools can be used in an alliance project to eliminate these waste types. Additionally, several wastes were caused by other parties (site workers and sub-contractors) who were not attached to the main alliance team. This chapter forms the basis for chapter six, which analyses the eighth waste in terms of site workers and sub-contractor integration in alliances.

6 BEHAVIOURAL WASTE ANALYSIS

6.1 INTRODUCTION

The previous chapter identified process waste and causes for process waste in the selected alliance project. Moreover, process study observations in the case study identified that behavioural waste caused most of the process waste. It was noted that the site managers do not have the solutions to all process related issues, while the site workers and their sub-contractors have the detailed knowledge and experience of how the job needs to be done and how improvements affect them. The creativity or ideas of site workers and sub-contractors were not used to eliminate process waste. In the selected alliance project, sub-contractors and site workers were not part of the main alliance team mainly in information sharing and decision-making. This could have a negative impact on project results. This section explains findings on behavioural waste due to the unused creativity of site workers and sub-contractors.

This chapter contains four sections. The introductory section outlines the focus of the chapter and the roadmap for the chapter. Section 6.2 covers the unused creativity of site workers while section 6.3 covers the unused creativity of sub-contractors. Section 6.4 summarises the chapter findings. This analysis provides the necessary foundation for the research outcomes, which will be presented in the next chapter.

6.2 UNUSED CREATIVITY OF SITE WORKERS

The success of a construction project never relies only on technology and innovation. The project team makes the difference through its collective knowledge and skills. Different scholars (for example: (Edkins & Smyth, 2006; Miles, 1998; Mossman, 2009c) have shown that an enduring lean change is influenced by a bottom-up approach rather than the top-down approach. Lack of bottom-up initiatives might lead to limited success of the process improvement approach, which was explained in chapter five (section 5.10.4). Since Lean aims to maximise value and minimise waste, organisations need to plan an organisational change with participatory practices that will yield more value without excess waste (Rothenberg, 2003). Consequently, available practices of channelling workers for process improvements were identified under five variables in the literature review (section 3.8) including relationships, information, reward and recognition, knowledge and power/decision making. The following sections (6.2.1-6.2.3) explain existing worker participation practices under each data collection method in the referred project.

6.2.1 Process study observations

Yin's (2003) advice is to present the case study as a story, an advice which was followed in this study. That also explains what does and does not work in the observed alliance culture. Various worker participation practices used in the case study project were identified during process studies. These practices were typified by exclusion of operative levels and aimed mostly towards upper middle management (above the supervisor level). The change of the alliance project manager during the study resulted in an introduction of new worker participation practices that were accepted and acknowledged by workers. This section discusses practical examples of worker participation practices applied in the project.

Relationship management

Relationship management is a key element in a high performance plan and crucial to alliance success. Observations showed that strong and defined top-down support existing in the case study, especially the project alliance board, offers continuous support and direction for the ALT. The ALT frequently communicated project progress to the wider project team. One of the symbols of the alliance relationship was the alliance charter, which was signed by all the alliance participants and displayed in the project office. The placement of an organisational chart of the wider project team on the site increased the relationships as it enabled various people of the project to get to know each other easily.

Observations indicated that the bottom-up support for alliance relationships was slightly weak. In the early stage of the project, there was no formal forum to explain alliance principles and expected behaviour to the wider project team although several project celebration events were held to acknowledge the project team efforts and to communicate the current project status. Before a change in the alliance project manager's position, such celebration meetings were the only forum to meet the project teams.

After a new alliance project manager was appointed, the 'one team session' was introduced. ‘One team sessions’ were held monthly in the initial stages and weekly in the later stages. The researcher attended 11 meetings of one team sessions during the process study observation stage and discussions were voice recorded. All site and office staff members were required to attend ‘one team sessions’ and these sessions lasted about 30 minutes. These sessions reviewed the recent failures or successes, informed about upcoming project events and community events. In a ‘one team session’, the management requested suggestions and discussions from the project team. However, site workers paid relatively little attention to that.

In addition, the middle management formed relationships with the site workers through pre-start meetings and site visits. Section 5.10.4 shows that there was a lack of worker interactions in the pre-start meetings. The observations showed that there was relatively poor presence of middle management (site engineer or project engineer) in pre-start meetings. The foreman or charge-hand conducted those meetings. After the appointment of the new alliance manager, an effective pre-start meeting was included as an alliance best practice principle with the revision of alliance principles and values. After that, there were some audits conducted by the superintendent on pre-start meetings and meeting minutes.

Knowledge management

A very tight labour market and shortage of skilled workers are challenges in construction. The case study alliance addressed this challenge by investing in training for both casual and permanent staff including sub-contractors’ staff. Most of the workers received different training opportunities depending on their job requirements, which changed frequently as the project progressed. Even though extensive training would enhance the retention of workers, observations showed that the project still faced worker retention difficulties. For example, in process D, only one supervisor and two foremen remained while all the other workers left during the northbound construction. Moreover, analysis of the training program register revealed that there was a lack of skills development in people management and problem solving for the supervisory level.

The induction program was conducted throughout the project. Everyone who worked on the project had to go through the full induction regardless of the length of the contract. The researcher attended the induction programme four times (February 2010, August 2010, January 2012 and July 2012) as it was a requirement of the project.

In the initial stage of the project, the safety manager conducted the induction program focusing only on safety aspects. In 2012, a new induction program extended the duration of the induction programme from one hour to three hours. The relevant ALT members explained the principles and values of the alliance, safety and environmental aspects of the project. An assessment was carried out at the end of the induction program session. Only successful participants were allowed to enter the site. The induction program and safety training programs had positive results on safety conformance at the site. The worksite injury rate of site workers reduced by 95% overall from 2010 to 2012.

Reward and recognition

An effective reward and recognition program is a key practice of a participative culture. However, alliance projects mainly emphasise organisational level reward mechanisms (gain:pain share mechanism) but pay little attention to an individual’s level. In order to be truly effective, appraisal programs should be linked with reward and recognition to the employees who contribute to the success of the project. Several past studies in construction have shown that reward and recognition will lead to improved worker productivity (Olomolaiye, Jayawardane, & Harris, 1998), project performance with regards to schedule, cost and quality (Aziz, 2007), material waste reduction (Yeung, Chan, & Chan, 2007) and safety improvements (Aksorn & Hadikusumo, 2008). Apart from the value of the reward, recognition is also regarded as an influential way to motivate workers.

In the reference case study, the middle management was assessed based on the achievements of main KPIs (example: cost, time, quality and safety) and the monthly updated achievements were displayed on notice boards. Therefore, site engineers and project engineers who produced remarkable results were recognised in a meaningful way. However, the informal discussions with the site workers and supervisors revealed that there was no specific performance related reward scheme for site workers. Furthermore, they revealed that in the past, only a few site workers received prizes for identifying ways to improve the quality and safety of their operations. These prizes were awarded at the 'one team sessions'.

Decision making/power

Several practices for enhancing worker suggestions were observed in the selected case study. They were pre-start meeting, lessons-learnt workshops and a suggestion system. The pre-start meeting was conducted every day before starting the shift, in the presence of the site engineer and the supervisor. The observations of the pre-start meeting (section 5.10.4) showed that there was low worker involvement and the site management occasionally asked for the site workers' views on the discussion points. Greasley et al.(2005) have pointed out that some managers assert that workers could perceive this consultative approach as a weakness of the management. Therefore, there was little room for new issues to be discussed through pre-start meetings and suggestion boxes.

The middle management participated in lessons-learnt workshops to conduct process improvement decisions but the participation of site workers and sub-contractors was very low. Outcomes of lessons-learnt workshops were shared at the pre-start meetings and transferred to the lessons-learnt register. The goal of the lessons-learnt register was to use the learning experiences in the subsequent phases. However, the usage and popularity of the lessons-learnt register among the middle management was not great. The following issues were identified, which limited its use in this context:

- since evidence (example: photographs and reports) was not included with the identified issue, it was difficult to recall the issue
- the lessons-learnt register was not updated
- searching within the lessons-learnt register was not efficient and
- only final decisions on improvements were captured in the documentation, and no alternative approaches were recorded.

In order to facilitate worker suggestions, a 'suggestion box' was established. Workers were encouraged to submit suggestion forms in the suggestion boxes placed on the site. The suggestion box system can work as one of the main vehicles of worker participation and process improvements. Regardless of these good aims, the 'suggestion box' was not successful in this particular project.

The reasons for the failure of the suggestion box system were identified during discussions with site workers and these issues were:

- workers did not see any benefits to themselves
- frequent informal communications already happening between workers and supervisors on site and
- workers could not make suggestions due to insufficient information and training

Information sharing

Information sharing with workers is a key ingredient to developing worker-management relationships. This case study used ‘one team sessions’ as the main method to pass project related information to workers. These sessions had many items on the agenda such as project progress, safety and environmental issues. Although most of the representatives of sub-contractors attended 'one-team sessions' regularly, it was uncertain how this information transfer happened to sub-contractors who were working off site. Raiden, Dainty and Neale (2004) have claimed that team briefings in construction are infrequent and ineffective. However, this project adopted ‘one team sessions’ and ran them frequently in an effective manner.

The project circulated newsletters among the wider project team. The findings of lessons-learnt workshops and changes taking place were shared across the project team through emails. Due to a lack of a shared platform for site workers, outcomes of the lessons-learnt workshops were discussed in the pre-start meetings. However, a few incidents occurred at the site due to the forgetfulness of the workers about a process change, which caused waste (section 5.6.7). The alliance principles were communicated to the project team via ‘one team sessions’, the induction program and the visual boards at the project site. All these sources were introduced during the midpoint of the project. Visual displays played a key role in communicating project performance, alliance principles and values. Such information focused project members’ expected behaviours and helped them recognise how their individual performance could add to the project success.

Observations drawn from the process studies

The findings from the process study indicated that there is a gap between the worker participation practices in a real alliance and the suggested practices in lean literature as presented in Table 6.1. Most of these practices were implemented in the middle of the project. Therefore, it could be difficult to expect the necessary behavioural changes of a wider project team before the midpoint of the project. This observation highlights the requirement of strong commitment to alliance principles and values from all levels that are achieved with necessary practices in place at the project on-set. In the next phase of the research, interviews were conducted with the alliance management to gain insight into their perceptions of worker participation practices.

Table 6.1: Comparison of worker participation in the alliance and lean theory

Factor	Worker participation in the alliance	Worker participation in Lean
Relationship management	Good relationship with workers	Good relationship with workers
Knowledge management	Continuous training for all	Continuous training for all
Reward and recognition	Lacking in alliance project	Reward and recognition are central
Decision making / power	Lacking in alliance project	Main principle to improve innovation
Information sharing	Among all organisational levels	Among all organisational levels

6.2.2 Semi-structured interviews

Background of interviewees

ALT members are the champions of specific aspects of the project with shifting roles and responsibilities, working closely with a number of employees across all levels of the alliance. In particular with this investigation, five ALT members who were actively engaged with site workers were selected. Semi-structured interviews with an interview guide (Appendix U and Appendix V) were conducted with the following ALT members. Table 6.2 outlines interviewees' professional experience and the purpose of the interview. All the interviewees except INT 2 had prior experiences in alliances.

The interviews were conducted to identify the relevance and importance of various worker participation practices (identified in the literature review section 3.8.3) and barriers to implementing those practices in an alliance environment. Interviewees provided their perceptions on the applicability of the worker participation practices in the alliance and their impact on performance improvements. The interview quotes were used to demonstrate the participants' perceptions of the worker participation practices in the alliance project and the findings are explained in the following sub-sections.

Table 6.2: Profile of interviewees and purpose of interviews

Interviewee ID	Purpose of the interview	Experience in construction (*) / alliance project (√) (Years)				
		< 5	5 -10	10 -15	15 - 20	> 20
INT 1	To identify existing worker participation practices in the case study	-	√	-	*	-
INT 2	To identify existing worker participation practices in the case study	√	*	-	-	-
INT 3	To identify worker participation and alliance best practices in the case study	-	√	*	-	-
INT 4	To identify existing worker participation practices in the case study	-	√	-	-	*
INT 5	To identify existing worker participation practices in another alliance project	-	√	*	-	-

Interview findings

Relationship management

Interviewees agreed that it is essential to encourage the project team to act as a unified team to foster relationships across organisational boundaries. INT 3 clarified that the unified team concept prevailed in the project:

> *"In this office you cannot spot any difference in a contractor or a designer; even you cannot identify their original company. They all work as one team"*

Interviewees stated that middle managers had effective working relationships with their subordinates. The interview participants strongly agreed with the view that 'commitment of all participants' is a critical element of project success. INT 2 explained it as follows:

> *"Restoring trust in the minds and hearts of workers is the main challenge and it has been identified as a key factor in project success"* (INT 2)

This alliance project was a continuation of another alliance project. Therefore, an initial relationship workshop was not carried out to develop the team of this alliance project. Interviewees agreed that conducting such workshops at the beginning of the project was vital. INT 1, INT 2, INT 3 and INT 4 mentioned the 'one team sessions' and social gatherings as good practices to improve relationships within the project team. However, INT 5 noted that these practices were hard to put into practice due to the intangible nature of the benefits.

Knowledge management

Evidence confirmed that a skilled workforce is vital to the project due to the project's complexity. Therefore, the project was committed to the training and development of site workers and it contributed to addressing the skill gap which is common in construction. Interview findings showed that training for workers was prioritised within project plans. This view appears in an INT 1 quote as follows:

> "*The project certainly understood the importance of people. Given the difficulty in attracting and retaining workers, providing training is a good practice to attract and retain workers."*

Apart from the company level appraisal, a separate project level appraisal system existed to discuss and identify the employee training needs. This appraisal system was used only up to the foreman level. Thus, recognition of training needs for site workers had to be done through job analyses.

> *"Supervisors identify the training needs for site workers. There is no formal process. For supervisors there is no specific people management skill training program conducted, but I believe that it will be of benefit."* (INT 1)

The interviewees were asked about the lack of rigor in the induction and pre-start meetings and interviewees accepted the deficiencies in current practices. Effective pre-start meetings were included as an alliance practice and a new induction program was introduced after the replacement of the alliance project manager.

Decision making / power

Interviewees mentioned that all the project staff members including workers were widely encouraged to get involved in suggesting solutions for process improvements. In this project, workers were encouraged to halt the job if they felt the work was unsafe. ALT members always communicated this message to the workers. This reflects that workers have flexibility and power in their work. In practice, worker involvement in decision-making took a variety of forms including suggestion schemes, informal discussions between managers and workers, pre-start meetings and value management workshops. The interviewees pointed out the unsuitability of suggestion schemes in this project as follows.

> “The e*nvironment in here is open enough to meet relevant managers and discuss improvements. It is an open door policy and they can reach any of their superiors to make suggestions. Therefore a separate, formal suggestion system is not required” (INT 4)*

Interviewees noted the reasons below for the failure of the suggestion box.

- no clear reward mechanism stated for participation,
- workers do not know the suggestions evaluation process, and
- long delays in getting the suggestions processed.

Reward and recognition

Many workers across the construction industry often feel that they are not noticed by management and their improvement efforts which are critical to project progress are not being acknowledged and this view prevails in alliance projects as well (Powell, 2012) although INT 1 noted that certain improvement ideas were praised by rewards and recognitions. However, it was further noted that there was no well-defined rewarding mechanism for suggestions. The INT 1, INT 3 and INT 4 referred to some practices they had adopted to improve the motivation of workers. The following quote represents those new practices.

> *“A simple form of recognition used in this project is where I pay daily site visit. The workers who maintain the site tidy and work according to safety standards are praised.”* (INT 4)

A few interviewees pointed out that this type of recognition may be unfeasible for large construction sites. Site engineers and project engineers could adopt the same approach for their work team to develop a good working culture. This type of scheme would work very well with a measurement scheme of worker performance. According to INT 1and INT 3, a number of group recognition practices were used, which often involved holding events, if performance targets were met. These types of events were used to bring the workforce together to improve relationships. In order to ensure the operatives’ willingness to engage with the process of improving performance, some kind of reward mechanism needed to be employed. However, practices aimed at motivating workers to make suggestions were hardly found in the project and none of the interviewees mentioned that an incentive was a motivator for process improvement suggestions. According to INT 1, introducing incentive schemes to suggest improvements may at best be difficult to monitor and, at worst, be seen as conflict-ridden.

Information sharing

For workers to participate, information is an essential element. The main aim of information sharing with workers is to effectively communicate project decisions to give a better understanding of the project. There has been a great deal of interest in increasing downstream communications to workers typically via the 'one team sessions'. These sessions communicate alliance principles, values and the current project status to change the project team behaviour. INT 1 explained the reason behind the implementation of 'one team sessions' as follows:

> *"Earlier we thought alliance guidelines and project work will bond each other. Later we realised that this will not work automatically. That is why one team sessions were implemented. It is useful to have this kind of meeting because all of them realise the project progress and they are in one team*."

Interviewees noted that the alliance should involve site workers in increasing participation from the beginning of the project. Moreover, to extract ideas, the project leadership team put a lot of effort into communicating project principles, strategy and the importance of innovation. However, the project did not specifically emphasize the importance of sharing employee creativity among the project team. This was highlighted by INT 3 as follows;

> "*We do not have any robust system to share the knowledge among team members. It is probably ad-hoc and shared at a higher level by project engineers. There is no set system. It is an improvement point.* "

Different worker participation practices surfaced in the interviews and the key enabler of such practices was identified as leadership and management style. The change of the alliance project manager led to the introduction of new practices and this was acknowledged by most of the interviewees.

Barriers to implementing worker participation practices in alliance

Despite previous worker participation studies in construction, no known study has identified the specific barriers to implementing worker participation practices in alliance projects. The current study was designed to address this important research gap. Identifying these barriers will help alliance to minimise any obstacles to participation that may prevent workers from taking part.

The success of worker participation practices depends on the support provided by top-level management especially the alliance project manager (INT 1, INT 2, INT 3, INT 4 and INT 5). According to these interviewees the alliance project manager commitment in the form of how the practices are monitored, the allocation of resources and the amount of training provided are essential for sustainable worker participation practices. INT 3 explained the change in mind set and behaviours of wider project team after the positional change of the alliance project manager in the current project.

According to INT 4 employee costs seemed to increase with the rise in training that is necessary to maintain worker participation practices. Although there are naturally increasing employee costs associated with training and worker participation practices, the merits of these practices could benefit in the long run. This guarantees that allocation of resources is a major factor to sustain worker participation practices in alliance projects. However, INT 5 insisted that the short-term nature of employee contracts and the project would reduce the advantages of training in those practices even on the same project. The study identified that 80% of the workforce at the alliance project site worked under sub-contractors. All interviewees agreed that implementation of these practices takes time and site management is often reluctant to suffer through the short-term consequences, especially if the goals and objectives fall far short of the time for benefits of the new systems to be realised, and they are unable to foresee the long-term benefits of these changes. This is mainly due to the short term nature of the project and pressure of routine work.

Furthermore INT 1 noted that the failure of new practices was due to employee resistance caused by ingrained experience and a lack of belief in new practices.

Summary of findings: The perception of worker participation practices

The summary of interviewees' views of worker participation practices is presented in Table 6.3. Findings reveal that 'reward/recognition' and 'decision making/power' practices are lacking in the project. The results show that none of the interviewees believed that the 'team and individual rewarding systems' and 'suggestion system' were important and sustainable practices. According to the interviewees, 'worker opinion survey' and 'people management skill training for supervisors' are most important but not practiced in the project. Conducting relationship workshops and social activities for workers was rated as an unimportant practice by the majority of the respondents. Moreover, relationship workshops were not conducted in the current project while the social activities were operating.

Table 6.3: Relevance and importance of worker participation practices

Area	Worker participation practice	Exists			Interviewee (INT)				
		Start	Mid	Final	INT 1	INT 2	INT 3	INT 4	INT 5
Relationship	Treat the entire workforce as equals	√	√	√	Important	Important	Important	Important	Important
	Conduct social activities	√	√	√	Important	Neutral	Neutral	Unimportant	Important
	Conduct relationship workshops	X	X	X	Neutral	Important	Unimportant	Unimportant	Important
Knowledge	Formal appraisal system to assess training needs	X	√	√	Important	Important	Unimportant	Unimportant	Important
	Supervisors trained in people management skills	X	√	X	Important	Important	Neutral	Neutral	Important
	Site workers have job training opportunities	√	√	√	Important	Important	Important	Important	Important
Reward and recognition	Regular employee performance appraisal	X	√	√	Neutral	Important	Neutral	Unimportant	Important
	Site workers receive performance related rewards	X	√	√	Unimportant	Unimportant	Unimportant	Unimportant	Neutral
	Work team receive performance related recognition	X	X	X	Neutral	Neutral	Unimportant	Neutral	Neutral
Information sharing	Management gives project information to employees	X	√	√	Important	Important	Important	Important	Important
	Standard job related induction programme	X	√	√	Important	Important	Important	Important	Important
	Opinion survey of employees by third party	X	X	X	Important	Neutral	Important	Neutral	Important
Decision making/ power	'Feedback box' to make suggestions	√	X	X	Unimportant	Unimportant	Neutral	Neutral	Unimportant
	Worker involvement in lessons-learnt workshops	X	X	X	Neutral	Neutral	Important	Neutral	Neutral
	Requests for employees' ideas and input	X	X	X	Unimportant	Unimportant	Neutral	Important	Neutral

Key for existence: √, fully implemented; X, not implemented (absent).

Key for importance: 🔴 Unimportant, 🟡 Neutral and 🟢 Important

From the analysis it was found that certain practices were introduced in the middle of the project and which are mainly due to the new appointment of the alliance project manager. These practices are:

- Formal appraisal system to assess training needs
- Supervisors trained in people management skills
- Regular employee performance appraisal
- Site workers receive performance related rewards
- Management gives project information to employees
- Standard job related induction programme

Out of those six practices four practices were identified as important practices by the interview participants (if a practice got more than two important rating by interview participants). The imporatnat practices but implement in the middle of the projects are:

- Formal appraisal system to assess training needs
- Supervisors trained in people management skills
- Management gives project information to employees
- Standard job related induction programme

Out of those important practices except 'supervisors trained in people management skills' all other practices were continuously conducted during the project.

Summary of findings: The perception of barriers to implementing worker participation

Most of the interview participants indicated a positive attitude to implementing worker participation practices and all agreed that the workforce is the main driving factor for the project success. The identified barriers to implementing worker participation practices surfacing from the interviews were:

- lack of top-management commitment
- short term nature of the project and employee contracts
- pressure of routine work and
- additional task of process monitoring, resource allocation and training.

The next section presents findings from a questionnaire survey that sought to examine the middle management perception of worker participation practices.

6.2.3 Questionnaire findings

In an attempt to uncover the underlying factors that describe the behavioural waste in an alliance project, a questionnaire was conducted with the middle management. The total number of middle level managers working under the selected alliance project was 31. An online questionnaire was sent to all middle level managers and 27 responses were received. The analyses of response patterns and respondents' profiles were explained in section 5.10.1. Two questions were related to the worker participation practices. The first question examined the participants' view of worker participation practices (question 6 in Appendix E) while the second question examined their view about the barriers for the implementation of worker participation practices in alliance projects (question 8 in Appendix E)

Consistency and reliability assessment

In order to evaluate the consistency and reliability of the scales, three methods were used, namely Cronbach's alpha coefficient, Mann-Whitney test and Spearman correlation. The Cronbach alpha coefficient was used to assess the internal reliability of the questionnaire. Prior to undertaking a detailed analysis, each of the variables was tested for reliability using Cronbach's alpha (Table 6.4). All questions had alpha values above 0.7 which indicated a good internal reliability as suggested by Nunnally (2012).

Non-parametric tests were chosen because of the relatively low number of respondents in the groups (N <20) and non-normality of the data for several items (assessed using the rule of thumb of skeweness to standard error ratio >2.0). The Mann-Whitney test is a nonparametric test used to test the significance of the differences between the perceptions of two groups with less than 20 responses. Spearman's rank correlation coefficient is a nonparametric rank statistic, which is used to assess the reliability of the ranking of categories.

Table 6.4: Cronbanch's alpha coefficient measures

Description	**Worker participation practice questions**			**Sub-contractor management practice questions**		
	6*	**8(a)***	**8 (b)***	**9 (a)***	**9 (b)***	**10***
Number of variables	15	16	16	18	18	15
Cronbach's alpha	0.730	0.767	0.754	0.894	0.874	0.850

* Note: Question numbers are as per the web based questionnaire (Appendix E)

In order to test the degree of agreement between the two respondent groups, two tests were conducted. First, the Mann-Whitney test was conducted to determine the difference in mean responses of different categories of respondents (Table 6.5, Table 6.6 and Table 6.15). Second, Spearman correlation was conducted to assess the reliability of the ranking of categories and the analysis was conducted by using Equation 6-1.

$$\text{Spearmen's rank coefficient } r_s = 1 - \frac{6 * \sum d^2}{(N^3 - N)}$$ **Equation 6-1**

Where, r_s - Spearman rank correlation coefficient

d - Difference in ranking of two respondent groups and

N - Number of variables (practices).

This analysis procedure had been widely used by other construction management studies (for example: (Chen, Zhang, & Xie, 2010; Love, Mistry, & Davis, 2010) to ensure internal consistency. Results show that there is relatively close agreement between each two groups in ranking the importance of worker participation practices (r_s=0.811) and lean supply principles (r_s=0.916).

As a measure of external reliability, the analysis was conducted with the early and late respondents. The concordance analysis was also repeated with the early and late respondents. No significant differences were noted in the measurements between the early and late respondents in all five questions. These results suggest that respondents were representative of the population. Since it is impossible to know the opinions of non-respondents, late respondents were used as a proxy for non-respondents.

Importance of worker participation practices

Question 6 in the questionnaire (Appendix E) aimed to seek opinions on the importance of worker participation practices in alliance projects. The principle worker participation variables were assessed based on the mean scores calculated using the following Equation 6-2 and findings are shown in Table 6.5.

$$\text{Mean score } \overline{X} = \frac{\sum_{i=1}^{5} W_i \times X_i}{\sum_{i=1}^{5} X_i}$$ **Equation 6-2**

Where, i - Response category index,

W_i - Weight assigned to the i^{th} response and

X_i - Corresponding frequencies of the i^{th} response.

Given the nature of the study, the experience of the respondents in the alliance project was considered as critical. Therefore, prior to the detailed analyses, the agreement between the two groups (based on alliance experience) was analysed to detect any discrepancies. Group A refers to respondents with more than five years prior experience in an alliance and group B refers to respondents with less than five years prior experience in an alliance.

In most circumstances, a sample size of 15 cases per group should be sufficiently large to yield an accurate result (Doloi, 2012). However, with a small sample (27) with skewed distribution with two participant groups, instead of a t-test, the Mann-Whitney test was used. According to many authors in the social sciences, a significance level of 5% is regarded suitable for most statistical tests. This convention of significance was applied to the various tests that were undertaken in this study. According to this convention of significance, in the Mann-Whitney test, if the significance level (ρ) is below 0.05 it designates a high degree of difference in the opinion between groups on that factor.

Table 6.5: Ranking of criticality of worker participation variables

Principle variables in Question 6 (Appendix E)	Group – A *		Group – B*		Significance level ρ	Aggregate	
	Mean	σ**	Mean	σ**		Mean	σ**
Relationship	3.800	0.754	3.943	0.633	0.165	3.864	1.223
Knowledge	4.067	0.866	3.778	0.978	0.090	3.938	1.056
Reward and recognition	3.222	0.906	3.220	0.641	0.190	3.222	1.447
Information sharing	3.089	0.672	3.444	0.672	0.070	3.247	0.974
Power/decision making	2.689	0.388	3.056	0.802	0.045***	2.852	1.363

* Group A refers to respondents with greater prior experience in an alliance; Group B refers to respondents with less prior experience in an alliance

**σ – Standard deviation, ***Significant difference between the means at the 0.05 level, two-tailed test

Based on the results of the Mann-Whitney test, there was no statistical variation in the responses between the two groups in the first four constructs in question 6 in the questionnaire (Appendix E). According to the overall mean score above, the respondents agreed that the very important worker participation variables were ‘knowledge’ and ‘relationship’ while the other three variables were moderately important. Respondents with more experience in alliance projects rated ‘knowledge’ as a very important variable while the other group rated ‘relationship’ as the most important variable. The ‘reward and recognition’ variable had an almost equal rating from the two groups and the 'power/decision making' variable had the lowest rating from the two groups.

To identify important worker practices under each principle variable, the relative importance index (RII) was calculated. Past construction management research, e.g. Chan and Kumaraswamy (1997) and Kometa, Olomolaiye, and Harris (1994), used the RII method to determine the relative importance of various factors. The same approach was used for the analysis of the current questionnaire (for question number 6 and 9, (Appendix E)) with various groups as classified based on the previous alliance experience of the participants (i.e. whether less than five years' experience in alliance and more than five years' experience in alliance).

The five point Likert scale used in the questionnaire was converted to relative importance indices for each factor, using Equation 6-3, to determine the rank of the different factors. These rankings made it possible to cross compare the relative importance of the factors as perceived by the two groups of respondents. The mean and standard deviation of each individual factor was not statistically suitable to assess the overall ranking because they did not reflect any relationship between them. Hence, all the numerical scores of each of the identified scores were transformed to relative importance indices to determine the relative ranking of the factor. Since there was a difference in one construct, the 'power/decision making' (Table 6.5) RII analysis was conducted separately for the two groups. The RII was evaluated using the following Equation 6-3 and the findings are shown in Table 6.6.

$$\text{Relative importance index (RII)} = \frac{\sum_{i=1}^{5} W_i \times X_i}{A \times \sum_{i=1}^{5} X_i} = \frac{\text{Mean score}}{A}$$

Equation 6-3

Where,

I - Response category index

W_i - Weight assigned to the i^{th} response

X_i - Corresponding frequencies of the i^{th} response and

A - The highest weight (i.e. 5 in this case)

Table 6.6: The importance of worker participation practices

	Practices	Group – A		Group – B		Aggregate	
		RII	Rank	RII	Rank	RII	Rank
A	Treat the entire workforce as equals	0.853	2	0.883	1	0.866	2
B	Conduct social activities	0.800	5	0.817	4	0.808	3
C	Conduct relationship workshops	0.627	11	0.667	9	0.645	11
D	Appraisal system to assess training needs	0.787	6	0.800	5	0.793	4
E	Supervisors trained in people management skills	0.840	3	0.733*	8	0.792	5
F	Site workers have job training opportunities	0.813	4	0.733*	7	0.777	7
G	Regular employees' performance appraisal	0.880	1	0.867	2	0.874	1
H	Site workers receive performance related rewards	0.400	14	0.417	15	0.408	15
I	Site workers receive performance related recognition	0.653	10	0.650*	11	0.652	10
J	Management gives project information to workers	0.693*	9	0.750	6	0.718	8
K	Standard job related induction programme	0.733	7	0.850	3	0.785	6
L	Opinion survey of employees by third party	0.427	13	0.467	14	0.445	13
M	'Feedback box' to make suggestions	0.373	15	0.517	13	0.437	14
N	Worker involvement in lessons-learnt workshops	0.547	12	0.667	9	0.600	12
O	Requests for employees' ideas and input	0.693*	8	0.650*	12	0.674	9
	Number of respondents	**15**		**12**		**27**	

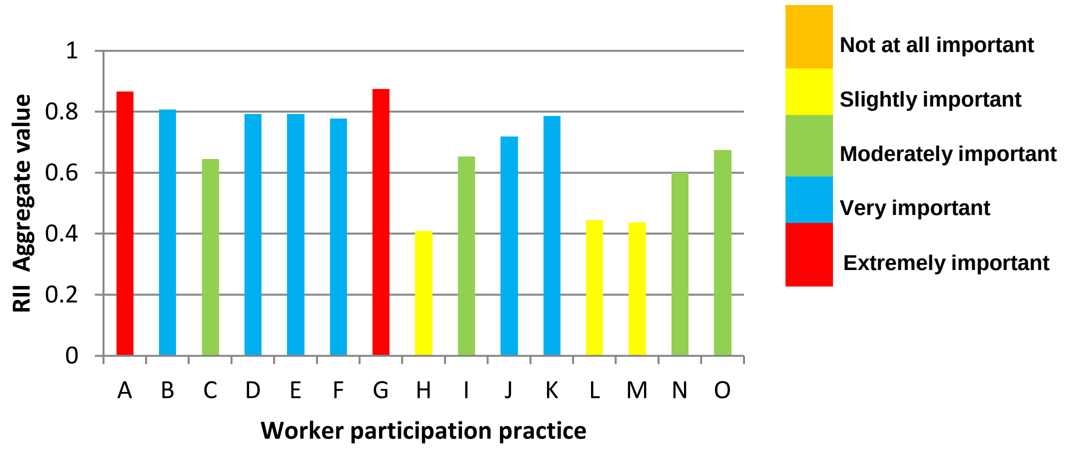
* Equal relative importance indices of the factors ranked according to the least standard deviation figures.

Scholars have claimed that only one number could not quantify each qualitative expression in a Likert scale. Therefore, the RII is divided into five ranges using the 95% confidence technique (Table 6.7).

Table 6.7: Likert scale conversion with intervals

Scale for question	Not at all important	Slightly important	Moderately important	Very important	Extremely important
Confidence interval	0.2 ≤≤0.36	0.36≤≤0.52	0.52≤≤0.68	0.68≤≤0.84	0.84≤≤1.00

Based on the intervals worker participation practices are categorised into five groups as shown in Figure 6.1.

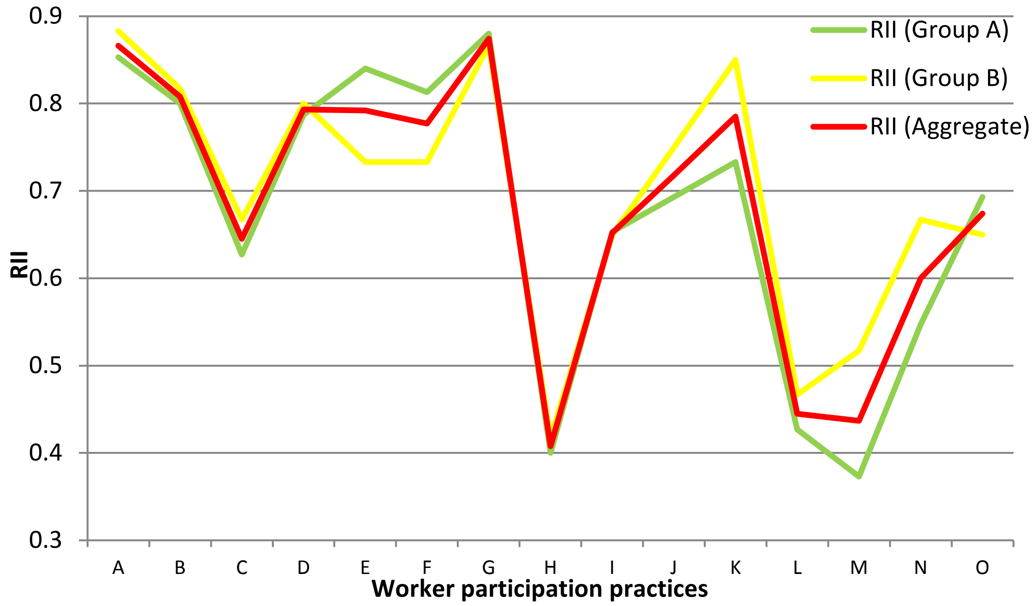


A Treat the entire workforce as equals
B Conduct social activities
C Conduct relationship workshops
D Appraisal system to assess training needs
E Supervisors trained in people management skills
F Site workers have job training opportunities
G Regular employees' performance appraisal
H Site workers receive performance related rewards
I Site workers receive performance related recognition
J Management gives project information to workers
K Standard job related induction programme
L Opinion survey of employees by third party
M 'Feedback box' to make suggestions
N Worker involvement in lessons-learnt workshops
O Requests for employees' ideas and input

Figure 6.1: Categorisation of worker participation practices

Analysis of the results indicates that the most important practices in worker participation programs are 'regular employee performance appraisals (RII =0.874, Table 6.6)' and 'treat the entire workforce as equals (RII=0.866, Table 6.6)'. There is no practice identified as an unimportant practice. Three practices namely 'site workers receive performance related rewards (RII=0.408, Table 6.6)', 'opinion survey of employees by third party (RII=0.445, Table 6.6)' and 'feedback box' to make suggestions (RII=0. 437, Table 6.6)' were identified as slightly important practices. There is no practice from the 'power/decision making' variables appearing as an important practice. A cross comparison of the RII values of the practices as perceived by the different groups of respondents is presented in Figure 6.2.

In general, the rankings of the two groups indicate less discrepancy across the most important worker participation practices, especially the 'work team receive performance related rewards', 'regular employees' performance appraisal' and 'appraisal system to assess training needs'. However, a wider discrepancy is shown in 'supervisors trained in people management skills', 'site workers have job training opportunities', 'standard job related induction programme', 'feedback box' to make suggestions' and 'worker involvement in lessons-learnt workshops' practices. The ‘supervisors trained in people management skills’ and ‘site workers have training opportunities’ practices were ranked much higher (3rd rank and 4th respectively) by group A than group B (8th rank and 7th respectively). However, the ‘standard job related induction programme’ and ‘worker involvement in lessons-learnt workshops’ practices were ranked much lower (7th rank and 12th rank respectively) by group A than group B (6th rank and 9th rank respectively).



A Treat the entire workforce as equals
B Conduct social activities
C Conduct relationship workshops
D Appraisal system to assess training needs
E Supervisors trained in people management skills
F Site workers have job training opportunities
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H Site workers receive performance related rewards
I Site workers receive performance related recognition
J Management gives project information to workers
K Standard job related induction programme
L Opinion survey of employees by third party
M ‘Feedback box' to make suggestions
N Worker involvement in lessons-learnt workshops
O Requests for employees’ ideas and input

Figure 6.2: Most significant practices according to two respondent groups

Analysis of worker participation implementation barriers

The possible barriers to implement worker participation practices that were reported in previous research (section 3.8.4) and findings from ALT members’ interviews (section 6.2.2) were further investigated with the middle level management of the selected case study. In this a specific question (question 8 in Appendix E), respondents were asked to evaluate the barriers for implementing worker participation practices. Participants were required to indicate their experience with implementation barriers of worker participation practices by referring to the alliance environment. Since there was no significant difference between the two groups (group A and B), all the responses were analysed together. The barriers were ranked using COV of influence on the success of worker participation practices and the difficulty of overcoming the barriers (Table 6.8).

Table 6.8: Ranking of worker participation implementation barriers

#	Barrier description	Strength of influence			Difficulty of overcoming		
		E(X)	COV(X)	Rank	E(Y)	COV(Y)	Rank
A	Inability to overcome mindset	3.852	0.276	7	2.926	0.444	12
B	Short-term nature of employee contract	3.407	0.219	3	3.519	0.228	1
C	Lack of leadership of management	3.852	0.172	2	2.704	0.445	13
D	Pressure of routine work	3.185	0.370	10	2.852	0.409	10
E	Lack of trust between workers and management	3.222	0.277	8	3.556	0.274	2
F	Lack of communication with workers	2.667	0.441	14	2.926	0.390	8
G	Lack of confidence in worker participation	1.630	0.486	16	1.519	0.528	14
H	Lack of training in participative practices	2.852	0.373	11	1.963	0.556	16
I	Special interest groups (e.g.union)	1.482	0.473	15	1.370	0.359	6
J	Difficult to measure individual performance	2.889	0.400	13	1.704	0.535	15
K	Short term nature of projects	2.296	0.397	12	3.482	0.280	3
L	Organisational politics	2.852	0.302	9	1.741	0.341	5
M	Personal agendas	2.852	0.232	4	1.296	0.359	7
N	Little organisational commitment	4.185	0.274	6	1.926	0.405	9
O	Fear of decentralisation of power	3.222	0.131	1	2.148	0.442	11
P	Lack of HR policies	4.074	0.254	5	2.741	0.297	4

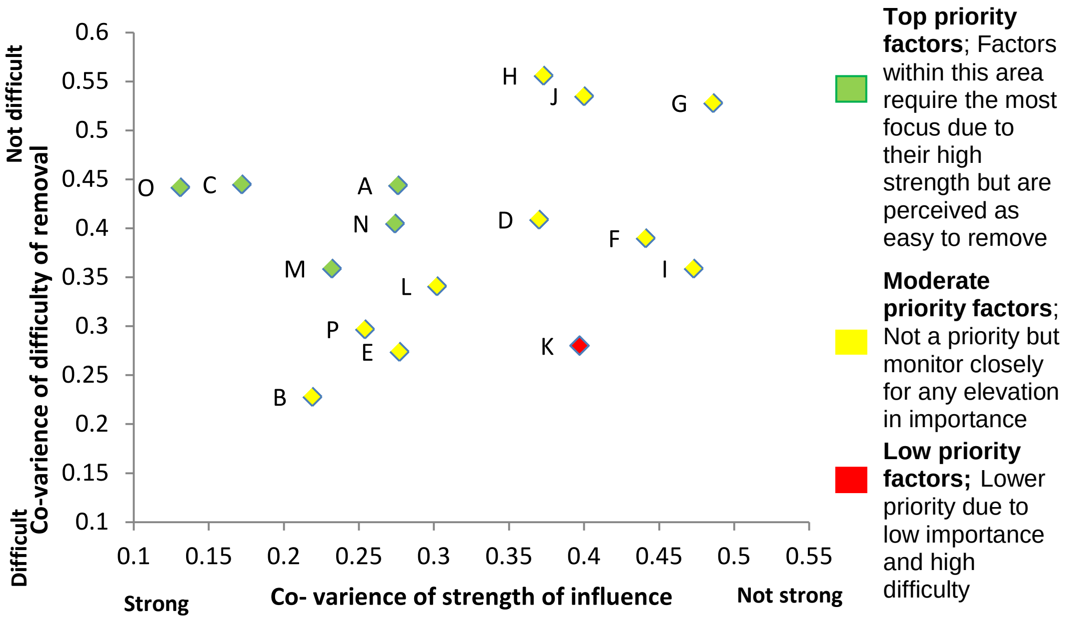
The five barriers with the highest rank in strength are related to :

- fear of decentralisation of power
- lack of leadership of management
- inability to overcome mind-set
- personal agendas
- lack of HR policies

The top five barriers that are regarded as easy to overcome are

- lack of training in participative practices
- difficulty to measure individual performance
- lack of confidence in worker participation
- lack of leadership of management
- inability to overcome mind-set

A complete picture of the barriers can be obtained by combining both aspects of the barriers. For that, the COV of strength is plotted against the COV of difficulty level as shown in Figure 6.3.



A	Inability to overcome mindset	**I**	Special interest groups (e.g.union)
B	Short-term nature of employee contract	**J**	Difficulty to measure individual performance
C	Lack of leadership of management	**K**	Short term nature of projects
D	Pressure of routine work	**L**	Organisational politics
E	Lack of trust between workers and management	**M**	Personal agendas
F	Lack of communication with workers	**N**	Little organisational commitment
G	Lack of confidence in worker participation	**O**	Fear of decentralisation of power
H	Lack of training in participative practices	**P**	Lack of HR policies

Figure 6.3: Prioritising barriers to worker participation practices

Figure 6.3 shows that 'lack of leadership of top management', 'inability to overcome mindset', 'fear of decentralisation of power' and 'little organisational commitment', and 'personal agendas' factors have top priority. Additionally, barriers falling in the marginal area ('lack of HR policies' and 'organisational politics') may also be added to the top priority. The study further identified that 'short term nature of the project' is not a barrier when worker participation practices in alliance projects are considered. This is because they are the least influential barriers and they cannot easily be eliminated. The remaining barriers are moderate: either influential but difficult to overcome, or not influential but easy to overcome. The next section investigates the unused creativity of sub-contractors in an alliance project.

6.3 UNUSED CREATIVITY OF SUB-CONTRACTORS

Integrating project participants is one of the solutions to the productivity problems in construction. According to Ahmed, Azhar, and Ahmad (2000) the construction supply chain is assembled into two processes, namely construction services process and procurement process. The alliance model integrates only part of the construction services which includes owner, architect, designer, main contractor and critical sub-contractors. This means the alliance integrates fragmented parties only up to a certain extent and has not much influence on downstream participants. The increasing extent of sub-contracting in alliances still leads to fragmented project activities, which ultimately affects productivity. Since the referred case study focused only on the first tier of project participants, this study is designed to identify lean supply based solutions to integrate lower tier project participants.

The next section (6.3.1) explains the findings of the process study observations related to sub-contractor management practices and their deficiencies in relation to the referred case study.

6.3.1 Process study observations

This section explains how sub-contractor activities influence process waste in alliance construction sites. In the following, five scenarios were identified in five process studies as introduced in section 5.4.2. These five examples (observed during five process studies explained in section 5.2) were used to illustrate the interaction between sub-contractors and the alliance. Moreover, each example explains the influence of sub-contractor performance on project performance.

Process study A

The rebar cage fabrication, which was approximately 20% of the total cycle time of the entire pre-cast production process, was sub-contracted at a fixed price. The process study found that 45% of the cycle time for the fabrication of the rebar cage consisted of waste activities. These waste activities included rework, unnecessary motion/transport and waiting. Improvement opportunities were identified in this process around rebar steel identification and handling, job-site layout and process delays due to material and equipment unavailability (section 5.6.1). Furthermore, there were different fabrication issues in the construction phase, mainly because the sub-contractor was not a part of the design team.

This process study also indicated that a certain amount of misunderstanding existed between what site management believed sub-contractors were doing and what actually happened. For example, the study found that some of the activities that sub-contractors were responsible for under the sub-contract agreement were transferred to the mould section crew members who represented the alliance due to the constructability issue. However, this task transfer was not identified by the site management and therefore the sub-contractor was paid the same agreed sub-contract price. Task responsibilities were not well communicated and performance monitoring was not effective in this situation. Moreover, the sub-contractor was not participated in the work schedule preparation and regular lessons-learnt workshops.

The improvement opportunities identified in the process study A (Table 5.9) were discussed with the alliance management. However, these opportunities were not implemented directly as the concerned sub-contractor's processes were out of alliance management control. There were also few or no incentives to influence any change in the sub-contractor's activities as the sub-process was awarded at a fixed price. It is apparent that the benefits of team-work among upper tier parties were not transmitted down the supply chain. Project participants of the alliance very often tried to keep the sub-contracting firms at arm's length. Thus, sub-contractors were unable to visualise how marginal improvements could benefit the entire project. During the data collection stage of process A, it was observed that each party was not willing to share their best practices with other parties and acted as competitors.

Process study B

This process study revealed that NVA activities contributed to 49% of the total cycle time. The NVA activities included poor workmanship, non-optimal layout, and ineffective work methods. The study found that the sub-contractor who was handling this work process placed little emphasis on efficient work performances. The terms of engagement did not provide any direct benefits for efficient work methods and higher performances. Incentives offered by the alliance for performance improvements did not diffuse down the supply chain to motivate the reduction of waste.

The main contractor implemented process controls such as a daily monitoring of production and comparison with planned targets and subsequent monthly forecasting of the performance of the process. Although the process was completed on time, it incurred 23% excess over the original budget. The process study determined that rework activities accounted for 17% of the total NVA activities. The main reason for rework was poor workmanship of unskilled workers supplied by the sub-contractor.

Process study C

Continuous downtime resulting from equipment failure was a major problem consistently faced in process C. During the observation period, disruption of the construction activities due to machinery breakdown accounted for 12% of the total working hours of the process. Managing construction equipment was tightly connected to various activities and machinery breakdowns invariably caused downtime for workers and suppliers. For example, due to the breakdown of a cutting machine, the process was delayed and during that time, a crane supplier was paid at a rate of NZ$ 500 per hour. Similarly, a crane breakdown caused downtime for the cutting crew, which resulted in a payment to idle operators who were provided by a sub-contractor.

Due to delays in response time to machine breakdowns, the project suffered from cost and time overruns. The deficiencies in contractual arrangements with labour sub-contractors and risk assessments were discussed as further action points by the alliance management in the lessons-learnt workshops. Since most of the project works were inter-reliant and sub-contracted, such uncertainties need to be considered to prevent incurring costs due to the propagation of disturbances throughout the project network with a negative impact on the project.

Process study D

In general, quality control issues become less complicated for main contractors when special sub-contractors are utilised (Hinze, 1994). In this process, the risk of quality defects increased due to sub-contracting with inexperienced parties. The fabricated steel supplied by the sub-contractor contained hidden welds. This caused site workers to rework and reanalyse the steelwork that was not checked earlier. This disrupted the current workflow and subsequent processes.

This had demotivating effects on the steel fabricator as well as on other sub-contractors with the consequence of declining productivity. Later, to eliminate any further delays, the alliance allocated about 650 hours to ensure quality specifications of steelwork supplied.

Moreover, adequate lead-time was not given to fabricators to follow correct procedures. The alliance team did not monitor the performance level of sub-contractors continuously, which ultimately affected the project performance. Alternatively, sub-contractors did not recognise the significance of their work in relation to subsequent processes and the main project. Such a NVA activity would have been avoided if the design coordination had occurred during the earlier stages of the project and quality inspection procedures were adopted for critical and large sub-contractors.

Process study E

Site management had many coordination concerns that involved material deliveries from different suppliers and scheduling those deliveries with site activities. Due to the complexity of the project, the processes contained a huge number of activities and deliveries at the site. The uncertainties of material delivery and equipment breakdown influenced the project duration.

Process study E discovered that 8% of extra cycle time was due to delays of transporting vehicles. According to the method statement, the cut segment should be directly unloaded onto a trailer. However, because of payment issues with the transporting company, the transportation service was delayed. Therefore as a temporary measure, the cut segments were unloaded onto the ground. This unloading activity resulted in unnecessary motion, transporting, extra-processing and disruptions to the other construction activities due to space limitations and safety issues. Moreover, delays in the material/service delivery caused process waste as mentioned in section 5.6. Observations revealed that the relationship with sub-contractors was not strong and stable which often resulted in process waste.

Observations drawn from the process studies

The process study observations confirmed that some aspects of lean supply principles (section 3.9.2) were already adopted by the case study project. Table 6.9 provides a comparison of sub-contractor management in the observed processes and lean supply theory. Most of the sub-contractors engaged in the project had long-term relations with alliance participants. In this alliance project, the major determinants of sub-contractor selection were price and prior working relationships. Previous working relationships had improved the trust and interdependence, so that commitment towards waste reduction could come naturally. However, the aforementioned process study findings showed that sub-contractors can create waste. The alliance management did not seem to exploit opportunities to eliminate waste because of the fragmentation of sub-contractors.

The key areas where sub-contracting practices in the project differ from the lean supply concept were information sharing and joint development. Transparency of information was not always present. The selected alliance project excluded critical sub-contractors at the design phase, thus missing innovative ideas at that stage. Although the main contractor made efforts to keep sub-contracting teams informed about alliance decisions, better integration and coordination would have been realised if they were project participants making key decisions from the outset of the alliance project. However, the referred alliance project did not offer any tangible incentives to sub-contractors to commit to such objectives. The interaction between the sub-contractors and the alliance project on continuous process improvement was low.

Table 6.9: Sub-contractor management practices in a real alliance and Lean

Sub-contractor management practices	**Real alliance project**	**Lean supply system**
Selection criteria	Price and past experience	Past performance
Transparency	No transparency of cost figures	Information sharing practice
Contract time	Informally long term	Long term
Involvement in project design	None/very little	Involved
Knowledge of supplier capabilities	Very limited	Greater awareness
Relationship	Arm’s length, project basis	Closer and long term
Level of trust	Lack of trust	Develop trust
Behaviour	Win-lose	Win-win
Incentive to cost saving	One party	Both parties
Communication	Work independently	Open and frequent
Competition	High competition	Mutual assistance
Hierarchy	Well defined	Well defined tiered structure

The study reveals that in many cases, sub-contractors were used for expanded roles but commercial relationships were traditionally defined.

The findings of interviews are presented in the following section.

6.3.2 Semi-structured interviews

Background of interviewees

In particular with this investigation, four ALT members who actively engaged with sub-contractors were selected. Interviews were conducted with the participants described in Table 6.10. They appeared to have ample experience in sub-contracting and alliance projects. The interview guide is contained in Appendix V. Important points arisen from the interviews are explained in the following sections.

Table 6.10: Profile of interviewees and purpose of interviews

Interviewee ID	Purpose of the interview	Experience in construction (*) / alliance project (√) (Years)				
		< 5	5 - 10	10 - 15	15 - 20	> 20
INT 6	To identify sub-contractor management practices in the project	-	√	-	*	-
INT 7	To identify quality management strategies for sub-contractors in the project	√	*	-	-	-
INT 8	To identify sub-contractor management practices in the project	-	√	*	-	-
INT 9	Compare sub-contractor management practices with other alliance projects	-	√	-	-	*

Interview findings

The study conducted interviews with senior management of the project to confirm the findings of the process studies. The interviews began by determining company practices in the engagement of sub-contractors. The questions covered sub-contract types, significance of the sub-contracts and the way sub-contractors were introduced to the alliance. The study found that there were 74 sub-contractors engaged in the project with 17 being involved in major work contracts and 28 in minor works and service contracts. According to INT 6, sub-contractors who were involved in ‘work contracts’ were paid on a ‘schedule rate basis’ and other contracts were paid at a ‘fixed price’. The total cost of sub-contracts was 40% of the project cost and all the sub-contractors were engaged at the construction phase of the alliance project. The percentage of cost for sub-contracts was lower in NZ compared with other countries. INT 9 confirms this:

> *'The major infrastructure contractors in NZ have significant work forces of their own and hence only sub-contract smaller work packages. They have better project control when major works are not sub-contracted.'*

Literature on sub-contracting suggests that a sub-contracting strategy is usually chosen to achieve high quality, flexibility and cost savings. According to INT 6, sub-contracting decisions in alliances are for the purpose of smoothing resources and spreading the project risk. Non-specialist sub-contractors may not be capable of dealing with the risks allocated to them. It is apparent from the interviews that the modes of engagement of the sub-contractors were not aligned with the alliance KRAs. All interviewees agreed on such misalignment and INT 9 suggested having a very simple framework with a small number of KRAs for sub-contractors.

The alliance participants selected sub-contractors according to the complexity of the work and previous working relationships. However, the existing relationship was a cost focused relationship as the benefits from other soft criteria are difficult to evaluate compared to the benefits from the lowest quotes. The study findings indicated that the criteria used by the alliance in the sub-contractor prequalification were only limited to safety and technical ability.

Alliance principles aim at developing a strong alliance team which is important to the project success. Such a strong work relationship is equally important for sub-contractors because they are the ones who carry out the actual site work. However, the referred case study did not fully identify the importance of building strong relationships with sub-contractors in the initial stage of the project and no special workshops were conducted for sub-contractors. In later stages of the project, 'one team sessions' were introduced to fill this gap. The sub-contractors also had different objectives from the main alliance. ITN 7 noted that aligning the objectives of its sub-contractors with the project objectives is vital.

> *"Sub-contractors may want to finish the work quickly to save time by sacrificing quality. But the alliance has the responsibility of meeting quality and project time. Therefore, the alignment of objectives is mandatory."*

Interviews revealed that even though sub-contractors were not part of the alliance commercially and did not benefit from the gain:pain mechanism, the alliance team treated sub-contractors as part of the alliance in every other way. In order to ensure project performance, the alliance offered extensive technical training to their sub-contractors. All sub-contractors were invited to the 'one team sessions' and project celebrations. INT 8 strongly agreed 'commitment of all participants' is a critical element to successful alliancing. However, there was a difference in individual standards of commitments and therefore 'one team sessions' were used to cultivate the conditions for realising the full commitment of the participants. This session created a forum to explain the current picture of the project to the wider project team and the mutual exchange of ideas initiated by this process led to commitment to achieving project goals.

Interviewees indicated that the alliance provided assistance to sub-contractors' business development through sharing knowledge and providing necessary training. This inter-organisational involvement was evident in this particular alliance project but without any commercial benefits. This is a challenge to the alliance contract type, which INT 8 alluded to as follows:

> *'A sub-contractor is not part of the alliance but still works for the alliance. A sub-contractor does a large proportion of the actual project work at the site but still is not part of the alliance. This is a challenge.'*

Summary of findings: The sub-contractor integration practices

Interviewees were asked to comment on current sub-contractor management practices. The summary of the interviewees' view is presented in Table 6.11. Responses revealed that some lean supply principles were adopted by the case study project, namely long term informal relations with sub-contractors, sub-contractors within the alliance were seen as one group and usage of group-based development tools and joint training programs. However, the innovativeness of the sub-contractors was not sufficiently exploited in the referred project. There was evidence of interactions with sub-contractors at an operational level, but sub-contractors' management level representation in those occasions was minimal. They were also not involved in the early stages of the project. Interviewees ranked the 'risk-reward system' and 'information transparency' as not important practices. Frequent meetings with sub-contractor management, opinion surveys and early involvement were identified as important but non-existent practices in the project.

Table 6.11: Relevance of sub-contractor management practices

Practice	Exists	Interviewee ID			
		INT 6	INT 7	INT 8	INT 9
Long term relationship	√	Important	Important	Important	Important
Mutual trust	√	Important	Important	Important	Important
Frequent communication with sub-contractor management	X	Important	Important	Important	Important
Collaborative team culture	O	Important	Important	Important	Important
Consistent objectives	X	Neutral	Neutral	Neutral	Neutral
Win-win attitude	√	Neutral	Important	Neutral	Important
Risk-reward sharing	X	Neutral	Neutral	Neutral	Unimportant
Regular performance monitoring	O	Important	Important	Important	Important
Early contract involvement	X	Important	Neutral	Neutral	Important
Defined responsibilities	√	Important	Important	Important	Important
Selection criteria - other than price	√	Important	Important	Neutral	Important
Knowledge of supplier capabilities	O	Important	Neutral	Important	Neutral
Information transparency	X	Unimportant	Unimportant	Neutral	Neutral
Training and development	√	Important	Important	Important	Important
Opinion survey	X	Important	Important	Important	Important

Key for existence: √, fully achieved; O, partially achieved; X, not achieved (absent).

Key for importance: 🔴 Unimportant; 🟡 Neutral; 🟢 Important

Barriers to implement sub-contractor integration practices in alliance

Interview participants (INT 7, INT 8 and INT 10,) thought that if sub-contractors were to enter into integrating relationships, the likelihood would be that they would be more involved in pre-planning and process improvement work and would therefore need extra skills in this area. Since the NZ construction industry contains a small sub-contractor base with fewer skilled sub-contractors this will be a hindering factor for sub-contractor integration into an alliance.

The interview participants INT 7 and INT 9 identified a lack of trust between sub-contractors and main contractors who represent the alliance as a barrier to sub-contractors' integration into the alliance project. However, other interview participants (INT 8 and INT 6) viewed that the small sub-contractor base would indirectly improve the long-term informal relationship between sub-contractors and main-contractors.

The majority of the interview participants thought that both parties needed a better understanding of the sub-contractors' business, and vice versa. However, they thought that sub-contractors did not want to reveal too much about their businesses or were worried that if the main contractor knew more, main contractors would demand that prices were reduced.

All interviewees agreed that the traditional tendering processes used in selecting sub-contractors hindered knowledge exchange between the two parties, but integrating relationships enabled companies to start to understand others in the supply chain and to provide better information. However, INT 6 noted that there should be tangible benefits for both parties in order to convince them of the integration process and share knowledge. INT 6 mentioned it as follows:

> "*People are willing to share knowledge related to complete the project unless sharing knowledge may influence the benefits of their companies*."

Furthermore, INT 7 and INT 8 noted that both parties must understand the principles of integration and must not use it for the wrong reasons. INT 7 explained that sometimes these integration mechanisms were used because the project owner wanted to work in such a relationship and therefore, they would only win the work if they were integrated with their sub-contractors. The next section presents findings from the questionnaire.

6.3.3 Questionnaire findings

A questionnaire was distributed among the middle management of the project to determine their opinion on sub-contractor performance. These results were used to gain insight into improving the current sub-contractor management practices in the alliance and to identify areas of concern regarding the project performance. The analysis of the questionnaire participant information is shown in section 6.2.3. The sub-contractor practices related questionnaire consists of two parts. The first part contains the respondents' views of the sub-contractors' current performance (Question 9 in Appendix E). The second part aims at the suitability of different sub-contractor management strategies for improving alliance performance (Question 10 in Appendix E).

Evaluation of the current performance of sub-contractors – Question 9

In this section, the overall performance of the sub-contractors of the alliance was evaluated against predetermined performance criteria identified from the interviews and the literature review. Two different methods, namely mean score and coefficient of variation, were used to statistically quantify the performance. Similarly, the degree of importance of the performance criteria was also obtained. Analogous to the procedure used in section 6.2.3 the mean score of performance is divided into five ranges based on the 95% confidence technique (Table 6.12).

Table 6.12: Likert scale conversion with intervals

Scale for question 9 (a)	Not at all satisfied	Slightly satisfied	Moderately satisfied	Very satisfied	Completely satisfied
Scale for question 9 (b)	Not at all important	Slightly important	Moderately important	Very important	Extremely important
Confidence interval	1.0-1.8	1.8-2.6	2.6-3.4	3.4-4.2	4.2-5.0

Importance of performance criteria

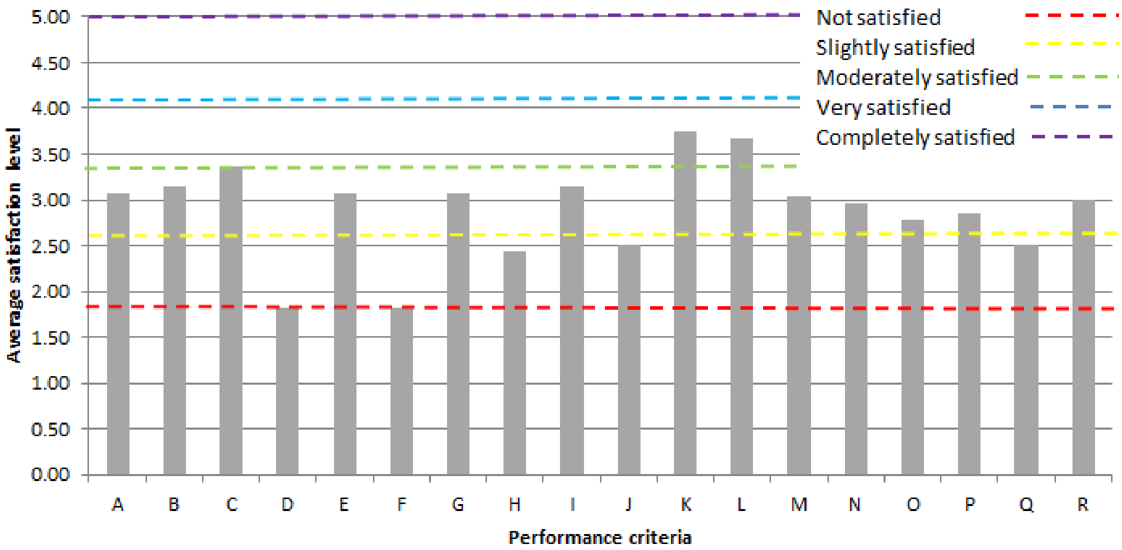
The importance of each performance criteria was identified based on the COV and criteria ranking are shown in Table 6.13. The questionnaire findings indicated that the alliance management pays most attention to safety, quality, time, cost and technical competence of sub-contractors. However, there was less focus on decision making in the field, housekeeping at the site, accuracy and completeness of the documentations.

Table 6.13: Importance of sub-contractor performance criteria

#	**Performance criteria**	**Mean score**	**COV**	**Rank**
A	Quality of workmanship	4.52	0.21	2
B	Technical competence	4.37	0.25	5
C	Timeliness of performance	4.33	0.22	3
D	Accuracy and completeness of documentation	2.22	0.68	16
E	Labour force coordination	3.96	0.29	10
F	General site management practices	4.04	0.28	9
G	Conformance to safety program	3.89	0.21	1
H	Conformance to the project budget	3.93	0.23	4
I	Flexibility for changes	3.30	0.30	11
J	Level of innovation	2.19	0.46	15
K	Cooperation and coordination with others	3.59	0.28	7
L	Overall craft productivity	3.22	0.30	12
M	Adherence to environmental programme	3.26	0.25	6
N	Housekeeping at the site	2.22	0.68	17
O	Effective communication	4.15	0.27	8
P	Decision making in field activities	2.22	0.68	18
Q	Periodic onsite evaluation	3.07	0.38	14
R	Adherence to project alliance decisions	3.70	0.31	13

Satisfaction of sub-contractor performance

As shown in Figure 6.4, the mean scores of performance criteria were plotted to represent an overall assessment of sub-contractor performance. In terms of actual performance, performance of 'general site management practices' and 'accuracy and completeness of documentation' were ranked relatively low indicating significant room for improvement in these aspects. 'Overall craft productivity' and 'cooperation and coordination with others' were considered as the most well performed criteria by sub-contractors.



A	Quality of workmanship	J	Level of innovation
B	Technical competence	K	Cooperation and coordination with others
C	Timeliness of performance	L	Overall craft productivity
D	Accuracy and completeness of documentation	M	Adherence to environmental programme
E	Labour force coordination	N	Housekeeping at the site
F	General site management practices	O	Effective communication
G	Conformance to safety program	P	Decision making in field activities
H	Conformance to the project budget	Q	Periodic onsite evaluation
I	Flexibility for changes	R	Adherence to project alliance decisions

Figure 6.4: Satisfaction level for sub-contractor performance

The findings are further analysed based on two respondent groups (Table 6.14). Although the Mann-Whitney test shows that there is a significant amount of agreement among the respondents in each group in all the factors, there are differences at the micro level (i.e. criteria ranking). In terms of overall 'average' satisfaction levels, respondents with more alliance experience were found to be less satisfied than respondents with less alliance experience, though this gap was not statistically significant. In terms of actual performance, 'general site management practices' and 'accuracy and completeness of documentation' were ranked relatively low indicating significant room for improvement in these aspects. This could be due to a lack of managerial capabilities of sub-contractors, which was mentioned during the interviews. 'Overall craft productivity' and 'cooperation and coordination with others' were considered the most well performed criteria by sub-contractors.

Table 6.14: Sub-contractor performance scores

	Performance criteria	Group A (n=15)		Group B (n=12)		P*	Aggregate	
		Mean	COV	Mean	COV		Mean	COV
A	Quality of workmanship	3.13	0.11	3.00	0.28	0.98	3.07	0.20
B	Technical competence	3.13	0.11	3.17	0.30	0.75	3.15	0.21
C	Timeliness of performance	3.60	0.20	3.08	0.29	0.05	3.37	0.25
D	Accuracy and completeness of documentation	1.60	0.70	2.08	0.56	0.37	1.81	0.63
E	Labour force coordination	3.13	0.11	3.00	0.28	0.98	3.07	0.20
F	General site management practices	1.60	0.70	2.08	0.56	0.37	1.81	0.63
G	Conformance to safety program	3.13	0.27	3.00	0.00	0.37	3.07	0.20
H	Conformance to the project budget	2.33	0.39	2.58	0.31	0.53	2.44	0.35
I	Flexibility for changes	2.93	0.24	3.42	0.23	0.16	3.15	0.24
J	Level of innovation	2.27	0.42	2.83	0.33	0.11	2.52	0.39
K	Cooperation and coordination with others	3.80	0.15	3.67	0.13	0.66	3.74	0.14
L	Overall craft productivity	3.80	0.15	3.50	0.19	0.73	3.67	0.17
M	Adherence to environmental programme	2.93	0.20	3.17	0.30	0.46	3.04	0.25
N	Housekeeping at the site	2.80	0.24	3.17	0.26	0.57	2.96	0.26
O	Effective communication	2.73	0.26	2.83	0.33	0.41	2.78	0.29
P	Decision making in field activities	2.80	0.20	2.92	0.23	1.0	2.85	0.21
Q	Periodic onsite evaluation	2.47	0.21	2.58	0.39	0.65	2.52	0.30
R	Adherence to project alliance decisions	2.93	0.42	3.08	0.17	0.81	3.00	0.32

* Level of significance on Mann-Whitney test

There are five sub-contractor management practices lacking in the case study project as listed below:

- General site management practices
- Conformance to the project budget
- Workforce coordination
- Level of innovation and
- Periodic on-site evaluation.

Despite the alliance/sub-contractor relationship being largely transactional, it is important to note that the site management considers 'cooperation and coordination with other contractors on site' was at a 'very satisfied' level. This specifies fertile ground for the development of a relationship based procurement systems such as partnering or strategic alliances with sub-contractors.

Importance and performance satisfaction analysis

Figure 6.5 presents the importance-performance matrix developed by combining the actual sub-contractor performance with the importance of criteria. The performance data are categorised into four quadrants and most of the performance criteria (11 out of 18) fall into the 'no immediate action' zone. This shows a good overall performance in sub-contractor management. Two criteria namely 'conformance to the project budget' and 'accuracy and completeness of documentation' are the top priority.

By combining the sub-contractor performance with the importance of criteria, the alliance management can assess the actions needed to be taken on sub-contractors' performance. Also, a similar method can be extended to measure individual sub-contractor performance. Through the collective efforts of alliance management and sub-contractor management, the underperforming factors can be improved. This kind of performance evaluation tool is not currently used in the selected case study. This performance evaluation tool acts as a feedback mechanism to sub-contractors and both alliance management and sub-contractors will benefit from improved performance.

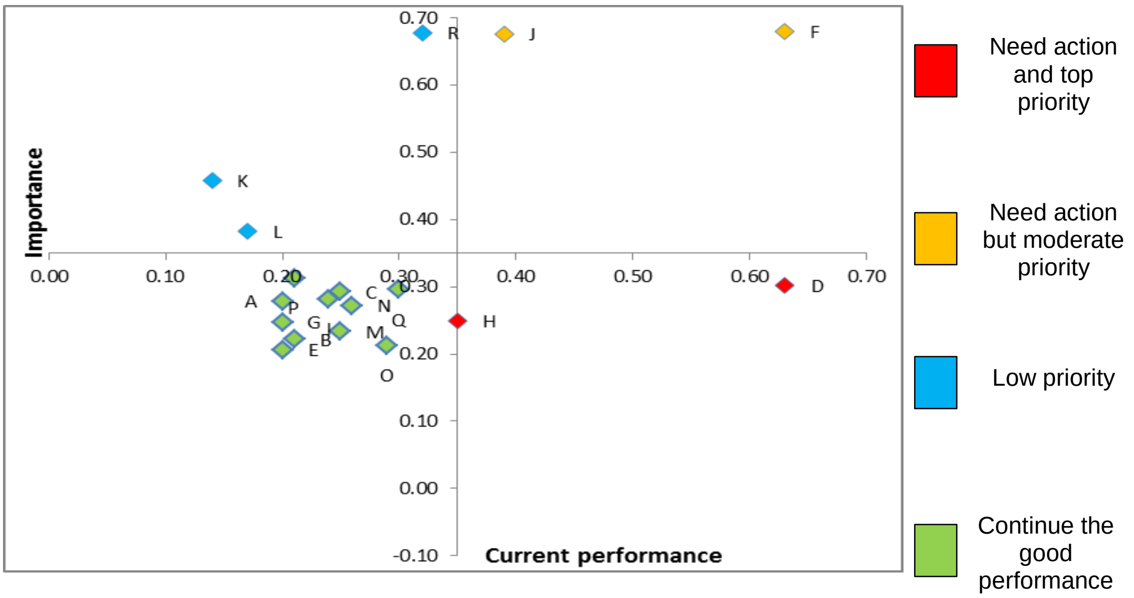


Figure 6.5: Performance-importance matrix on sub-contracted activities

Importance of lean supply practices in the alliance project – Question 10

Informants were asked to assess the importance of the 15 lean supply principles identified in the literature (Question 10 in Appendix E). Table 6.15 provides more details on the ranking of factors and measures based on the responses collected. Through the questionnaire, ten lean supply principles have been identified as critical. The most important principles are mutual trust, frequent communication and defined responsibilities. Additionally, the results reveal that respondents have identified important principles but some of them such as 'frequent communication', 'early contract involvement' and 'opinion survey' are not practiced in the project.

The Mann-Whitney test shows that there is a significant amount of agreement among the respondents in their rating of all the factors. In terms of importance, 'defined responsibilities', 'frequent communication' and 'mutual trust' were identified as the most important criteria by the two respondent groups with differing rankings. This shows the need for alliance participants to adopt appropriate systems to improve communication and trust while defining sub-contractors' responsibilities precisely at the beginning of the project.

Table 6.15: Mean and standard deviation scores for lean supply principles

Strategy	Group A			Group B			p	Aggregate		
	RII	COV	Rank	RII	COV	Rank		RII	COV	Rank
Long term relationship	0.907	0.141	6	0.900	0.116	4	0.77	0.904	0.128	4
Mutual trust	0.933	0.105	3	0.917	0.112	2	0.71	0.926	0.106	1
Frequent communication	0.947	0.097	2	0.867	0.114	3	0.08	0.911	0.111	2
Collaborative team culture	0.920	0.137	5	0.867	0.150	6	0.29	0.896	0.143	6
Consistent objectives	0.520	0.431	14	0.567	0.295	13	0.38	0.541	0.367	14
Win-win attitude	0.507	0.444	15	0.583	0.342	14	0.25	0.541	0.395	15
Risk-reward sharing	0.507	0.391	13	0.600	0.348	15	0.26	0.548	0.373	13
Regular performance monitoring	0.827	0.180	10	0.850	0.177	8	0.73	0.837	0.176	9
Early contract involvement	0.800	0.164	8	0.883	0.117	5	0.16	0.837	0.149	7
Defined responsibilities	0.960	0.086	1	0.850	0.106	1	0.02	0.911	0.111	2
Selection criteria- other than price	0.520	0.283	11	0.483	0.213	11	0.64	0.504	0.255	11
Knowledge of supplier capabilities	0.813	0.173	9	0.883	0.180	9	0.22	0.844	0.178	10
Information transparency	0.547	0.323	12	0.550	0.274	12	0.83	0.548	0.297	12
Training and development	0.813	0.113	4	0.767	0.151	7	0.37	0.793	0.131	5
Opinion survey	0.813	0.146	7	0.767	0.187	10	0.40	0.793	0.164	8

6.4 CHAPTER SUMMARY

The research sought to assess the impact of lack of integration of site workers and sub-contractors in alliances by considering the views of the top and middle management of the alliance project. Therefore, in this chapter, process study observations, questionnaires and interview findings in relation to worker and sub-contractor involvement in the alliance project are presented. The process observations show the implications of the non-integration of site workers and sub-contractors from an alliance. Mainly the process study observations revealed that the characteristics of a real alliance lie between a traditional construction project and a lean integrated project in terms of worker and sub-contractor integration practices.

Although the literature identified downstream participants as a weaker link in the construction project and requiring improvements, this is rarely appreciated due to a lack of evidence. The process study observations show the improvement opportunities in worker participation and sub-contractor management practices in an alliance projects. Relevance and feasibility of the practices with regard to worker participation and sub-contractor management pooled from literature were checked with the alliance management via interviews and questionnaires. Findings surfacing from the interviews were used to modify the questionnaire and therefore interviews acted as a pilot study for the questionnaire.

The questionnaire analysis revealed that ‘regular employee performance appraisal’, ‘treat the entire workforce as equals’, ‘conduct social activities’, ‘appraisal system to assess training needs’ and ‘supervisors trained in people management skills’ are the most important worker participation practices and this has been confirmed by respondents. Other practices, except ‘treat the entire workforce as equals’ and ‘conduct social activities’ are not available in the current alliance project. This leads to the development of an effective system of performance appraisal with a link to training and development in alliance projects. On the other hand, the existence of barriers for implementing worker participation was identified. The barriers are prioritised based on the influence on success of worker participation and whether they are easy to overcome.

In response to the ninth question of the questionnaire (Appendix E), respondents described the current performance of sub-contractors in the referred alliance project with regard to performance factors, which were identified in the literature. It is noted there was no sub-contractor performance measurement system adopted by the alliance and therefore, such an analysis could be used as a regular assessment for sub-contractors. The findings of interviews and the ninth question suggest that effective sub-contractor management practices and a re-orientation are required for this alliance project. Therefore, in the tenth question, the importance of lean supply principles was tested. Ten lean supply principles were identified as critical to sub-contractors in the alliance and the most important principles were mutual trust, frequent communication and defined responsibilities.

A closer look at the results revealed that in certain scenarios the obtained results from interviews were divergent from the questionnaire findings. For example, during the group interviews, alliance management stressed that they see an ‘opinion survey of employees by a third party’ as an important practice. However, in the questionnaires, the middle management ranked these as less important practices. Such divergent results led to new insights, which is an important aspect of triangulation. Therefore, the next chapter synthesises the research findings from the different data collection methods and explores the implications of these findings.

7 DISCUSSION OF THE RESEARCH RESULTS

7.1 INTRODUCTION

The results in chapter five highlighted the level of process waste and the causes of causes at the case study project. The process study findings in chapter five established the potential for improvements by using Lean. Chapter five identified the existence of behavioural waste due to a lack of integration of site workers and sub-contractors in this particular case study project. Consequently, chapter six investigated the behavioural waste and their causes. Based on the analyses conducted in chapter five and six, this current chapter aims to triangulate the research findings. Research results are also discussed within the context of the opinions expressed by subject matter experts and the conclusions are preluded in chapter seven.

This chapter is divided into five sections including this introduction (section 7.1). The rest of the chapter is organised as follows. Section 7.2 provides an overview of the research study. It reviews the process of triangulation. Section 7.3 discusses the main findings which surfaced from chapters five and six by comparing them with the literature. The main findings discussed under three main sections include process waste related findings (section 7.3.1), behavioural waste due to site workers (section 7.3.2) and sub-contractors (section 7.3.3). The next section (section 7.4) explains the findings from the validation exercise. The final section (section 7.5) provides a general summary of the research findings presented in this chapter.

7.2 OVERVIEW OF THE RESEARCH

This study is intended to explore how lean thinking can be utilised in alliance projects to improve the alliance project performance. Due to the lack of alliance contracts in NZ, the researcher selected an in-depth and longitudinal study of an alliance project. There were three distinct phases involved in the research investigation, which are briefly explained in the following paragraphs.

In the first phase, the study collected data from the case study project by conducting five process studies. This involved participant observations at the site, follow-up meetings and examination of project documents. The observational study allowed direct examination of activities and potential waste on the alliance project site. After completing the preliminary analysis, improvement opportunities of particular processes were identified and discussed with site management at follow-up meetings. Discussions at the follow-up meetings enabled the researcher to check the views of the site management of lean strategies to reduce identified waste and to make recommendations. The discussions with site management helped identify barriers to lean thinking within typical alliances. During the longitudinal phase, follow-up process studies were conducted at the northbound construction to verify the findings of the first set of process studies from the southbound construction. During the follow up process studies, the effects of the suggested improvements were also observed. The detailed findings from the two sets of process studies were discussed in chapter five.

In the second phase data collection, the views of management on behavioural waste were investigated through interviews and a questionnaire survey. Relevance and feasibility of the practices with regard to worker participation and sub-contractor management pooled from literature were checked with the alliance management through interviews and questionnaires. Thematic analysis was used in the interview analysis and descriptive statistics were used in the questionnaire analysis. These were covered in chapter six of this thesis. In the final phase of the data collection, the research collated the opinions of subject matter experts within the context of the research investigation. The opinion of the subject matter experts enabled the verification of the research findings and also provided some confirmation of some of the recommendations made by the study.

A process of triangulation should improve the credibility and validity of the overall conclusions of the study. The triangulation of findings is presented in this chapter in line with the techniques suggested by O'Cathain et al. (2010). The findings of process studies, interviews and questionnaire are triangulated and reference is also made to the literature review findings of chapter two and three. An overview of the alliance project research is shown in Table 7.1.

Table 7.1: Brief details of the study

Parameter	Characteristics
Alliance type	Project alliance
Number of alliance participants	Eight
Number of employees in the case study	Approximately 200
Number of process studies observed	Five
Process studies observation time period	February 2010-November 2012
Senior managers interviewed	Nine
Participants involved in the questionnaire	Twenty-seven
Validation interviews	Five

7.3 MAIN FINDINGS OF THE STUDY

The multiple data collection approach used in the current study provided a good opportunity to triangulate results. Two types of triangulation, namely methodology and data source, were employed following a separate analysis of the participant observations, interviews and questionnaire respectively. Methodological triangulation involves the use of multiple data collection methods. Results from participant observation, interviews and questionnaires were compared. The current study can utilise the strengths of each method by combining multiple data collection methods, while overcoming their unique deficiencies. Data triangulation involves the use of different sources of information. Data sources used in this study were site workers, top management and middle management of the alliance project. The data triangulation improved the validity of evaluation and research findings. The next three sections explain the findings of the process waste study (section 7.3.1) and behavioural waste related to site workers (section 7.3.2) and sub-contractors (section 7.3.3).

7.3.1 Process waste in alliance projects

Many researchers have pointed out productivity issues in construction and integrative project delivery systems like alliance contracts were developed to address these issues. However, improvement opportunities still exist in construction projects. Therefore, this study has tried to discover how project results could be positively influenced using a lean approach. The lean philosophy is meaningful only if waste is defined and eliminated (Jorgensen & Emmitt, 2008). Hence, this study was carried out in three main stages namely identifying waste, quantifying waste and formulating suggestions to eliminate waste. The key findings from the 'process waste' studied are summarised in the following sections.

Finding one: No defined operational framework in alliances

Based on the literature review and the process studies, it was identified that there is no indication of an operational system within the alliance framework (section 2.4). The process study findings show that this particular alliance project employed certain lean techniques (for example: JIT material delivery system, visual management and collaborative planning). However, these techniques were implemented in an ad-hoc manner, based on the judgment or experience of site management.

The participant observation found that most of the site managers carried out local improvements mainly through informal knowledge (Figure 5.20). These discrete, stand-alone initiatives were not sustained due to low retention rates of project team members (section 6.2.1), poor knowledge sharing with other project teams (section 5.8.1), and a tendency to rest on success (section 6.2.1). This reveals that even though alliancing focus on high performance, there is no defined and integrated operational framework to detect site level improvement opportunities.

This finding drives the need for a 'toolbox' of an operating system that permits an alliance to improve the performance of a given project. It was found that alliance principles focus more on contractual and organisational domains through collaboration. Yet, these two domains mainly affect the ways in which people work together. In that situation, a third aspect of a project delivery system, which is an operational system, does play a vital role. A literature analysis on different operational systems was carried out (section 3.3) to identify a suitable operational system for an alliance project. It was found that an alliance project can focus on a third aspect of internal process integration through lean thinking (section 3.3). Lean implementation in the site level may ideally be suited to alliancing since alliance participants will benefit from cost savings through process improvements (section 3.6).

Finding two: Applicability of VSM methodology

VSM methodology was used as a tool to examine waste at the case study project site. The studied processes contain different characteristics. Especially, the column and deck deconstruction processes were equipment intensive, highly repetitive with less variability. In contrast, the pre-cast segment production, parapet and bridge construction processes are labour intensive, with less repetitive tasks but with more variability. The applicability of VSM for most construction processes was demonstrated (section 5.4.1 and 5.4.3).

Picard (2002) has suggested that reducing the activity or task cycle time would have greater impact on construction operations compared to reducing sub-task or method cycle times. In the current study, the traditional VSM was modified due to the complexity of the processes with multiple crews, input materials and activities. VSM methodology was applied at three levels while more improvement opportunities at micro and sub-micro levels were discovered. This could be due to a lack of consideration of micro and sub-micro level improvements in a real alliance environment where macro level improvements such as early value management workshops and first run studies of the operations are mainly considered. Since all five processes are cyclical and repetitive, the effort invested in critical examination at the micro and sub-micro level proved to be beneficial. This finding shows the presence of an innovation focus in the alliance (Table 6.3) as a prime mover of change rather than an incremental improvement culture. This finding confirms the necessity of an operational framework to spot improvement opportunities at site level.

Finding three: High process waste on alliance project sites

Toyota started developing the lean philosophy with a very good understanding of waste in existing value streams. This research also focuses on waste reduction within an alliance project site (section 5.3). The study of the alliance project shows that waste is extensive at least in the range of 47- 62% of the working time but with some variations between processes (section 5.5.4). Aggregate results show that the proportion of VA was 11%, which needs to be increased in projects executed using alliancing. Also study found that 53% of the time is NVAU activities, which need to be eliminated (section 5.5.4). Therefore, a comparatively high percentage of workers' time is spent on waiting, rework, transportation and motion, which add no value to construction work activities (section 5.5.4). There are also NVAN activities (20%), which need to be minimised.

Previous studies (47 articles in section 3.7.2) on lean implementations and process waste evaluation have not stated the procurement methods used, limiting the comparison of research findings with former works. However, recent studies of Lean were used to compare the activity composition obtained in the current study. Through correspondence with the relevant authors of these studies, the procurement methods were identified. The activity composition of the current study is almost consistent with a Swedish study (Josephson & Saukkoriipi, 2007) and a USA study (Diekmann et al., 2004) as depicted in Table 7.2.

Table 7.2: Work activity comparison with past studies

Study origin		Current study (NZ)	Swedish study	USA study	Norwegian study
Activity category	VA (%)	6-21 (11)	17.5	8-24	19-49
	NVAN (%)	24-48 (20)	31.5	19-35	33-43
	NVAU (%)	47-62 (53)	51	53-72	18-38
Procurement		Alliance	Design-build	Traditional	Design-build

A study in Norway indicates considerably lower figures for NVA activities compared to those presented in Table 7.2 . The Norwegian study was based on second-hand data and the differences in figures can be attributed to the use of measurement methods and a discrepancy in activity categorisation. However, no single study out of 47 articles reviewed clearly explains the activity categorisation rules for comparing findings. Therefore, the researcher had to develop a set of rules for activity categorisation for making observations (section 5.3.2). In conclusion, the study findings show that there is an immense potential to eliminate waste in alliance projects. Changing the procurement type alone is not sufficient for detecting and eliminating of process waste.

Finding four: Construction waste composition

The categorisation of waste (section 3.7.4) was used in this study as a theoretical framework to measure waste. When an attempt was made to categorise the measured waste in the analysis, it was found that some of the waste categories are difficult to accommodate based on the theoretical framework (see section 3.7.4: e.g worker unavailability). This waste category was also left out of the construction waste model since it was not reported in past studies. This waste category was added as it was one of the stand-out waste types that is worth highlighting. This study showed about 53% of the overall time as waste. The new categorisation helps to understand the main driver of waste in the construction project. Almost all of the values of waste categories found in the current study are consistent with previous studies as shown in Table 7.3.

Table 7.3: Comparison of magnitude of waste

Waste category	Current study	Swedish study	USA study	Norwegian study
Waiting	22%	22.8%	34%	20.8 %
Rework	11%	2%	-	10.4%
Unnecessary motion	6%	13.9%	13%	6.8%
Unnecessary transportation	1%	-	9%	0.1%
Extra processing	4%	-	4%	-
Unavailability of workers	9%	10.4%	-	-

All the waste categories identified in the current study were related to each other and elimination of one source of waste led to either elimination or reduction of other waste categories. The summary of identified waste at the case study project is presented in the following sub-sections. It will give an idea of what types of waste can be expected in an alliance project site making future applications of Lean easier. This way the study makes it clear how lean principles could be applied to these types of projects.

Waiting

The major factors contributing to waiting are unavailability of materials and equipment and site layout. In certain cases, waiting could be a result of distraction from other processes. However, in contrast to reports by Josephson and Saukkoriippi (2007) and Mossman (2009b), waiting due to accidents on site was not identified in this study. This could be due to the high safety culture in the observed alliance project. The obtained aggregated figure for waiting (22%) is consistent with the Swedish study but lower than the USA study (34%) which is probably due to the nature of work. Its main focus was on steel erection jobs which were mainly depending on cranes. Similarly, process C and D of this study reported 37% and 26% of waiting time respectively. Cranes were often the bottleneck resource in these processes.

Unnecessary motion and transportation

Unnecessary movements were the most visible waste in this project. The lack of pre-planning and disorganisation of the site were identified as the reasons for unnecessary movements. Moreover, unnecessary motion and transportation caused other workers to wait. Compared with the USA study, unnecessary motion and transportation of the current study are lower but consistent with the Norwegian study. The activity classification seems to be the reason for this difference. In the current study, the preparation of an initial workstation (mainly transporting material and equipment to the workplace) was considered as a NVAN activity but the USA study considered it as NVAU activity. During the middle of the operation, site workers tended to go to stores due to a lack of preparation. It was accounted for as unnecessary motion in the current study. Bringing material back to the workstation (other than during the initial setup) was recorded as unnecessary transportation. Similar to other studies, unnecessary transportation was not a significant waste and reported only in process A. This was mainly due to movement of conjugate segments. It was minimised by rearranging the segment production sequence.

Rework

Regardless of the quality assurance system in place, quality issues occurred possibly due to a lack of coordination, lack of competence, forgetfulness of workers and lack of information on the site investigated. Time spent on rework was higher in the current study compared to the USA and Swedish studies but closer to the Norwegian study. The USA study recorded all rework activities as extra processing. The current study recorded rework and extra processing separately. The remedial work of pre-cast segments in process ‘A’ mainly contributed to rework. Causes of most of the rework incidents were identified in the upstream process. Thus, downstream processes were affected and additional resources were required to rectify the problem.

Extra processing

In this study, defective materials delivered to site, inappropriate storage at the site and re-handling of material/equipment were identified as main causes for extra processing. The results of this study are consistent with the USA study. The other two main studies did not measure extra processing. The USA study included only brief site visits and therefore the rework waste due to defects was not observed. In the USA study, extra processing and rework were combined to obtain a similar figure to findings of the current study.

Overproduction waste

Overproduction waste is rare in construction due to ‘build to contract mentality’ and no past studies have recorded this category (Table 7.3). This study found that WIP is evident in certain operations due to an imbalance of activities. However, categorising WIP as a waste depends on the activity level being viewed. According to the site management, the majority of WIP on site appeared due to variations in upstream operations and they were short term. In this study, waiting time of WIP at the site was not included in the waste categorisations. WIP inventory time was incorporated into lead time (section 5.5.4).

Unnecessary inventory

Similar to the overproduction waste, the unnecessary inventory waste has not been detected in past studies (Table 7.3). It was not measured in the current study at the micro and sub-micro level. However, at process level, the waste associated with unnecessary inventory was measured (section 5.5.4). Similar to the other three studies, this waste was not included in the waste categorisations as it is a separate component of the processing time. A major improvement prospect related to inventory was identified in process A, where delays in the designer inspection caused an accumulation of segments.

Worker unavailability

Another waste observation was the unavailability of workers at the site other than the normal personal breaks. Frequent interruptions to the operations and extended breaks were major causes for this waste. Since no alternative work was planned for during interruptions, workers took breaks until the problem was solved. Further observation shows that the worker unavailability on the site was also a result of transporting material from the stores to the site. The analysis of process studies found that lack of supervision from foremen caused higher unavailability of workers on site as well. Only the Swedish study has used a similar waste category and they have measured personnel breaks during the operation time. The result of the current study is similar to the Swedish study findings.

Behavioural waste

In addition to process waste, Liker (2004) has identified unused creativity of workers as a waste category. In order to eliminate aforesaid process waste, it is necessary to get inputs from workers. The referred case study project failed to create a true alliance environment because only a part of the value chain (client, designer and main contractors) was considered for collaboration (section 6.2.1 and 6.3.1). It was observed on the case study observations that arm's length relationships between alliance participants and process participants often create waste. However, behavioural waste is difficult to quantify and it is normally evaluated through a questionnaire and interviews. The eighth category of waste is separately discussed in section 7.3.2 and 7.3.3 of the current study.

Finding five: Little understanding of process waste

Construction waste is not only referred to as material waste but also process waste such as waiting, rework, unnecessary motion and transportation. Process waste was not well understood by project participants of the case study project and there was often confusion with these terms at the follow-up meetings. Consequently, participants were not in a position to realise many activities in the current process as NVA activity. Nevertheless, the site management was able to easily provide the best solution to eliminate causes of waste that were identified in the process studies. This finding shows that the failure to identify NVA activities was often due to a lack of lean thinking on site (section 5.6, section 5.8, section 5.10.2 and section 5.10.3). In the absence of such an understanding, no effort could be made for process improvements in the long run. However, due to good analytical thinking capabilities of the site management, it was easier to conduct solution development workshops for the waste activities that were identified during the process studies.

Finding six: Lack of effort in waste control

The study found that the site management was not putting much effort into identifying process waste since it compared the average output against the standard productivity rate, which was useful for cost estimating. With low and constant targets, in most of the cases, a high productivity level was recorded. This practice did not help continuous improvement. Furthermore, the limited scope of KPI measurements with little influence at the site level caused a lack of focus on process waste controls. Process waste control was not integrated with the current production and control processes although there were efforts made to eliminate material waste. Therefore, a broader view of waste considering both material and process waste would be more effective.

Finding seven: Introduction of process improvement methodology

This study yields a methodology for waste detection and improvement that could be applied on alliance projects. In order to sustain such a process improvement methodology, there needs to be an inbuilt mechanism at construction sites. Therefore, in this study 'waste walk' was introduced where the site management walk through the site daily to observe any evidences of waste. Although discussions with site management on the case study project showed that there was little or no time available for them to devote to such studies due to routine work. It was also identified that site engineers were mostly concerned with verifying facts rather than monitoring. Even when they were monitoring, they monitored safety aspects and VAA rather than NVAA. This study contends that the responsibility of waste elimination should not only be for site managers but extended to all process participants including sub-contractors and site workers. Therefore, all project participants will need to work together to minimise any waste in construction project.

Finding eight: Expected and achieved improvements from lean thinking

The implementation of a process improvement methodology in an alliance project was projected to improve cycle time, labour utilisation and process efficiency by 12 %, 16%, and 14% respectively (Table 5.11). The attained improvements in these categories were recorded as only 8%, 10%, and 8% respectively (Table 5.12). All the improvements made within the case study project were communicated to the wider project team and recorded as 'best practice' in lessons-learnt registers. By focusing on the process waste, the study laid a base for continuous improvement in the alliance project site. However, certain recommended practices that were agreed upon during the initial study were not spotted during the follow-up studies due to the reasons explained in the finding nine.

Finding nine: Barriers for process improvements

A list of barriers against executing a process improvement framework was identified from literature, management views at the follow-up meetings and the follow-up studies. By following Alinaitwe's (2009) analytical approach as explained in section 5.10.6, top priority barriers are identified as follows:

- difficult to change behaviour and attitude of the project team
- lack of leadership
- lack of education and training to drive the improvement process
- lack of evaluation of the site management of process improvements and
- lack of mechanisms for improvement suggestions

Compared to Alinaitwe's (2009) study, the current study identified that changing behaviour and attitude of the alliance project team was less difficult barrier but the impact of this barrier in process improvement initiatives is high. Although construction study findings of Abdul-Hadi et al. (2005) had indicated that employee behaviour is a difficult barrier to overcome. This is a major difference observed between alliance projects and general construction industry culture. Alliance principles and practices, and the large and long-term project nature also help to develop such general construction industry culture in alliance projects. This shows that the alliance site management has a good relationship with workers. The site management understood that worker participation in process improvement is vital and achievable.

The lack of commitment or leadership of the senior management is the most cited barrier in process improvement related practices (e.g.: (Alinaitwe, 2009) (Antony et al., 2012) (De Souza & Pidd, 2011) (Kim & Park, 2006) (Abdul-Hadi et al., 2005)). Although the current study identified this barrier in alliances as relatively easy to overcome as alliance principles place much emphasis on the 'right people in right place' practice.

Construction managers often failed to identify or address waste in a construction process. One of the reasons for not recognising waste properly is the absence of appropriate tools for identifying and measuring waste (Lee et al., 1999). The current study found that most of the process improvements were identified by site management through informal data collection and analytical methods (Figure 5.20) and they were not aware of waste identification tools and techniques available in Lean. During follow-up meetings, site management noted that there was a lack of training in Lean to implement a process improvement methodology at site level. Site management do not consider this as a barrier in long term hence the alliance is heavily investing in their people in terms of training and development.

Despite a lack of focus on process improvement at site level in the selected case study in the past, the case study organisation introduced an evaluation system for site engineers and project engineers in which performance was updated and displayed on notice boards. Similar to the Buch and Sander's (2005) study, the current study shows that assessing middle managers is a critical success factor for a process improvement programme. The long term and repetitive process nature of the project allows for the creation of a continual improvement culture while the alliance contractual structure improves coordination, cooperation and innovation among project members. Therefore, site management involvement is easier alliance projects. It is also easy to implement an assessment mechanism for site managers to improve processes.

Finally, Jaca, Viles, Mateo and Santos (2012) have identified a lack of reward systems as the most frequently cited reason for the failure of improvement programmes. This study finding showed that this barrier is placed in moderate quadrants (Figure 5.23) as participants did not recognise a reward system as an important practice. However, reward systems play a major role as it ensures active worker participation.

Triangulate current process improvement practices in alliance

Table 7.4 presents a summary of the research findings and indicates the relevant data collection method for each outcome variable.

Table 7.4: Mixed method matrix for key findings for process waste

	Finding	Literature review	Process study	Interview and questionnaire results	Implication
1	**No defined operating system**	Alliancing is silent on operating system (section 2.4)	Employed certain lean techniques without referring to their formal terms	Techniques implemented by experience of site management	Alliance requires a defined operating system
2	**Applicability of VSM**	Past VSM studies conducted (section 5.5) -for short term projects -by using second-hand data -only at process level	Study used real time data and piloted in a longitudinal manner. Study identified a number of micro and sub-micro level improvements	Lack of focus on micro level improvements in an alliance	VSM process flexible enough to apply to the construction processes and served as a guide for improvements.
3	**High process waste in alliance**	Past studies do not reveal procurement method (section 3.7.2)	VA, NVAN, and NVAU time was 11%, 20% and 53%.	Not relevant	No difference in waste with the procurement model
4	**Construction waste composition**	Less clear and not as visible as in manufacturing (section 3.7 3.)	Some of the waste categories are difficult to fit. Major wastes are waiting, rework, worker unavailability and motion.	Not relevant	The identified waste examples help practitioners to get an idea of what type of waste exists on the site
5	**Little understanding of process waste**	No indication of logic of waste categorisation (section 3.7 3.)	Lack of lean thinking prevails on site	Process waste is not well understood (referred to as material waste not process waste)	Waste categorisation method was developed and improved repeatability of the research
6	**Lack of effort in waste control**	Learning climate in relational contracting for continuous improvement (section 3.6)	The limited scope of KPI measurements with little influence on the site level	Lack of management belief in the value of incremental improvements	Waste control system integrated into the site level production process
7	**Introduction of process improvement methodology**	Limited studies conducted with a complete methodology for the elimination of waste (section 3.7.5)	Developed and validated process improvement methodology through five process studies	Elimination of waste does not depend only on site managers, but also on the sub-contractors and site workers	Waste minimisation system should be an inbuilt mechanism at the construction site
8	**Barriers for process improvements**	List of barriers identified in section 3.7.6.	Overall the team members were interested in making changes and willing to extend their joint effort	Identified top priority barriers are •difficult to change behaviour •lack of leadership •lack of education and training to drive the improvement process •lack of site management evaluation •lack of mechanism for improvement suggestions	This analysis will allow alliance management to identify barriers and their difficulty of overcoming in order to minimise waste at sites

7.3.2 Behavioural waste due to lack of worker participation

In order to succeed in eliminating waste through continuous process improvements as explained in section 7.3.1, there should be a culture that encourages site workers to look at their work, identify waste and redesign processes. The focus of this section is to present investigations into the degree of worker participation in the project by integrating the findings from different data collection strategies. The key findings were identified in the following attributes by analysing the existing participation practices for site workers.

- Type of project organisation (i.e. tradition based (segmentalist) or dynamic based (integrative)) and
- Mind-set of management towards change

Finding one: Type of project organisation

From observations and interviews, it was identified that four practices were successfully implemented while four practices were partially implemented and seven practices were not implemented at all in the project (Table 6.3). These findings reflect the partial integrative nature of the project. Raja et al. (2012) have shown that procurement methods based on ‘framework agreements will elevate the strategic importance of HRM. The current study findings showed that there was a limited strategic influence of HRM in the early stage of the project even though alliances use framework agreements. Most of the important worker participation practices were implemented in the middle of the project mainly after a new project alliance manager joined. Therefore, the current study identified that the alliance project manager has an influential position in creating a suitable alliance culture thus great care is required when this position is to be filled.

Participants in this study identified practices related to ‘relationship management’, ‘knowledge management’ and ‘information sharing’ as important practices and they were implemented in the project. However, the practices related to ‘reward/recognition’ and ‘decision making/power’ were not used in the project and they were recorded as not important practices. Irrespective of alliance experience, the majority of respondents chose the practices they are familiar with. This implies that the alliance management is mainly interested in ‘top-down’ approaches rather than ‘bottom - up’ approaches.

However, past studies show that continuous improvement depends on worker participation and motivation. Process studies revealed that workers do not take responsibility to engage in improvement decisions (section 5.10). This means a simultaneous top-down/bottom-up practice is vital to achieve an improvement culture in alliance projects. Watson and Gryna (2002) have showed that the level of worker participation depends on the management style. Therefore, finding two to finding six will discuss the management views towards worker participation practices.

Mind-set of management: Importance of worker participation practices

A successful process improvement methodology is conditioned by worker participation in improvement programs. Therefore, existing worker participation practices in the case study project were examined. As for triangulation, the findings of the process study were corroborated by the findings of the interviews and the questionnaire with the management on the case study project. Finding two to finding six provide the main findings under the five main constructs of worker participation practices, which were presented in section 3.8 and 6.2.

Finding two: Positive attitude towards relationship management practices

The case study project concerned maintaining good relationships and a harmonious working atmosphere with site workers. Observations show that most of the 'relationship building' practices in the project were introduced in the middle stage of the project. Meantime, all three practices noted under the 'relationship management' construct were consistently identified as important practices by both top and middle management (Table 6.3 and Table 6.6). The second highest overall RII was found in the relationship management variable (RII=0.773, Table 6.6). Practices found under this variable treated the entire workforce equally (RII=0.808) and social activities (RII=0.866, Table 6.6) were fully implemented and respondents found them important. This explains the positive attitude towards removing barriers between management and workers. Success was achieved through various approaches. For example, all project members irrespective of their job titles were required to attend the induction programme and 'one team sessions', and to wear standard personal protective equipment at the site (according to INT 3). Moreover, the co-location of all project members was a favourable condition for relationship development (according to INT 3).

Dibia (2012) has revealed that conducting social events improves organisational culture which creates a conducive environment for lean implementation. Interview participants claimed that it is difficult to get buy-in for these relationship development practices from alliance participants due to the intangible nature of the benefits (according to INT 1, and 5). Attendance of a relationship development event must not be undervalued because these practices help team members understand each other which enhance communications and work outcomes. Monthly morning tea with the project teams was implemented in recent alliance projects (e.g. Manukau harbour crossing and Victoria Park tunnel) in NZ (Alliancing Association of Australasia, 2011a) and this learning was carried forward to a future project (Waterview connection) in NZ (according to INT 5). This practice acts as a communication tool to understand each other better and build trust (section 3.8.3), but such practices did not prevail in the case study project investigated.

The majority of the surveyed managers were of the opinion that 'conducting relationship building workshops for site workers' as a moderately important practice (RII=0.645, Table 6.6) though it was not implemented in the case study project (Table 6.3). This is supported with the argument by the alliance management (according to INT 1, 2 and 3) in which such workshops need to be conducted continuously and partially due to low retention of workers in the project. This requirement was fulfilled by the 'one team sessions' and 'induction programme'. However, according to Cheung and Rowlingson (2005), there is lack of buy-in of alliancing principles and values at the operational level. Their findings show that a full day relationship building workshop for all operational level staff has a significant influence on the effectiveness of the team in alliance projects. Moreover, Davis and Walker (2009) have shown that such coaching programmes throughout the project will improve the collaboration among the project teams. The current study findings show that there needs to be a frequently conducted forum to explain alliance principles and values to the wider project team. It is also an opportunity to unify people from different organisations (according to INT 1, 2, 3, 4 and 5).

Finding three: Positive attitude towards knowledge management practices

A substantial investment in training was considered as the highest priority for alliance projects. Therefore, the case study alliance used 'skill development' as a main KPI with 5% weighting of the overall performance score (New Zealand Transport Agency, 2009). A number of initiatives took place throughout the project to develop skills including training for site workers. A large majority of respondents of the questionnaire (78%) agreed that knowledge management practices are important in alliance projects. These findings were consistent with top and middle level managers' views of different levels of experience in alliances (Table 6.3 and Table 6.6).

MacKenzie, Kilpatrick and Akintoye (2000) have shown that the growth in labour only sub-contracting has led to a decline in training prospects for workers. However, the selected project offered training to their sub-contractors as well. Accordingly, the current case study project showed high commitment to site worker training (RII=0.777, Table 6.6) since skill development is one of the project KPIs and it was easy to achieve compared to the other KPIs. The success of process improvements depends on the problem solving ability of the workers (Pasquire, 2012) and formal training in problem solving. On the other hand, studies conducted by Low and Omar (1997) and Meiling et al.(2012) have revealed that there is no formal training in problem solving in construction and the case study project was no exception.

Training programmes conducted for site workers consisted of only technical level training. The majority of respondents to the questionnaire (70%) reported that a management skill development programme for site supervisors was essential (RII=0.792, Table 6.6). In line with Gann and Senker's (1998) study results, the interview participants accepted that most of the supervisors are not skilled in worker management. The top management interviewed (INT 1, 4 and 5) believed that such skills come through learning by doing, rather than formal qualifications.

According to the KRA guidelines of the case study project, the project should maintain a competency register. It is used to identify skill gaps and training requirements. Study participants are of the opinion that this practice as important (RII=0.793) and it allows the workforce to see how they have improved their skill base over time. According to Raiden, Dainty and Neale (2004), construction staff appraisal records were rarely considered in training decisions while performance appraisal systems were the only formal means of providing a structure for promoting people. One of the findings emerging from the analysis in the current study is that alliance projects acknowledged a higher importance of knowledge management practices compared to the rest of the construction industry.

Finding four: Moderate attitude towards reward and recognition practices

Ahmad, Russell and Abou-Zeid (1995) have noted that the establishment of suitable reward and recognition procedures will encourage team-work and stimulate continuous improvement culture in construction projects. A monetary reward is recognised as the most significant motivator for all construction workers (Asad & Dainty, 2005; Hutchinson & Gallagher, 2003). In the study conducted by Holmes (2011) on large NZ construction companies, have revealed intrinsic rewards was the most significant motivating factors relative to extrinsic rewards. The current study also found a lack of acceptance for extrinsic reward systems aimed at site workers by the middle and top management of the case study project (Table 6.3 and Table 6.6).

Interview participants felt that team rewarding was more feasible in the project as teams conducted most of the activities. They are of the opinion that it is difficult to separate individual contributions. Moreover, the site workers of the project recalled a few recent incidents where site workers received reward coupons for suggestions made by the workers but most of the workers were not aware of the system to submit the suggestions. Therefore, as recommended by Kululanga and McCaffer (2002), reward policies should be openly communicated to workers to stimulate innovative behaviour.

Apart from rewards, the ‘recognition’ through appreciation of a high level of behaviour or accomplishment is still an important management tool to improve worker motivation. Ng, Skitmore, Lam and Poon (2004) have found that lack of recognition for the performance of site workers is one of the main demotivating factors in construction. The study participants identified that providing recognition for site workers was partially used in the project as a moderately important tool (RII=0.652, Table 6.6). This finding show that middle management also prefer a ‘recognition system’ rather than a ‘reward system’, providing a higher rating to a recognition system (RII=0.652, Table 6.6) than to an individual reward system (RII=0.408, Table 6.6). This finding agrees with

Holmes's (2011) idea that providing recognition for site workers is important for project performance.

The process study found that the site walk conducted by the site management was the main means of identifying worker performance. Most of the time, workers received recognition for cleaning and safety achievements. This practice was encouraged after revisiting the project practices in the middle of the project. There was no formal mechanism for providing recognition for workers. Moreover, reward and recognition require an evaluation of performance, which did not exist for site workers of the case study project (Table 6.3). Study participants consistently agreed that regular worker performance appraisal is an extremely important factor (RII=0.874, Table 6.6) but this was not fully implemented for the site workers. An appraisal system was implemented for middle management during the latter part of the project and those appraisals mainly focused on the achievement of project KPIs.

Finding five: Moderate attitude towards information sharing practices

Information sharing practices were highlighted as major ways to get workers involved in process improvements. During the middle of the project, the alliance management showed visible commitment to sharing information with workers by introducing new practices mainly the 'one team sessions' (according to INT 3). Nevertheless, the investigation of worker participation in 'rewards and recognition' related practices showed that there was a lack of open communication about reward mechanisms. The project's management personnel understood the importance of this practice and implemented the 'one team session' and the 'improved induction programme'. The majority of respondents to the questionnaire (80%) agreed that those two programmes are important practices. These two programmes were executed mid-way through the project which may have caused the loss of their full benefits.

Huselid (1995) has shown that regular opinion surveys improve the project performance. Past alliance projects in NZ used the 'opinion survey of workers' (Alliancing Association of Australasia, 2011a). However, the current project has not implemented this practice and the two participant groups had differing insights into the issue. The top management believed that such a practice is important (Table 6.3) but the middle management believed that it is only a slightly important practice (RII=0.445, Table 6.6). Nevertheless, such a practice could allow site workers to feel confident about voicing their opinions to management so that the management could monitor changes in attitudes of its workers. Therefore, workers are motivated when they know that the management is really interested in their opinions.

Finding six: Negative attitude towards decision making/power distribution

The involvement of site workers in decision-making is necessary to sustain a process improvement programme in the long run. However, actions taken to increase the level of participation in decision-making have been the least executed ones (Table 6.3). This brings to question mark about the commitment of the management. A suggestion system was frequently identified as a worker integration practice by the majority of the construction management research. A suggestion box system was implemented in the referred case study in the initial stage of the project (according to INT 1). This showed that the alliance management was keen on suggestions and they valued the ideas of workers. The suggestion box system failed in the middle of the project. The majority of the study participants identified the suggestion system as an unimportant practice (RII=0.437, Table 6.6). Moreover, the questionnaire identified a lack of follow-up, lack of workers' interest and slow response to suggestions as reasons for its failure. This was a result of the workforce not understanding the benefit of making suggestions and being reluctant to come forward with suggestions. Consequently, constant encouragement is required to overcome this obstacle which was not seen in this project.

The process study observation revealed that process improvement related problem solving was conducted by middle management with little or no participation of site workers in those forums (section 5.10.4). This was verified by the questionnaire results with participants noting little or no worker involvement in their lessons-learnt workshops (Figure 5.21). The management highlighted the fact that there was an open door policy (INT 4 and follow up meeting in process study D). Nevertheless, process observations show that there was a lack of worker level participation at the pre-start meetings and one team session (Figure 5.22). Haque, Green, and Keogh (2004) have noted that workers have ideas whether the environment is conducive or not, but the worker would not submit ideas if the environment is not seen as supportive. In this case study project, the management did not agree with the incentive system for suggestions (finding four) even though such an incentive system makes workers feel that their ideas are rewarded.

Finding seven: Practices implemented in the middle of the project

Literature shows that a project culture must be established from the very beginning and kept up all the time. The experts who participated in the interviews (INT 1, 2, 3, 4 and 5) strongly agreed with the above statement and also stated that lack of attention to the alliance culture could actually inhibit the project. In this case study, most of the important worker participation practices (practices with RII>0.6, three out of 15) were implemented mid-way of the project (Table 6.6). Out of the important practices (practices with RII>0.6), only four practices were fully implemented in the project (Table 6.6). Most of the important practices were implemented after the alliance project manager was replaced. This observation shows that the project leadership plays a major role in implementing worker participation practices. The subject matter experts who participated in interviews (INT 1, 2, 3, 4 and 5) noted that certain practices needed a change in attitude and behaviour throughout the project team from ALT to site workers and from owner participant to non-owner participants. Since certain practices were implemented while the project was going on, it was difficult to adopt necessary attitudinal and behavioural changes in the wider project team. These findings suggest that a strong commitment to alliance behaviours from all levels can be achieved if necessary practices are in place at the project onset.

Finding eight: Barriers for worker participation in an alliance

A successful implementation of worker participation practices was hindered by a number of difficulties. Strength of barriers and difficulty level of eliminating each barrier were identified through the questionnaire. High priority barriers to adoption of worker participation practices in an alliance were found to be:

- lack of leadership in top management
- inability to change mind set
- fear of decentralisation of power
- less organisational commitment and
- personal agendas.

Also, there are medium priority barriers such as ‘organisational politics’ and ‘lack of HRM policies’. Even though researchers have recorded ‘resistance to change’ as a major barrier in construction, this study shows that it is not difficult to overcome this in an alliance project. Workers’ flexibility to change could be mainly due to the strong relationship between workers and management.

Alinaitwe (2009) has observed a lack of organisational culture for teamwork and top management leadership as major barriers to achieving team work in construction. The study shows that leadership and project organisational culture can highly influence worker participation practices, they are also easily achievable in an alliance. Thus, an alliance needs to have strong leadership qualities to successfully implement the concept of worker participation. These qualities should be capable of integrating the project team within an organisation and promoting effective skills and knowledge enhancement of the workforce. The current study found that there was a lack of focus on worker participation practices in the initial stage of the project due to a lack of leadership. Most of the other barriers’ namely ‘fear of power decentralisation’, ‘inability to overcome mind set’, ‘little organisational commitment’, ‘personal agendas’, ‘organisational politics’ and ‘lack of HRM policies’ can be mitigated through strong leadership.

Triangulate current worker participation practices in an alliance

Table 7.5 presents the summary of research findings. It can be claimed that real worker participation is at a comparatively low level in the referred case study project. The main problem in implementing such practices is related to the absence of strong leadership at the initial stage of the project and difficulty of changing the project culture in the middle of the project even with a strong leadership.

Table 7.5: Mixed method matrix for behavioural waste (site workers)

	Finding	Literature review/process study	Interview findings	Questionnaire findings	Conclusion/Implication
1	Partial integrative nature of the project	Relational procurement elevates the importance of HRM. (Raja et al., 2012)	Partial integrative nature	Mainly interest in 'top-down' practices not in 'bottom - up' practices	Top-down/ bottom-up practices encourage worker participation
2	Positive attitude to relationship management practices	Level of worker participation depends on management style (Watson & Gryna, 2002)	Only two practices under the relationship management identified as an important practice. Difficult to get buy-in due to intangible benefits	Relationship management was identified as important practice by middle management	Frequently held forum to explain alliance principles to project team is required
3	Positive attitude to knowledge management practices	'Skill development' as a main KPI with 5% weighting (New Zealand Transport Agency, 2009)	Acknowledged the importance of all three practices under the knowledge management practices	Acknowledged the importance of knowledge management practices. Management skills for supervisors rated as important practice.	Alliance projects acknowledged more the importance of knowledge management practices compared with the construction industry
4	Moderate attitude to reward and recognition practices	Reward/recognition encourage team-work and continuous improvements (Thorpe & Dugdale, 2004)	Lack of acceptance of the reward system for site workers and only regular employee performance appraisal	Participants prefer 'recognition system' rather than the 'reward system'	'Reward and recognition' system - embedded with site workers' performance evaluation and linked to selected project KPI is desirable
5	Moderate attitude to information sharing practices	Project implemented sharing information with workers during middle of the project (Section 6.2.1)	All three practices under the information sharing construct identified as important	Respondents agreed that induction and one team sessions are very important practices but 'opinion survey' rates as slightly important.	One team and induction sessions implemented in the middle of project limit the full benefit.
6	Negative attitude to decision making/ power	Workers will not submit ideas if the setting is not supportive (Haque et al., 2004)	Actions taken to increase the level of participation in decision making are the least implemented ones	Respondents rated practices which integrate decision making with site workers as unimportant	Worker involvement can be increased with the methodology developed in section 7.3.1.
7	Practices implemented in the middle of the project	Project culture plays a vital role in achieving high performance (Ghassemi & Becerik-Gerber, 2011)	Difficult to adapt necessary attitudinal and behavioural changes of the project team in the middle of the project	Most of the important practices are implemented in the middle of the project	Strong commitment to practices can be achieved by implementing essential practices at the project onset
8	Barriers to worker participation in an alliance	16 barriers were identified (section 3.8.4)	Most of the barriers identified can be eliminated through strong leadership	Lack of leadership of top management is identified as top priority barrier	Analysis will assist management to identify barriers and their difficulty of overcoming

7.3.3 Behavioural waste due to lack of sub-contractor management practices

Approximately 40-45% of construction work in the selected project was carried out by sub-contractors. The process studies provided evidence to show that waste was generated within the alliance through the work carried out by sub-contractors (section 6.3.1). The process study results showed that improvement prospects were not exploited by the alliance due to the poor integration of the lower tier project participants with the main alliance. Therefore, an exploration of reforming sub-contractor practices was conducted through a questionnaire and interviews with various management levels. This section reports the triangulated results (literature, process study, questionnaire and interviews) of data collected on sub-contractor management practices in this case study.

Finding one: Sub-contractor management practices in an alliance

Project participants of the case study worked with equal commitment towards a common goal under an alliance (according to INT 1 and 3). Alliance projects often need special skills and resources which are readily available from sub-contractors. All sub-contractors of the project were introduced by the alliance participants based on their past relationships. The case study project was an extension of another alliance project (New Zealand Transport Agency, 2009). Therefore, the continuation of an alliance project improved the relationship that persuades sub-contractors to focus on value in the project. However, sub-contractors were under third party contracts and were not included in the pain: gain share system (according to INT 6).

The study findings reveal that sub-contractor management practices in an alliance were a crossover between traditional and lean supply systems (Table 6.9 and Table 6.11). They showed that some principles of the lean supply model (mutual trust, long term relationship, defined responsibilities, non-price selection criteria and common training programme) were well adopted in the referred case study. This supports the fact that the mutual trust observed in alliance-sub-contractor relationships was facilitated by past relationships, usage of team development tools like one team sessions and common training programmes.

Incentive arrangements, information sharing and frequent communication did not exist in current practices. In addition, the results revealed that important but not committed practices in the project were ‘frequent communication’ (RII=0.911, Table 6.15), ‘early contract involvement’ (RII=0.837, Table 6.15) and ‘opinion survey’ (RII=0.793, Table 6.15). In this project, only operational level representatives of sub-contractors (foreman or charge hand) participated in ‘one team sessions’ (according to INT 6 and 8). There was a lack of evidence of interactions between managerial level representatives and alliance members. Past NZ alliance projects were able to improve the communication with sub-contractors mainly through monthly meetings and opinion surveys ((Darrington, 2011) and INT 9). However, such practices were not identified in the current project (according to INT 6, 7 and 8).

Finding two: Lack of early involvement of key sub-contractors

The basic idea of a project alliance is to bring the required knowledge together at an early stage and to improve trust, commitment to goals and close cooperation among partners. In this project, only main alliance participants were involved in the preparatory work while specialist sub-contractors were introduced at a later stage (section 5.8.1). The literature review identified the advantages of sub-contractor involvement in the early stage of a project (section 3.9.3). Interviews with the alliance leadership participants (according to INT 6, 7 and 8) revealed that since this alliance project was an extension of a past alliance project, all the previous main sub-contractors were involved in the current project at different phases.

The tight schedule and delays of initial designs led to delays in sub-contractor involvement in late design stages (according to INT 6). This fact prevented sub-contractors from giving suggestions during the project design phase where value engineering and analysis were conducted. The questionnaire participants identified the early involvement of sub-contractors as an important practice (RII=0.837, Table 6.15). Interviewees agreed that little or no sub-contractor involvement in the design phase was a missed opportunity for the project (Table 6.11). The alliance case study implemented ‘work method briefing’ for all sub-contractors allowing sub-contractor representatives to provide their input in the site work to inspire innovation. Difficulties of sub-contractors getting involved at the design stage were the inadequate capability of sub-contractors, additional financial and resource requirements and lack of willingness to share knowledge

(INT 6, 7, 8 and 9). Although additional financial and resource requirements are believed to be incurred when sub-contractors are brought on board, the advantages are a decrease in cost due to reduced rework, improved designs and communication.

Finding three: Selection mainly by lowest price

Even though the sub-contractors were introduced through previous relationships, competitive tendering was the principal mechanism for selecting sub-contractors (According to INT 6 and 8). The project followed a traditional way of sub-contractor selection where alliance participants select known sub-contractors based on price competition. Previous researchers have noted merits and demerits of this kind of selection (e.g: (Kumaraswamy & Matthews, 2000; Pala, Edum-Fotwe, Ruikar, Peters, & Doughty, 2012)).

This study revealed that sub-contractors who submitted the lowest tender price with lack of experience and quality control measures cause negative effects on quality ((section 6.3.1) and according to INT 7. This shows that the low cost estimation impacts on the quality as sub-contractors who were interested in making a profit without paying adequate attention to the quality of their work. Doloi's (2012) study has shown that technical expertise, past safety records and relevant experience of sub-contractors have the strongest links to time and quality performance of projects. Participants of the questionnaire felt that the non-price based selection criteria is not an important practice (RII=0.504, Table 6.15) while the majority of the interview participants (60%) agreed that it is important (Table 6.11). These divergent views reflect the difference between corporate and individual viewpoints. Even though a high degree of sub-contracting was used in the project, the pre-qualification standards in sub-contract selection were not identified as an important measure by the middle management.

Other alliances in NZ have used techniques to improve the sub-contractor base such as 'sub-contractor open day to meet potential sub-contractors', 'pre-qualification survey to assess sub-contractors' and 'site induction to make them aware of the project dynamics' ((Wieneke, 2010) and according to INT 9). The referred case study did not have any evidence of the application of such tools. Interviews with the top management revealed the importance of these practices.

These practices were not present in this project since they require more senior management time and they need to be formulated at the project onset (according to INT 6 and 7).

Finding four: Disintegration from the alliance KPI system

The gain:pain share mechanism of an alliance contract is executed by measuring different KPIs. However, in the current project, the gain:pain share mechanism only extends to key alliance participants, i.e. owner, contractor and designer excluding sub-contractors who have a significant effect on project outcomes (Table 6.11). According to all respondents to the questionnaire, including sub-contractors in the alliance agreement was not considered as an important practice (RII=0.548, Table 6.15). Nevertheless, a case study of the Australian national museum which was mainly procured through an alliance used a gain:pain arrangement with sub-contractors (Hauck et al., 2004). Consequently, this arrangement encouraged the pursuit of innovative approaches to project delivery from a technology, management and workplace culture perspective (Walker, Peters, Hampson, & Thompson, 2001).

Interview findings reveal that the sub-contracting strategies were adopted by the alliance mainly to get expert skills as well as to transfer the risk warrant to sub-contractors (according to INT 6, 7 and 8). It could also be argued that non-specialist sub-contractors on this project were incapable of dealing with the risk allocated to them and it could be seen as countermanding the alliancing concept. At the same time, there was no robust framework for performance measurements of sub-contractors in the referred case study (Table 6.11), but all the participants in the questionnaire rated consistent performance monitoring as an important practice (RII=0.837, Table 6.15). When the performance of the sub-contractors was considered, only safety and schedule KPIs were covered in monthly performance reports.

A shared risk:reward arrangement serves parties in being able to align with the project objective. However, both participant groups paid little attention to consistent objectives (RII=0.541) and a win-win attitude (RII=0.541, Table 6.15). Accordingly, sub-contractors may not have significant motivation to improve the project performance. In order to improve the sub-contractor integration in the project team, the alliance needs to develop an incentive based agreement with sub-contractors based on alliance KPIs. Since most of the interview participants pointed out the issue of disconnection of alliance KPIs from the workers on the site, this practice is a good way to align the motivation of on-site staff with alliance KPIs.

A recent investigation by Rose and Manley (2010) has shown that the benefits of incentives for sub-contractors could be maximised through equitable contract risk allocation, early involvement in the design stage, conducting relationship workshops, value driven tender selection, and offering future work opportunities. Therefore, the importance of the aforementioned findings (particularly two and three) to reap the benefits of incentive systems is noted.

Finding five: Promote collaboration through facilitation and training

Training and development are vital elements of a successful project delivery. This study revealed that even though sub-contractors were not attached to the alliance commercially, the alliance treated sub-contractors as part of the alliance in every other way (according to INT 3 and 6). In order to ensure project success and to overcome the skill shortage, the project offered extensive training to their staff including sub-contractors. These practices were recorded as important (RII=0.793, Table 6.15). MacKenzie et al. (2000) have shown that the growth in labour only sub-contracting has led to a decline in training prospects for workers. Participants in the interviews (INT 6, 7, 8, and 9) noted that investment in sub-contractor training improved the project performance.

With the increase in the extent of sub-contracting in alliances, interviewees (INT 6, 7, 8, and 9) commented that the relationship with sub-contractors is vital. Participants in the interviews (INT 6 and 8) showed how they maintained good rapport with sub-contractors like on-time payment, facilitation of training, assisting with managerial challenges and creating a safe environment. All sub-contractors were invited to ‘one team sessions’ and to project celebrations. The interview participants strongly agreed with the statement of ‘commitment of all participants’ being a critical element in alliancing (Table 6.11). There still exists a difference in individual levels of commitments. ‘One team sessions’ could be used to improve participant commitments. The study identified that the managerial level representation of sub-contractors in those meetings was minimal. Frequent communication with the managerial level representation of sub-contractors' is necessary to create innovation and a learning culture.

Finding six: Evaluation of sub-contractor performance

Since most of the KPIs mainly aim at the performance of alliance participants, the essential performance criteria for sub-contractors are often ignored by principal stakeholders. An analysis of related research initiatives (for example (Arslan, Kivrak, Birgonul, & Dikmen, 2008) and (Cheng, Tsai, & Sudjono, 2011)) has identified that the performance of sub-contractors is based on 18 factors. Management satisfaction of sub-contractors' performance was evaluated against these factors. The importance of these factors was evaluated through the questionnaire. The questionnaire results indicate that the alliance management perceived sub-contractors' performance in safety, quality, time, cost and technical competence as important performance measurements. Sub-contractors of the current alliance project satisfied the performance requirements in the above measures.

The majority of respondents agreed that there was close cooperation between the alliance and sub-contractors. A number of authors have argued that close cooperation among project participants would enhance productivity and performance (Dubois & Gadde, 2000). In line with the above statement, the respondents were satisfied with the overall productivity of sub-contractors. In many procurement methods, the responsibility of specialised sub-contractors is substantial but site coordination of sub-contractors is often a problem (Bennett & Ferry, 1990). According to the questionnaire respondents sub-contractors achieved an acceptable performance outcome even though process study observations discovered few failures in sub-contractors' work.

Alliance participants from larger NZ companies were more capable of effectively dealing with site issues as they had more experience and resources than sub-contractors. Consequently, the alliance management was also satisfied with performances of most of the sub-contractors. The identified performance criteria for sub-contractors (Table 7.15) can help alliances benchmark the performance of sub-contractors and determine their capability to complete tasks.

Triangulate existing sub-contractor management practices in an alliance

Table 7.6 presents a summary of the research findings related to the sub-contractor management practices in an alliance.

Table 7.6: Mixed method matrix for behavioural waste (sub-contractors)

	Finding	Literature review and process study	Interview findings	Questionnaire findings	Implication/conclusion
1	State of sub-contractor management practices	Lean supply principles and practices pooled from literature (section 3.9.2)	Lean supply principles (mutual trust, long term relationship, defined responsibilities and common training programme) are implemented	Ten lean supply principles were identified as critical	Sub-contractor management practices in alliance are cross-over between traditional and lean systems
2	Lack of early involvement of key sub-contractors	Early involvement of participants will improve trust, commitment to goals and cooperation (Dainty, Briscoe, & Millett, 2001)	Hindrances of early involvement of sub-contractors are tight schedule of the project transition from previous alliance and delay of initial designs inadequate management capacity additional resource requirements	Early involvements of sub-contractors are seen as important practice.	It is vital that the expertise of sub-contractors is integrated into the main alliance to ensure commitment throughout the project value chain
3	Selection mainly on lowest price	Rework incidents by sub-contractors due to lack of past experience	Non price based selection criteria is an important practice	Non price based selection criteria is not an important practice	Selection should be focused on a sub-contractor's ability to deliver value to the project
4	No modern commercial arrangements	Incentives encouraged team building and problem solving (Hauck et al., 2004) No performance measurement for sub-contractors (New Zealand Transport Agency, 2009)	Sub-contracting adopted mainly to access expert skills and to transfer risk warrant Regular performance monitoring is important	Sub-contractors agreement through gain:pain mechanism is not an important practice Regular performance monitoring is important	To improve the sub-contractor integration, requires adopting an incentive based agreement related to alliance KPIs
5	Promote collaboration through facilitation and training	Growth in labour-only sub-contracting has led to a decline in training for workers (MacKenzie et al., 2000) Alliance offered extensive technical training to sub-contractors' staff	To maintain good relationship with sub-contractors alliance adopted practices of on-time payment, facilitation of training, assisting with managerial challenges and creating a safe and positive environment.	Facilitation of training is seen as an important practice	Frequent discussions and communications with sub-contractors' managerial level representation is necessary to create the potential for a learning culture
6	Sub-contractor performance evaluation	Close cooperation among the project participants would enhance productivity and performance (Dubois & Gadde, 2000)	There is close cooperation and a good flow of information exchange between general contractors and sub-contractors	'General site management practices' and 'accuracy and completeness of documentation' were ranked relatively low indicating significant room for improvement.	Most of the KPIs target only the main alliance participant's performance. Therefore essential performance criteria for sub-contractors are required.

A research validation exercise was adopted considering the qualitative and exploratory nature of the research. The findings of the validation exercise are reported in the next section.

7.4 RESEARCH VALIDATION EXERCISE

The validation exercise consisted of presenting the findings to alliance experts who were not involved in the initial study phases. INT 10, 13, and14 were not involved in the selected case study project. INT 11 was the new construction manager who was involved in the project only for the last six months of the referred case study project. INT 12 was the new alliance project manager for the second half of the referred alliance project. Table 7.7 gives an outline of their position and professional experience. Five semi-structured interviews were conducted. Main purposes of this exercise were:

- To assess the validity of the findings emerging from the study
- To discuss the wider applicability of the research findings and
- To evaluate the models and frameworks emerging from the research.

Table 7.7: Profile of interviewees

Interviewee job position	Interviewee ID	Experience in construction (*) / alliance projects (√) (Years)				
		< 5	5 -10	10 -15	15 - 20	> 20
Alliance project manager in a completed alliance	INT 11		√			*
Construction manager in an on-going alliance	INT 12	√	*			
Alliance project manager in an on-going alliance	INT 13	√			*	
Alliance project manager in a future alliance project	INT 14		√			*
Alliance expert practitioner	INT 15			√		*

The five expert participants were asked to express their views of the applicability of research findings. Seventeen questions based on the study findings and recommendations were presented.

All participants indicated positive remarks about the recommendations and all were keen to see the final report of this case study analysis. The participants indicated positive feedback on the waste identification methodology (Figure 5.2), sub-contractor evaluation matrix (Figure 6.5) and critical sub-contractor selection framework (Figure 8.3). The identified solutions were further refined based on their feedback as explained in chapter eight.

The validation results showed a slight disagreement among participants with four suggestions. One participant disagreed with the provision of reward and recognition for waste elimination suggestions because he believed that this task is one of the job responsibilities of workers. Further, he noted that rewards should be granted if the worker acts ‘above the line’. Another participant disagreed with the involvement of workers in lessons-learnt workshops as middle management has to explain the reasons for failures and suggestions for future developments. Furthermore, he added that there is no point in inviting site workers to lessons-learnt workshops as the existing issues are discussed with the crew members in the pre-start meetings. The extension of appraisal systems to the worker level was not accepted by one participant as he believed that it is difficult to conduct an effective appraisal system for site workers due to the temporary nature of the job contract and lack of capacity of site workers. Two participants did not agree with conducting meetings with the management representatives of sub-contractors because a large portion of sub-contractors had little connection with the work site. In particular, the introduction of such meetings caused poor acceptance and attendance by sub-contractors.

The frequency of agreement with each study finding is shown in Appendix W.

7.5 CHAPTER SUMMARY

This chapter presented the overall findings of the research (chapter five and six) by comparing them with current literature. The results strengthen the trends from recent literature by highlighting potential waste and causes in an alliance project. Proposals to reduce waste using a modified VSM approach are also discussed. The study concludes that lean tools and techniques have a high potential in process improvements in an alliance project. The alliance principles practised in this project are intended to encourage innovation via working arrangements with key project delivery teams.

The success of the process improvement methodology depends strongly on the active participation of sub-contractors and workers. The study identified the fact that the lower tier parties (sub-contractors and workers) who control a large portion of the actual construction were disintegrated from the alliance. This study suggests a way to extend the alliance principles to sub-contractors and workers. Further analysis of the results showed the most influential barriers to integrating workers and sub-contractors in the alliance project.

No assertion is being made about the generalizability to the construction industry from the experience of a particular project. However, there are lessons to be learnt from the knowledge gained in this project, which could be adapted in other alliances. These are discussed in chapter eight where the conclusions of the results and recommendations for further research are presented.

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 INTRODUCTION

Since the early 1990s, alliancing has been spreading as a project delivery system for improving relations and project performance in construction. Recent studies have shown that some alliance projects do not reach their true potential performance due to various interferences. A preliminary literature review was carried out to identify causes of those interferences. It was identified that a knowledge gap exists in the integration of operational systems in alliances. The central research aim was formulated (section 1.5.1) to explore how lean thinking can be utilised in alliance projects to improve project performance. Subsequently, this thesis addresses the main research questions namely "what are the operational deficiencies in an alliance from a lean perspective" and "how can lean thinking reduce the identified deficiencies in an alliance" (section 1.5.3).

A single case study approach was used to achieve the research aim and to address the aforementioned research questions. The study shows that waste can be extensive in an alliance and resulting waste figures are consistent with past studies on different procurement methods. Numerous measures were taken to eliminate process waste at the selected alliance project site. This research shows that lean thinking can provide an operational framework for an alliance. Alliance projects are quite conducive to lean implementations. Furthermore, the research identified behavioural waste in the referred alliance project due to the absence of worker participation and sub-contractor disintegration. The research provided some valuable insights into causes of process waste and behavioural waste in an alliance project.

This chapter summarises the knowledge gained from the research with reference to the research questions. The chapter is split into six main sections including this introduction section (8.1). The next sections conclude the research findings pertaining to the research questions, which were set in chapter one (8.2) and the recommendations derived from the study (8.3). The study contributions are explained in section 8.4. The next section (8.5) explains the future research directions while the final section (8.6) presents some summary remarks of the study.

8.2 CONCLUSIONS OF THE RESEARCH

Past studies have shown that one of the differences in alliances compared to other relational contracts is that alliances do not have a commonly accepted operational system for projects. As a result, this research study tried to find improvement opportunities in an alliance project by using lean thinking. Study findings of the theoretical review (8.2.1) and the more elaborate empirical review (8.2.2) are summarised as follows.

8.2.1 Conclusions from the theoretical study

Two separate systematic literature reviews were conducted for alliance and lean concepts since the main research was involved with these two concepts. A review of relational type project delivery systems such as partnering, ECI, alliancing and IPD revealed that all of the above four relational models mainly stress organisational factors focusing on different operational and contractual factors. The alliancing concept upgrades partnering and ECI concepts through a contractual and commercial framework. IPD has been improved with new technologies by integrating BIM, process management techniques and early stage co-location.

After identifying the key elements of a procurement system and drawing comparisons of relational type contracting methods, it can be seen that there is no indication of a defined operating system in the alliancing concept (Table 2.3). A further analysis shows the necessity of a defined operational system in alliances (section 3.5.3) and Lean as a suitable methodology among the existing operational methodologies (Table 3.1). The literature review of Lean found that there are no defined lean construction principles in the literature. Therefore, this study developed a categorisation of lean principles (Figure 3.3). A comparison of lean principles and project delivery systems found that relational contracts have more correlation with lean principles than other project delivery systems (section 3.5.3, Table 3.4). The theoretical applicability of Lean in alliances (section 3.6) is also analysed. This analysis concluded that lean principles naturally fit in alliance projects and it further identified principal distinctions between Lean and alliance concepts (section 3.6). A further analysis of alliancing literature identified limited collaboration of sub-contractors and site workers in alliancing.

The review of waste categorisation in the literature showed that there are different categorisation systems. Certain systems are based on the effect of waste while certain systems are based on the cause of waste. Further analysis shows that the effects of waste are easier to identify and to measure than waste causes (section 3.7.3). Furthermore, it was identified that there is no clear cut approach for defining process waste and therefore the current study developed a waste activity classification system (Figure 5.4) which can be used for future research and in practice.

8.2.2 Conclusions from the empirical study

The main purpose of this section is to show research findings by summarising coherent answers to the research questions. Prior to giving answers to research questions and drawing conclusions about them, it is appropriate to re-state the research questions as presented in chapter one:

- Research question 1: What are the operational deficiencies that exist in an alliance project from a lean perspective?
- Research question 2: How can lean thinking reduce the identified deficiencies in an alliance?

The rest of this section recaps the findings under the two research questions.

Research question 1: What are the operational deficiencies that exist in an alliance project from a lean perspective?

The first research question of this study is to identify main operational level deficiencies in alliance projects. The main goal of Lean is to eliminate waste. Therefore, this research question is directed to finding answers to "what are the operational deficiencies (i.e. waste) in an alliance project from a lean perspective". Waste can be divided into two main categories namely process and behavioural waste. This research question is divided into two sub-research questions. The first sub-research question (1(a)) "What are the types of process waste that exist in an alliance project from a lean perspective?" and (1(b)) "What are the types of behavioural waste that exist in an alliance project from a lean perspective?".

Sub- research question 1 (a): What are the types of process waste that exist in an alliance project from a lean perspective?

Identifying improvement opportunities in an alliance project is a key step in this research since lean implementation strategies were developed based on that. An investigation was required to determine the processes and operations associated with construction processes of alliance work sites. Uniqueness of a phenomenon (i.e. alliance projects are complex and Lean and alliances are new to the NZ construction industry) provides a sound basis for choice of the in depth case study approach (more details were discussed in section 4.3.2). The study concentrated on waste identification and elimination at the alliance project site through process study observations. Project documents, questionnaire and interviews were used to improve the validity of the process study findings. The analysis involved

- identifying nature of waste types at the alliance project site
- establishing practices and programmes of identification of waste at the alliance project site and
- determining reasons for not detecting improvement opportunities in an alliance.

A lean tool called VSM was used to identify and measure the waste. A theoretical framework was designed (section 3.7.4) that allowed the full analysis and modelling of waste with in the alliance. A number of conclusions were drawn from these study investigations.

Nature of process waste in an alliance project site

- *Types of process waste*

The study found that some of the waste categories (e.g: worker unavailability) are difficult to fit to the theoretical framework defined in section 3.7.4. So, a new waste category was introduced. Certain waste categories are rare, particularly ‘overproduction’ and ‘inventory’ due to ‘build to contract mentality’ usual in construction projects. The identification of certain waste categories depends on the activity level being viewed. For example, overproduction and extra inventory occurred seldom at the micro and sub-micro level.

- *Significance of process waste*

The study of the alliance project showed that waste was extensive at least in the range of 47-62% of the working time (section 5.5.4). This confirms the complex and uncertain nature of alliance projects. Aggregate results showed that the proportion of available time used in VA activities was roughly 11% while 53% of the time was NVAU activities (section 5.5.4). The most observed waste types were waiting (22%), rework (11%), unavailability of workers (9%) and unnecessary motion (6%). Almost all of the values of waste categories were consistent with recent international studies on non-relational type procurement methods (Table 7.2). These findings show that the procurement type alone is not a sufficient condition for detection and elimination of process waste at the site level. Therefore, it is valuable for alliance projects to start looking for improvement areas in terms of waste elimination.

Waste identification practices of at the alliance project site

This study used certain lean tools (section 5.3.6) to identify waste and develop strategies to minimise waste at the alliance project site. The current study fills some of the gaps in lean research by testing the effectiveness of lean tools in the selected alliance project (section 5.6).

- *Possible lean tools for eliminating waste*

Due to the dynamic and complex nature of the processes studied, several waste activities were identified (section 7.3.1). In this study, VSM served as a guide to identify and measure waste activities within the processes. It was difficult to identify micro level improvement opportunities with a traditional VSM. Therefore a detailed level VSM was developed. This helped to understand the locations of waste and provided a foundation for improvements. The study showed that waste at micro level appears to be negligible. However, if all these waste figures were added up, it could be substantial in the long run. This study suggests that a micro view of processes helps to identify present waste levels and to discover more hidden issues.

The causes of waste activities were analysed with the use of lean and industrial engineering tools (section 5.6). The focus on waste removal helped the researcher to apply many lean techniques and tools on site. Some of the lean tools used by the researcher include mistake proofing, total productive maintenance, production smoothing and visual management. From these lean tools, it was possible to identify a number of areas for improvement in an alliance such as crew work distribution, machinery maintenance, workplace arrangement, material delivery and storage.

- *Causes of waste*

Another important aspect of the current study is determination of causes of waste. This study shows that there is great potential to eliminate waste in alliance projects. The site management had worked on solutions to minimise waste but most of the time, these did not address the real root cause. Root causes for each waste were identified by using different lean tools such as five why analysis, FMEA and fish bone diagrams (section 5.6). The summary of the causes of waste identified is shown in Figure 8.1.

Most of the waste categories identified in the study were related to each other and elimination of one source of waste led to either elimination or reduction of other waste categories. The study found that more reliable provision of materials, information and equipment contribute to better performance. The case study project investigated showed extensive deficiencies in labour utilisation. It can be concluded that lean improvement initiatives could focus more on workforce management strategies to improve labour utilisation for better labour performance.

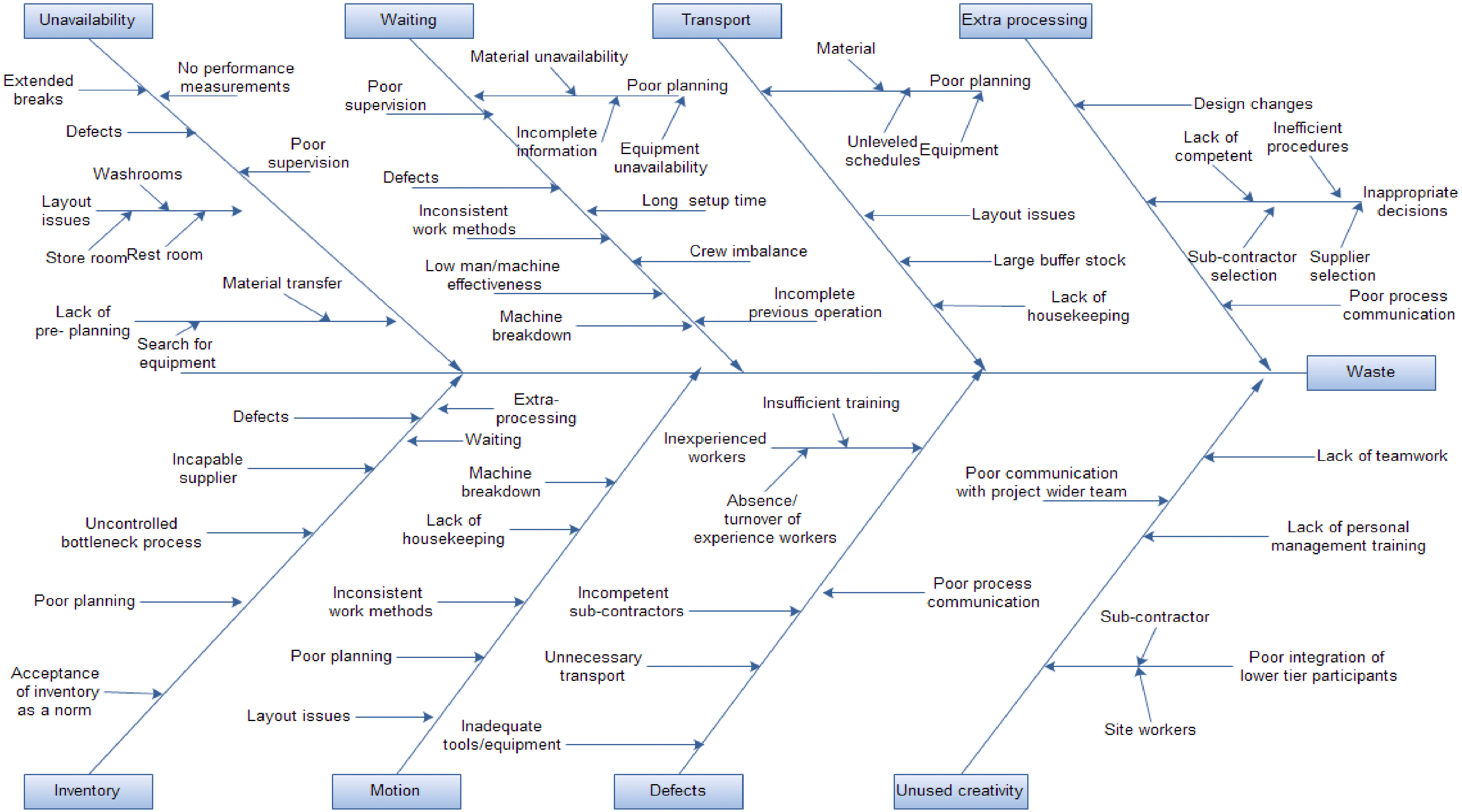


Figure 8.1: Causes of waste identified on the case study project

Reasons for not detecting improvement opportunities

It was identified from the research observations and validation studies through a questionnaire and follow-up meetings with site management that there was a lack of effort in waste control in the alliance case study project. This was due to the following:

- little understanding of the process waste and its causes (section 5.10.2)
- scope of alliance KPIs did not facilitate detection and improvement in the current process (INT 1 and 2)
- site management were mostly concerned with verifying facts rather than monitoring processes (section 5.8.2)
- site management were focused more on ‘conversion activities’ rather than ‘flow activities’ (section 5.10.2)
- process improvements were only conducted after failure incidents (section 5.8.3)
- lack of confidence in how marginal improvements would benefit the entire project (section1.9) and
- lack of integration of continuous improvement teams (lessons-learnt workshops) with general site workers (section 5.8.3).

The analysis of sub-research question 1(a) delivered a set of methodologies as listed below.

- the activity classification method (Figure 5.4)
- the waste categorisation and waste cause method (Figure 8.1) and
- the methodology to eliminate waste causes (Figure 8.2)

It can be concluded from the current study that a full understanding of waste generation and corrective actions through continuous improvements should be the first priority towards lean implementation in any alliance.

The next sub-research question 1(b) deals with the behavioural waste, which arises from limited integration of sub-contractors and site workers in the project.

Sub-research question 1(b): What are the types of behavioural waste that exist in an alliance project from a lean perspective?

The process study observations provided evidence that some of the generated process waste were caused by behavioural waste mainly due to a lack of active participation of site workers. The success of waste detection, explained in research question 1(a), strongly depends on active worker participation and their motivation to continuously improve processes. The study identified that 80% of the workforce at the alliance project site worked under sub-contractors and 40-45% of the construction work was performed by sub-contractors (acccording to INT 6). In practice, the alliance integrated only a part of the value chain and in particular, sub-contractors were not included in the alliance. Effective people management in developing relationships, leadership and culture is a pre-requisite for efficient project delivery. Consequently, this sub-research question tries to identify the behavioural waste in the project. The frequently cited worker participation (section 3.8.3) and sub-contractor management practices were identified in the literature review (section 3.9.2) and a situation analysis was conducted in the case study project.

Behavioural waste in terms of site workers

This study suggests that worker participation practices in the case study alliance project were a crossover between a traditional operating system and a lean operating system (Table 6.1). There is a partially integrative nature of worker participation in the alliance project. The management's view of worker participation practices was identified (section 7.3.2) and summarised below with five main constructs.

- Positive attitude towards relationship management practices
- Positive attitude towards knowledge management practices
- Moderate attitude towards reward and recognition practices
- Moderate attitude towards information sharing practices
- Negative attitude towards decision making/power distribution practices

The study identified the important practices and categorised them accordingly in Table 8.1. Evidence suggests that the case study project focused on top-down approaches and there was little focus on bottom-up approaches. The literature review shows that sustainable improvements in Lean are achieved via top-down and bottom-up approaches. In order to sustain process improvements, site workers' involvement in decision making is necessary. This study suggests integrating worker participation practices with the process improvement methodology developed by this study (Figure 8.2).

Table 8.1: Categorisation of important practices

Important practices	
Not implemented by the project	**Implemented at midpoint of the project**
Regular worker performance appraisal	Conduct social activities
Supervisors trained in people management skills	Formal appraisal system to assess training needs
Standard job related induction programme	

Behavioural waste related to sub-contractors

One of the important project participants is sub-contractors. Though sub–contractors were not commercially fully included in the particular alliance, the alliance considers sub-contractors as part of the alliance in every other way (according to INT3). The study observed the following on the case study project which provide evidence that the sub-contractors on the case study project are separated from the alliance project (more details in section 5.8, Table 6.9, and Table 6.11).

- Lack of involvement at the early stages of the construction project
- Lack of willingness to share knowledge and information
- Lack of assessment protocols to improve the sub-contractor base
- No specific framework for measuring performance
- Limited interest in improvements of sub-contracted processes

It is vital that the expertise of the key, first tier sub-contractors are integrated into the main alliance to ensure commitment throughout the project value chain. The study developed a framework for sub-contractor integration (sub-alliance team), which is consistent with the objectives of core alliances (Figure 8.3). The framework promotes the selection and formation of sub-alliance teams using similar criteria to those of the core alliance team.

Research question 2: How can lean thinking reduce the identified deficiencies in an alliance?

A vital step in the current research is the investigation of the applicability of Lean in improving alliance performance. This main research question is subdivided into three sub-questions. The first two sub-questions try to find out how to remove process and behavioural waste. The last sub-question determines the barriers and enablers to introducing lean concept in an alliance.

Sub-research question 2 (a): How can process waste be eliminated through lean thinking?

Improvement strategies developed from this study focus on eliminating process and behavioural waste. The objective of the sub-research question 1(a) was to develop a process improvement methodology (Figure 5.2). Furthermore, best practices for implementing the process improvement methodology were refined via five process studies. The following points conclude the findings related to question 2(a):

Improvements achieved during process studies

Five process studies were undertaken in the case study project and existing waste and their causes were determined. The implementation of process improvement methodology proposed by the researcher to management of the case study project brought positive results. Altogether, 124 improvement ideas were developed and improvements were predicted in required man-hours in the range of 9 to 30% with overall improvements of 16 % without increasing allocated resources (Table 5.11). Improvements were projected to improve the cycle time, labour utilisation and process efficiency by 12%, 16% and 14% respectively (Table 5.11). Follow-up studies identified that actual overall improvements achieved in cycle time, labour utilisation and process efficiency were 8%, 10%, and 8% respectively (Table 5.12). Inadequate attention to the suggestions made in certain processes resulted in not achieving the predicted results. Some of the factors that delayed the efforts for improving processes within the case study project include:

- low retention of site workers including site management (section 5.9)
- lack of reference to lessons-learnt registers (section 5.9)
- low level of awareness of the lean concept and its benefits (section 5.8)

- lack of recognition for process improvements initiated by site workers (section 6.2.1, table 6.1)
- lack of motivation for process improvements due to sub-contracting (section 5.8.1)
- fragmentated relationships between team members (section 5.8.1)

In all the processes studied, positive improvements on relevant measurements were obtained. Lean thinking helps to discover process waste in alliance project sites saving substantial amount of time. Lean can also be implemented in non-alliance projects. However, the collaborative and long term relationship culture in alliances is quite conducive to the application of lean principles resulting in greater output. This conclusion was reinforced by discussions with participants at follow-up meetings. Participants were satisfied with the improvement opportunities identified and suggested by the current study. Management's view of barriers in achieving the full potential of the process improvement methodology is discussed under the sub-research question 2 (c).

Proposed process improvement methodology

Since the process improvements mentioned in the thesis hinged around the researcher who was not a permanent staff member of the alliance case study organisation, an inbuilt mechanism at the site itself was required to sustain process improvements. The core of the continual improvement of processes is the application of improvement knowledge to daily work with the participation of site workers. It was identified in sub-research question 1(b) that there was a lack of worker participation and bottom-up approaches in the referred project. The study identified the failure of the suggestion system implemented to collect improvements ideas from workers. This study recommends the establishment of multifunctional work groups with reward/recognition schemes. The process improvement methodology used during the process studies was modified by adding another phase called 'recognition' (Figure 8.2).

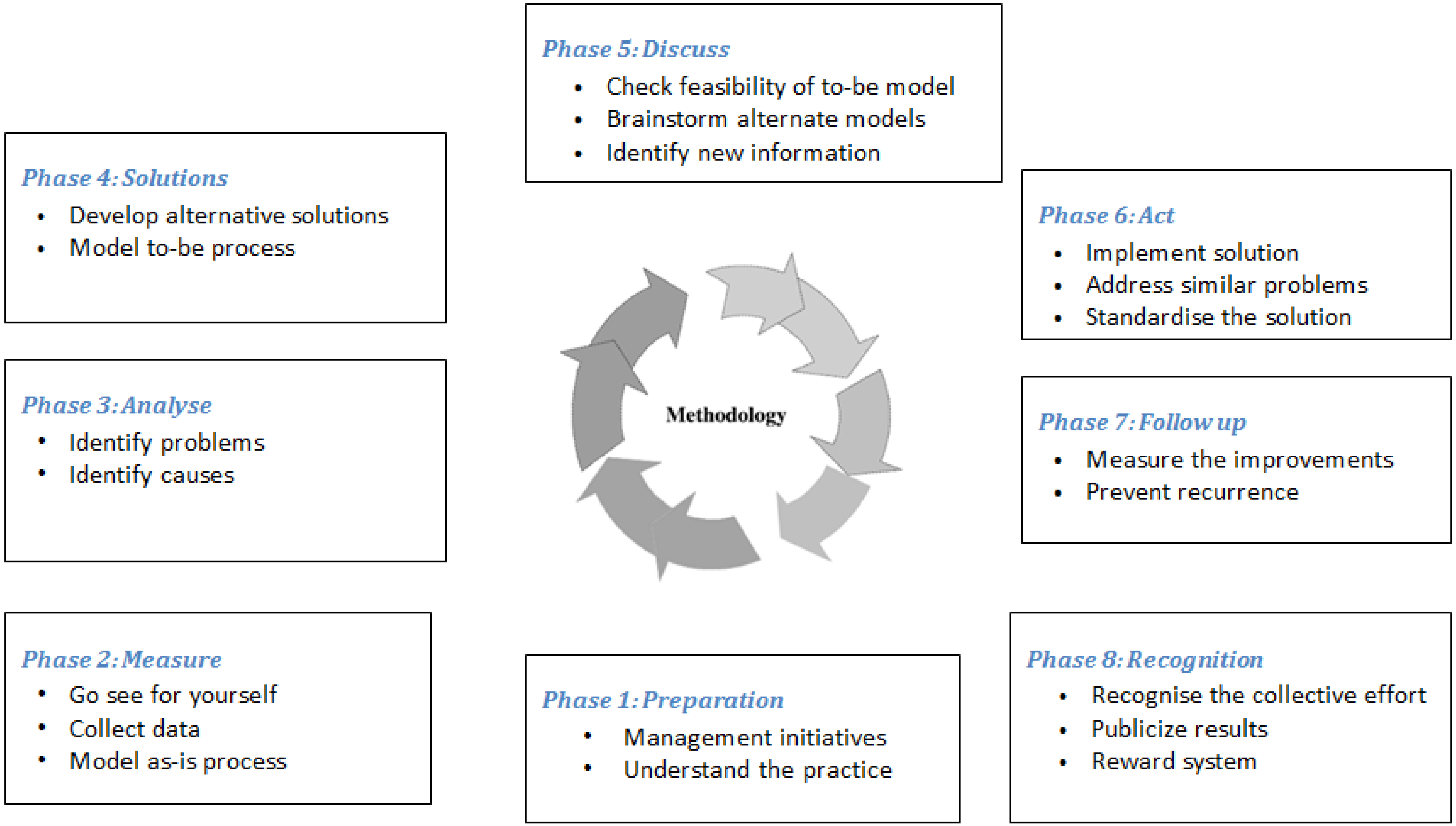


Figure 8.2: Process improvement methodology

Sub-research question 2 (b): How can behavioural waste be eliminated through lean thinking?

After the process improvement methodology (Figure 8.2) and related lean tools were implemented (as explained in section 5.3 and 5.6), the research came to the conclusion that the backbone for the implementation of Lean is active worker participation and sub-contractor integration in alliances. It can also be concluded that the involvement of site workers is necessary to achieve strong support as well as an understanding among personnel when developing and implementing new procedures. In sub-research question 2(a), worker participation is identified as a success factor of the process improvement methodology. Apart from that, other best practices of worker participation were identified through the interviews and the questionnaire with project management (section 6.2.2 and 6.2.3 respectively). In order to achieve the active participation of site workers in process improvements, the study found that the following issues need to be addressed in alliances.

- create site workers/teams based KPIs that are linked with the alliance project KPIs
- provide training in managerial/problem solving skills for foreman level
- encourage site workers to get involved in lessons-learnt workshops
- extend the performance appraisal system to worker level
- implement bottom-up practices at the early stage of the project and
- explain alliance principles to the worker level in the initial stage of the project.

The study provides evidence that certain waste activities were generated within alliance projects through the work undertaken by sub-contractors. Although efforts were made by the alliance to keep sub-contracting teams informed about alliance decisions, the study identified that better integration could be realised if they participated in key decisions from the beginning of alliance projects. As a result, sub-contractor integration into the main alliance framework was suggested (Figure 8.3). The following implementation steps offer a framework for developing the necessary tools to ensure its adoption.

Sub-contractor selection phase

Even though sub-contractors carried out large and critical work within the alliance project, the attention to sub-contractor selection was limited. Selection of the right sub-contractor contributes significantly to project performance. Therefore, this study suggests identifying potential sub-contractors during the alliance participant selection period with the help of potential main alliance members. This is the stage where previous relationships come into play and it is expected nominations will be on the basis of proven performance and demonstration of the capacity to contribute. The study identified the ad-hoc manner in which sub-contractors were introduced to the particular project, that there was no standardised procedure for sub-contractor selection and introduction to the project. The study found that the following practices need to be introduced in alliances.

- Identify sub-contracting work packages at an early stage (sub-contractor classification matrix)
- Select suitable procurement types for each identified work package (procurement strategy development matrix)
- Identify competency of sub-contractors introduced by alliance proponents (core competency matrix)
- Develop sub-contractor selection criteria through evaluation matrix
- Conduct value engineering workshops and request sub-contractors to provide their suggestions
- Arrange a site tour for sub-contractors before bidding
- Request sub-contractors bid for relevant work packages
- Select sub-contractors based on a sub-contractor evaluation matrix
- Debrief unsuccessful sub-contractors

Project team integration

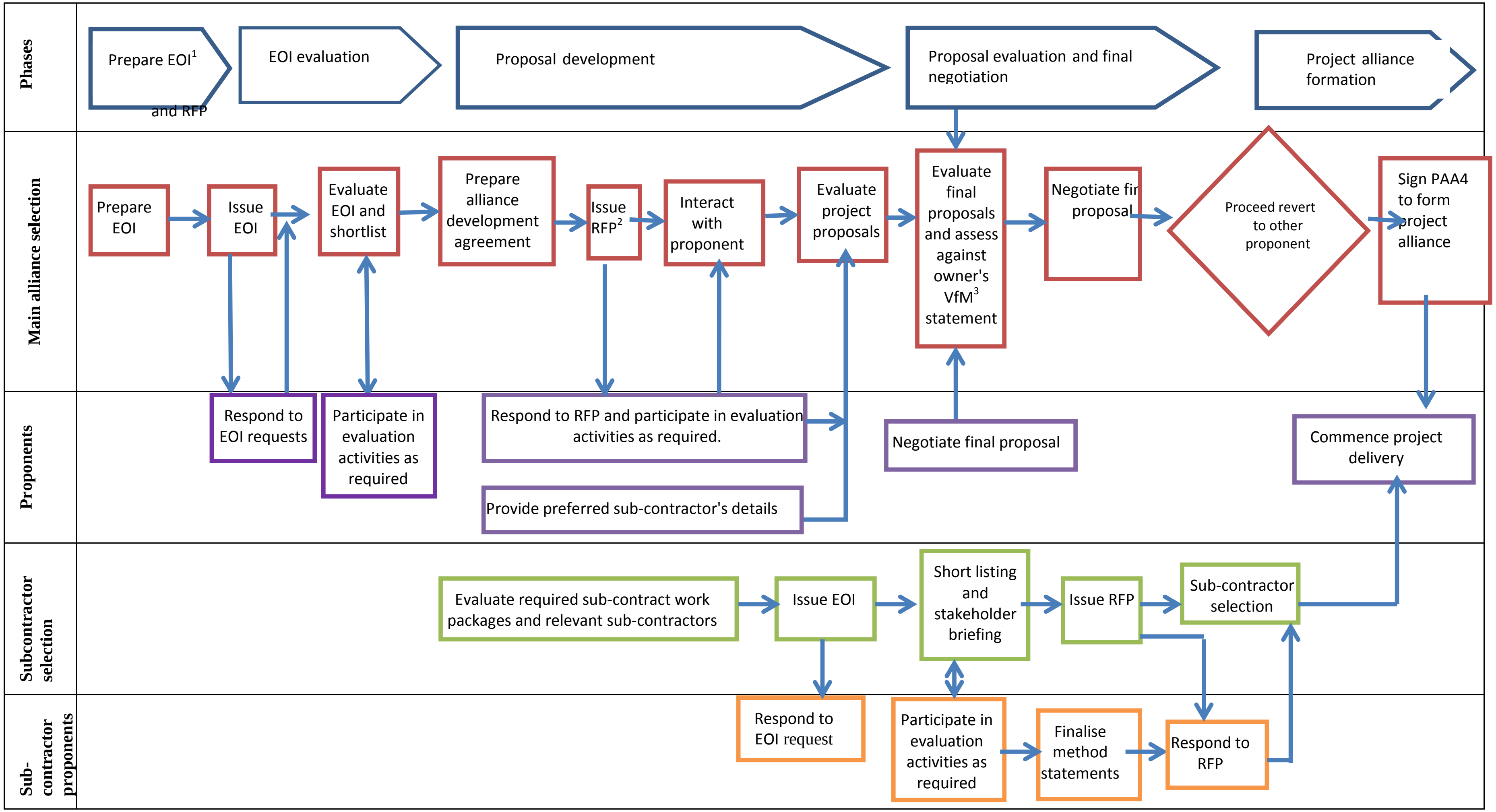
Dissemination of the alliance ‘one team’ culture among the wider project team (including sub-contractors) was identified as a vital practice for successful alliance. After selecting sub-contractors, all the alliance members and sub-alliance members should be invited to the sub-alliance initiative meeting. At the meeting, alliance members need to reconfirm their commitment to the project by presenting their responsibilities/objectives of the project and their appropriateness for the work. The final outcome of this activity is to develop a roles and responsibility matrix for all project participants. Although individual activities are the key responsibility of each participant, all members must ensure the progress of the project. The final agenda of the sub-alliance initiative is the signing of the sub-alliance agreements by relevant parties. Joint training programmes should be organised to meet the technical and managerial aspects of the project and to align these with the KPIs. Training programmes should be relevant to problems identified during performance evaluations and should enable participants to see things differently, do things differently and uncover potential. Inter-company training events should be conducted to exchange best practices during the project execution.

Performance evaluation

The current study recognised that there was no proper system to measure performance continuously and to provide feedback to sub-contractors in the case study project. Key alliance participants need to evaluate activities of sub-contractors on an on-going basis. Evaluation results can be used as references for future projects. Since the evaluation of sub-contractor performance requires a standard method, the appropriate measurements need to be identified as explained in Figure 6.5 of section 6.3.3. Furthermore, a main contractor who has a direct link with any sub-contractor could assess the performance of sub-contractors using an evaluation system. The main advantage of this evaluation system is that everyone is able to monitor their performance throughout the project. This performance feedback aids training development plans.

Immediately after the feedback, the sub-alliance team would be required to share information, discuss project plans and generate ideas. Consecutively, the relationship status monitoring could be used to assess alliance participants as perceived by other participants. A questionnaire could be distributed at monthly sub-contractor meetings where performance scores of other members are assigned and changes in the score may be openly discussed. Training programmes could be developed depending on the performance.

For technical issues, continuous improvement meetings could be conducted to analyse issues with the participants of the project.



Note: 1 EOI- Expression of interest 2 RFP- Request for proposal 3-VfM- Value for money 4 PAA- Project alliance agreement

Figure 8.3: Non-owner participant selection process

Source: (Vilasini et al., 2012)

Post project performance review meetings would be conducted with all alliance members to review value addition from the sub-contractors. The performance of each sub-contractor would be reviewed against set KPIs and strategic objectives which are agreed at the beginning of the project. At this meeting, the participants should actively discuss the opportunities for future alliances.

At the project completion stage, alliances should consolidate previous periodic evaluations and lessons-learnt in a central database. The study found that the following steps need to be introduced in alliances.

- Identify sub-contractor specific and important KPIs such as on-time deliveries, defect rates, and compliance with safety and environmental standards
- Implement a system that measures KPIs which allows comparison of the performance of all sub-contractors
- Conduct regular and event-driven reviews of sub-contractor performance
- Conduct sub-contractor association meetings
- Provide on-going feedback to sub-contractors on their performance level and
- Implement reward mechanisms for process improvements of sub-contractors

The last sub-research question seeks to identify enablers and barriers to implementing Lean in alliances and it also examines strategies employed to successfully remove barriers. It is noted that lean implementation in construction is believed to face vast difficulties as referred to by several scholars (e.g.: (Hook & Stehn, 2008a), (Dulaimi & Tanamas, 2001) and (Alinaitwe, 2009)) and participants of the follow-up meetings. Therefore, research question 2 (c) was formulated.

Sub-research question 2 (c): How does the alliance project environment facilitate a lean implementation?

Numerous process and people related challenges prevail in major infrastructure projects. The literature review identified the fact that traditional contracts do not facilitate the pursuit of lean principles, but relational forms of contracts are favourable ground for the lean application (section 3.5.3). A further comparison of Lean and alliance concepts shows that some aspects of lean thinking are already present in alliance projects and their application depends on the management culture (section 3.6). The review of alliance practices in the current project shows that certain practices elevate the project performance by adding value. These practices and their effects on waste are summarised below.

- Extension of the previous alliance project to a new alliance project: eliminates pre-alliance agreement period
- Open door policy: improves communication and teamwork
- Strong safety culture: reduces waiting and idling time
- Good focus on environmental management: eliminates shutdown time
- Co-location of the alliance parties: improves communication and teamwork
- Planning through look-ahead meetings: improves the project delivery and cost
- Involvement of community: eliminates shutdown time
- Good training and facilitation: improves the project delivery and quality
- Adoption of organisational and contractual arrangements: promotes collaborative working, early involvement and knowledge sharing
- Provision of incentives: improves collaborative working and project performance
- Involvement of client as part of governing body: improves faster decision making and ownership of the project and
- Keeping the project team focused and aware of project progress: improves communication and teamwork

In summary, the alliance follows the fundamental idea of lean principles, waste elimination by supporting the team-building process and rewards collaboration within the team. Alternatively, certain alliance practices that were hindering the case study project were identified and are summarised below:

- Variance in senior leadership standards: causes difficulty in developing and maintaining an alliance culture
- Insufficient information passed to lower tier participants: causes difficulty in developing team culture
- Exclusion of lower tier participants from alliance: causes difficulty in developing team culture

- Issues with alliance principles and objectives: at the midpoint of the project, the project identified the fact that the set alliance principles and objectives were more externally oriented and lack of focus on changing internal organisation. and
- Issues in KRAs: limited influence of the wider project team and complex system

Investing time and energy to achieve a truly united project team and to promote a constructive and high performance culture is critical to project success. Most of the interview participants admitted that the referred project did not put enough effort into those factors at the early stage. After changing the project leadership, particularly the alliance manager, more effort was put into establishing a high performance culture. These strategies need to be executed from the onset and actively managed over the lifespan of a project to ensure better project performance. The study investigated the management view on barriers hindering the introduction of process and behavioural waste reduction practices. The barriers were elicited from the literature review (section 3.7.6, 3.8.4 and 3.9.4) and feedback was taken in follow-up meetings. A questionnaire and interviews were used to prioritise those barriers. The study results gave some useful insights into the top priority barriers of an alliance project.

Methodology to reduce process waste

Main barriers to implementing the process improvement methodology were identified (section 5.10.6) as ‘difficult to change the behaviour of site workers’, ‘lack of leadership’ and ‘lack of education and training to drive the improvement process’. Additionally, barriers that are falling in the marginal area such as ‘lack of evaluation of the site management for process improvements’ and ‘lack of mechanism for improvement suggestions’ were also added to the top priority barriers. Alliance management is encouraged to use the following ways to overcome those barriers.

- Integrate top-down and bottom-up practices to improve worker participation in eliminating waste
- Develop a reward and recognition system to improve worker participation for eliminating waste
- Develop a KPI system to measure crew level performance

- Implement training programmes to improve problem solving and people management skills
- Encourage active participation of workers in worker participation forums such as pre-start meetings and one team sessions and
- Develop an evaluation mechanism for the site management to encourage improvements within their teams.

Methodology to reduce behavioural waste

Worker participation and sub-contractor integration are identified as critical conditions to sustain the process improvement methodology developed in section 5.3. Even though the site workers and the sub-contractors are influential participants, there are limitations in integrating them into an alliance.

The top priority barriers for worker participation practices in an alliance are: 'lack of leadership of top management', 'inability to overcome mind set', 'fear of decentralisation of power', 'little organisational commitment', 'personal agendas', 'lack of HR policies' and 'organisational politics'. In order to overcome these barriers construction firms need to:

- put effort into the selection of compatible project participants and the development of the alliance board particularly the alliance manager and
- achieve the full potential of the identified best practices by implementing them at the onset of a project.

The top priority barriers for integrating sub-contractors in an alliance are: 'more resources and senior management time', 'lack of capacity of sub-contractors', 'attitude issues of sub-contractors' and 'tight and uncertain schedule'. Therefore, this research recommends changes in the alliance process to integrate critical sub-contracting processes into the main alliance project. The sources of barriers provide useful guidelines to practitioners who wish to eliminate process waste and behavioural waste in an alliance project. Table 8.2 below provides a summary of key evidence and findings pertaining to the detailed research objectives.

Table 8.2: Summary of key evidence and findings

Chapter	Research step	Key evidence and findings
Two and three	To identify the current practices in an alliance and identify knowledge gap	- No defined operational framework in an alliance - Certain aspects of Lean are already in alliances and their application depends on the management culture
Five	- Identify the process waste in an alliance contract from a lean perspective - Eliminate process waste through lean implementation - Identify barriers in eliminating process waste	- Process waste is extensive at the site level - Procurement type alone is not sufficient for elimination of process waste at the site level - Use VSM with lean tools to detect and act on waste - Top priority barriers for process improvement : 'difficult to change behaviour of site workers',' lack of leadership', 'lack of education and training to drive the improvement process'
Six and seven	–Identify behavioural waste in an alliance from Lean perspective –Eliminate behavioural waste through Lean implementation –Identify barriers in eliminating behavioural waste	- Process waste are caused by behavioural waste - Little focus on bottom-up practices - Main barriers for worker participation: lack of leadership of top management, inability to overcome mind set, fear for decentralisation of power, little organisational commitment, personal agendas, lack of HR policies and organisational politics - Top priority barriers for sub-contractor integration: 'required more resources and senior management time', 'lack of capacity of sub-contractors', 'attitude issues of sub-contractors' and 'tight and uncertain schedule'

The main recommendations derived from this study are summarised in the next section.

8.3 RECOMMENDATIONS OF THE STUDY

Based on the results and conclusions, the current study makes recommendations to help improve the performance of alliance projects.

1. The current study identified that there is limited research conducted on measuring waste in heavy construction projects (Table 3.7) and similarly a lack of effort in waste control in a real alliance project. However, the existing process waste is high in alliancing and similar to other projects conducted under different procurement methods.The study recommends to:

- improve understanding of the process waste and its causes in alliance
- introduce alliance KPIs to improve the current operational process
- educate site management to focus more on flow activities rather than conversion activities
- integrate lessons-learnt workshops and pre-start meetings with higher site worker participation
- document generated ideas and the documentation system must eliminate the issues identified in the current lessons-learnt register (section 6.2.1)
- publicise the results of any process improvements in the weekly one team sessions and notice boards and
- reward those who are involved in implementing improvements

2. The study recommended two approaches for detecting waste at the construction sites.

   – ***Waste walks***

   The first approach is introducing 'waste walks' where site management walk daily through the site to observe waste. This should take place to find improvement opportunities while focusing mainly on flow activities. During the follow-up meetings, it was noted that there was little time available for such studies due to routine work. Hence, a second approach is proposed.

   – ***A dedicated unit/section***

   Since the site management can be overloaded and there can be a lack of formal knowledge in data collection and lean tools, it is beneficial to establish a dedicated unit to conduct process improvements. A similar approach was used in the manufacturing sector which is known as the 'continuous improvement team'. Such a team can follow the same methodology as in manufacturing to gain performance improvements.

3. Review of exsisting process improvement methodologies in section 3.7.5 identified that existing methodologies mainly deal with detection and correction of causes of waste in a process within a given set of main variables. They are not linked to radical changes while the governing variables rarely change. These approaches are 'single loop learning' cycles which are only concerned with technical solutions and

do not seem to emphasise the people side of its implementation, which could be useful for their sustainability. As a result, the current study developed and recommends the implementation of a process improvement methodology (Figure 8.2) with the following suggested improvements.

- integrate top-down and bottom-up practices to improve worker participation in eliminating waste
- develop a reward and recognition system to improve worker participation in eliminating waste
- develop a KPI system to measure crew level performance
- implement training programmes to improve problem solving and people management skills
- encourage the active participation of workers in worker participation forums such as pre-start meetings and one team sessions and
- develop an evaluation mechanism for the site management to encourage improvements within their teams.

4. Most of the past alliances particularly in NZ, consider only part of the value chain and therefore fewer studies are devoted to diffusing alliance principles and practices to sub-contractors and site workers (section 0). As a result, the study recommends integrating site workers and critical sub-contractors in alliance projects at an early stage by following the practices in section 7.3.2 and section 7.3.3 respectively.

5. The following recommendations are depicted in the study to enhance worker participation practices in the alliance project.
   - Ensure strong commitment and beliefs of the management in alliance principles and
   - Policy consistency of project practices (e.g. diffusion of alliance principles to the wider project team was not implemented at the project onset). Therefore the current study recommend to implement the identified best practices at the onset of a project to achieve the full potential of those practices.

6. The study identified the absence of a performance measurement system for sub-contractors. Subject matter experts who were involved in the validation interviews identified the importance of such a system (section 7.4). Consequently, a conceptual performance measurement system was developed (Figure 6.5). Periodic evaluation results can be displayed at the construction site as motivation for sub-contractors (Figure 8.4).

Sub-contractor	**Quality**	**Safety**	**Schedule**	**Cost**	**Competence**
Parapet finishing work	☺	☺	☹	☺	☺
Scaffolding	☹	☹	☺	😐	☺
Electrical	😐	☺	☺	☹	☺
Re-bar fabrication	☺	☺	☺	😐	☺
☺- Good performance		😐- Regular performance		☹- Bad performance	

Figure 8.4: Example of sub-contractor evaluation display at the site

7. Important recommendations related to sub-contractor integration process surfacing from this research are listed below.

- Initiate meeting for critical sub-contractors to discuss alliance behaviour
- Develop a statement of work for all sub-contractors. This statement should clearly identify their responsibilities and penalties for failing to meet these responsibilities
- Maintain clear channels of communication with sub-contractors
- Implement joint training programs/job evaluation schemes and
- Conduct coordination meetings with sub-contractor management (senior representatives from alliance and sub-contractors managements)

8. The current study was carried out to discover the feasibility of integrating Lean into alliance projects. In the literature review, it was identified that adherance to alliance principles throughout the project as a success factor requires an appropriate cultural shift in construction (section 0). Moreover, the selected case study shows missed opportunities, which are difficult to recover from, in the application of new alliance practices that were implemented in the middle of the project. Thus, the study recommends equipping the alliance management with the right alliance practices at the onset of the project and steering the right behaviour of the project team to obtain better project performance.

8.4 IMPLICATIONS OF THIS RESEARCH

This study is based on observations related to lean initiatives in the selected alliance project and it provides key recommendations emerging from the analysis to assist future alliance projects with lean deployments. As a result, the current study motivates practitioners to reap productivity gains through the lean concept which acts as an operational system in an alliance. Despite the study limitations highlighted in section 1.9, 4.8 and 5.10.7, this study provides important contributions to the existing practice and theory as explained in next two sub-sections.

8.4.1 Contributions to practice

This research contributes to organisational practice by providing an understanding of lean thinking in an alliance which could eliminates waste, sustains improvement ideas and supports further organisational developments. The alliance environment is expected to be a favourable ground for implementing lean principles as all parties share the benefits of such improvements.

This research assists the understanding of existing deficiencies in alliance practices while finding ways of removing such deficiencies particularly from a lean perspective. The study was able to develop methodologies and best practices to identify and eliminate waste streams in alliance projects. They are

- Waste activity classification system (Figure 5.4)
- Waste categorisation and waste cause system (Figure 8.1)
- Process improvement methodology to eliminate waste (Figure 8.2)
- Framework to integrate sub-contractors into an alliance (Figure 8.3)
- Best practices for worker participation (section 7.3.2) and sub-contractor management (section 7.3.3) in an alliance and
- Barriers associated with lean implementation in an alliance (section 3.7.6, 3.8.4, 5.10.6 and 6.2.3)

This study will eventually provide more confidence in lean initiatives in future alliances and will encourage future alliance projects to apply lean construction upon reviewing the benefits. The current study is significant to NZ since the lean concept is relatively new to the NZ construction industry. At completion of this study, other construction projects may use this lean implementation as a benchmark to improve performance. The current study is anticipated to be a framework or a benchmark for future studies in the academic field and for future alliance contract projects. In summary, this study advances the knowledge of alliance principles and its scope for improvements with a lean integration road map for alliance contracts.

8.4.2 Contributions to theory

This research covers a wide range of literature including alliance, Lean, sub-contractor management and worker participation practices in construction. This research particularly provides a systematic review of the body of knowledge of alliance and lean construction literature. Prior to this research, there was a limited systematic assessment of improvement opportunities in an alliance project site. This research has been able to present suggestions to address gaps in an alliance contract and the study also supports advancement in the lean construction research stream. The study contributes to theory in a number of ways as listed below.

- A comparison of different procurement methods shows that relational procurement methods provide a positive impact on profitability, time flexibility, risk and controllability but lead to a complex framework (Table Table 2.1).
- A comparison of relational procurement methods shows that there is no indication of a defined operating system mentioned in alliancing (Table Table 2.3).
- An analysis of alliancing literature identified that there has been more focus on organisational and contractual systems but little concern about the operational system (section 0).
- An analysis of alliancing literature also identified that there is an absence of coverage of lower tier participation (sub- contractor and site worker) (section 0).
- A comparison of operational methodologies shows Lean as a suitable methodology among the existing operational methodologies (Table 3.1).
- A review of lean construction found that there are no defined lean construction principles in the literature (section 3.5.2). The study developed a categorisation of lean construction principles (Figure 3.3).

- A comparison of lean principles and project delivery systems found that relational contracts have more correlation to lean principles than any other project delivery system (section 3.5.3, Table 3.4).
- An analysis in section 3.5.3 shows the necessity of a defined operational system in alliances and
- An analysis in section 3.6 shows that lean is a natural fit with alliance projects, but it also identifies principal distinctions between Lean and the alliance concept.

8.5 TOPICS FOR FUTURE RESEARCH

This research proves a successful approach of lean implementation for an alliance based project and overcomes the obstacles to lean implementation. However, this approach is far from final and perfect. Lean is a continuous journey. The study identified various areas where further research is required. Directions for future studies are divided into two areas, namely observations by the researcher and deductions from study limitations. These two areas are covered in the next sub-sections.

8.5.1 Observations by the researcher

Incentives under the ‘limb 3’ guarantee that each non-owner participant equitably shares the pain of wasted effort and rework paid in the ‘limb 1’ (Ross, 2003). The motivation to reduce rework in an alliance framework mainly depends on the relationship and the culture of the project. It is presumed that the alliance environment encourages the reduction of rework as it directly affects the final ‘limb 3’ amount.

In the case study project investigated rework was a major source of cost overruns in several processes. Lean concept has a lot to offer to the improvement of the quality at source through different techniques like mistake proofing and standardisation. A rework reduction procedure is a prerequisite for further alliance improvements and it will definitely pay benefits in any alliance. In future studies, the following questions could be answered to facilitate improvements of the current quality management system in alliance projects.

- What types of rework occur at construction sites and what are the causes and implications of such rework?

- What are the quality assessment tools used in alliance projects?
- What other quality assessment tools could be used in alliance projects?
- What are the barriers against implementing a quality at source program in alliance projects?

While past studies exist to support the success of alliances through establishing best practices for alliances, there are no in depth studies available to support the value for money position of an alliance. Hence, value for money remains the most controversial issue in alliances. It is suggested that the future study need to conduct a comparative analysis in terms of value for money between the alliance and other procurement models.

8.5.2 Deductions from the study limitations

The research presented in this thesis was based on a single case study and the research design limits generalizability. Future research into lean implementations in an alliance project should focus on elimination of those limitations by extending it to a multi-case study research. A framework to assist sub-contractor integration in alliance projects (Figure 8.3) was developed and presented in this thesis. Improvements could be expected if the framework is applied to further real case scenarios. Testing of this framework (Figure 8.3) could be readily undertaken in future work.

The target population for the interviews and the questionnaire were top and middle level management as they are responsible for directing workers and initiating changes in a project. Even though workers and sub-contractors are essential components of change, the present study focuses on behavioural waste issues from the management viewpoint. Consequently, the design of this research has a potential bias in the results. For unbiased results, it is necessary to examine the opinion of workers and sub-contractors as they are directly affected by the new practices. Future studies should consider taking their viewpoint as and when necessary.

Since the construction industry relied on traditional approaches of operating systems, it is hard to gain the required management commitment for implementing Lean. The reluctance to implement Lean arises due to the difficulty of envisaging the extent of realisable improvements through a lean implementation. In this study, improvements are predicted by evaluating the future state VSM, which was based on management acceptance of improvement suggestions, made during the study. However, simulation software could be used to quantify the improvement gains during the early planning and assessment stages. This enables management to compare the expected performance of the lean system with the existing system. Therefore, future studies could extend the lean application especially VSM with a simulation model to evaluate basic performance measures.

8.6 CHAPTER SUMMARY

This research study explored how lean thinking can be utilised in alliance projects to improve the alliance project performance. The study found that there is an immense potential to eliminate waste in an alliance project. This research suggests implementing a process improvement methodology as a daily practice as it will enable the site management and workers to deal with process control and improvements. Consequently, the study concludes that process improvements in an alliance project can be achieved by using several lean techniques and tools.

The study also revealed that process waste arises due to behavioural waste and is caused by poor integration of site workers and sub-contractors into an alliance. As a result, the study recommends several best practices in integrating site workers and sub-contractors into alliances in order to sustain the developed process improvement methodology. Furthermore, the study identified a list of barriers against integrating a process improvement methodology, implementing sub-contractor management practices and worker participation practices from a selected alliance project.

Finally, it is found that implementing lean concepts in an alliance acts as a catalyst to improve the operational system of the project resulting in performance improvements and greater satisfaction of project participants.

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APPENDICES

Appendix A: Glossary of terms

5 Why analysis	The problem solving technique used to dig for the root cause of a condition by asking *why* successively (at least five times) whenever a problem exists in order to get beyond the apparent symptoms. As each answer to the why question is documented, an additional inquiry is made concerning that response.
Behavioural waste	Losing improvements and learning opportunities by not engaging with or listening to project participants to eliminate the other seven wastes.
Cycle time	The time it takes a product or unit of work to go from beginning to completion of a production process; I.e., the time it is work-in-process
Cause- effect diagram or Fish bone diagram	The visual representation to clearly display the various factors affecting process
Worker participation	Rapid response to problems requires empowerment of workers. Continuous improvement is heavily dependent on day-to-day observation and motivation of the workforce, hence, the idea of quality circles. To avoid waste associated with division of labour, multi-skilled and/or self-directed teams are established for product/project/customer based production.
Gemba	The Japanese term for where value is added or the “work face.” Typically this is the shop or installation area.
Integrated project delivery (IPD)	A delivery system that seeks to align interests, objectives and practices, by reconceiving the organization, operating system and commercial terms governing the project. The primary team members would include the architect, key technical consultants as well as a general contractor and key specialty contractors. It creates an organization able to apply the principles and practices of the lean project delivery system.
Just-in-Time	A system for producing or delivering the right amount of parts or product at the time it is needed for production.
Kaizen	The Japanese word for continuous improvement. Kaizen has come to mean the philosophy of continuous improvement
Kanban	Japanese term meaning “a signboard.” A communication tool used in JIT production systems. The signal tells workers to pull parts or refill material to a certain quantity used in production
Last planner system (LPS)	A tool developed by the lean construction institute for applying Lean to project management. The Last Planner is the field supervisor who assigns work to the crews. The LPS shields the crews or project team from the variability associated with all projects. This allows the crew/team to deliver the project on time and at or below budget.
Lean construction	Lean construction is the continuous process of eliminating waste, meeting or exceeding all customer requirements, focusing on the entire value stream and pursuing perfection in the execution of a constructed project
Overall Equipment Effectiveness (OEE)	OEE is a "best practices" way to monitor and improve the efficiency of a Manufacturing processes (i.e. machines, manufacturing cells, assembly lines). It can also be used to

	discover and resolve bottlenecks or aid an organization in inexpensively tapping into an area that has excess capacity.
Plus/Delta review	A discussion done at the end of a meeting, project or event used to evaluate the session or activity. Two questions are asked and discussed: What worked or produced value during the session? What could we do different/ better next time to improve the process or outcome?
Poke yoke	A mistake-proofing method or device developed by Shigeo Shingo that is used to prevent an error or defect from happening or being passed on to the next operation.
Process waste	A process adds value by producing goods or providing a service that a customer will pay for. A process consumes resources and waste occurs when more resources are consumed than are necessary to produce the goods or provide the service that the customer actually wants. There are seven basic types of waste including: defects, waiting, transportation of goods, motion, inventory, overproduction, and unnecessary process steps.
Process mapping	Visual representation of a sequence of operations consisting of people, work duties and transactions that occur for the design and delivery of a product or service
Process owners	Person who has the ultimate responsibility for the performance of a process in realising its objectives measured by key process indicators, and has the authority and ability to make necessary changes.
Root cause analysis	A systematic method of analysing possible causes to determine the root cause of a problem. See also 5 Why Analysis.
Spaghetti diagram	A physical map of the work area that shows the path taken by the specific product or a person being observed. A line is drawn from start to end indicating the path moved by the product or person
Total quality management (TQM)	TQM is an approach for improving quality that involves all areas of an organisation with a focus on employee participation and customer satisfaction. TQM can involve a variety of quality control and improvement tools and emphasises a combination of managerial principles and statistical tools.
Value	What the customer is actually paying for the project to produce and install.
Value stream	Includes all the processes and activities used to design, produce and deliver the product or service to the customer
Value stream mapping	A diagram of every step involved in the material and information flows needed to bring a product from order to delivery.
Visual management (VM)	VM is an orientation toward visual control in production, quality and workplace organization. The goal is to render both the standard to be applied and a deviation from it as immediately recognizable by anyone.
Alliance	An agreement between two or more entities, which undertake to work cooperatively, on the basis of a sharing of project risk and reward, for achieving agreed outcomes based on principles of good faith and an open-book approach towards costs
Alliance leadership team (ALT)	The alliance leadership team consists of senior representation from each of the alliance participants. The team provides leadership, governance and oversight to the alliance. The overriding function of the ALT is to ensure that the alliance achieves its objectives and that the participants fulfil all their alliance obligations while also satisfying the corporate requirements and constraint of all alliance participants.
Alliance project	Day to day leadership and management of the project is the

manager	responsibility of an AMT headed by an alliance manager who is accountable for ensuring that the alliance meets or exceeds the agreed alliance objectives.
Alliance management team (AMT)	The AMT provides day to day leadership to the wider project team and managers the day to day activities of the alliance. Each member of the AMT and the wider team is appointed on the basis that they are the people best qualified to fulfil their role, not on the basis of which company employs them. The AMT consists with senior project personnel preferably people who are working full time on the project while it is preferable that each participant is represented on the AMT this should not take precedence over the principle that each role should be appointed on the best person for the job basis.
Early contractor involvement (ECI)	ECI is an approach to use the knowledge of the contractor/ sub-contractor during the design phase.
Expression of interest (EOI)	The allaince owner participants invites bidders who are technically and financially supplying various goods and services through EOI. This request doest not constitute a solicitation.
Gain/ pain share adjustment	Once performance targets have been agreed, the alliance participants assume collective ownership of the risks and responsibilities associated with delivery of the project, with equitable sharing of the 'pain' or 'gain' depending on how project outcomes compare with pre-agreed targets
Interim project alliance agreement	In the multiple TOC approach, the owner selects the two preferred proponents and negotiates separately with each agreed the commercial parameters for the alliance. The owner enters into an interim project alliance agreement with each group to develop separate TOCs and other performance targets.
Key performance indicator (KPI)	The alliance formulated alliance key performance indicators in the areas of cost, commercial risk, programme arrangement, quality within each KRA. After entering into the alliance agreement as part of the project development phase the owner and the non-owner participants need to develop detailed procedures for how these will be measured.
Key result area	For alliance projects the primary focus of the gain: pain arrangements will be on project cost, time and other KRA such as community and stake holder management, traffic management, social responsibilities, quality and legacy of the project. These KRAs drive outstanding behaviour in non-cost area of the project.
Non-owner participant (NOP)	Non owner participants include any service provider such as designers, constructors, specialist consultant and could also include an agency or government backed enterprise acting as a service provider rather than owner.
Project alliance	An agreement between two or more entities, which undertake to work cooperatively, on the basis of a sharing of project risk and reward, for achieving agreed outcomes based on principles of good faith and an open-book approach towards costs.
Project alliance agreement (PAA)	The owner select preferred proponent on the basis of the lowest or best TOC and some non-cost criteria and enter into PAA. PAA explains roles and responsibilities of alliance team, commercial arrangements and project management plan.
Alliance leadership team	The alliance leadership team consists of senior representatives from each of the alliance participants. The team provides leadership, governance and oversight to the alliance.
Target outturn cost	The TOC is a reasonable estimate (independently reviewed) of what it should take to deliver the aggred scope of work. The TOC is central to the allaince compensation model and the strategy for

	achiving and demonstrating value for money.
Value for money	Value for money is the core principle underpining in procurement system.Official buying goods and services need to be satisfied that the best possible outcome has been achieved taking into account all relevent costs and benefits over the whole of the procurement cycle.
Wider project team	All the employees including sub-contractors working on the project is known as wider project team. Each position in the wider project team has clear accountability for specific outcomes.
Limb1	100% of what Non owner participants expend directly on the project work including project specific overhead.
Limb 2	A fee to cover corporate overhead and profit
Limb 3	An equitable sharing between alliance participants of gain/pain depending on how actual outcomes compare with pre-agreed targets in cost and various non-cost key result areas

Appendix B: Categories of alliance publications

#	Author	Country	Purpose	Type (NE/E)*	C/O**	Publication type	Research type	Research method
1.	(Yeung, Chan, & Chan, 2007)	Hong Kong	Clearly distinguish amongst general prerequisites, hard (contractual) and soft (relationship-based)elements,	NE		Journal	Qualitative	Review
2.	(Baldwin, Thorpe, & Carter, 1999)	UK	The use of electronic information exchange in construction alliance projects	E	O	Journal	Quantitative	Survey
3.	(Cheng, Li, & Irani, 2004)	Hong Kong	A model supporting a long-term commitment in construction	E	C	Journal	Qualitative	Review
4.	(Ngowi, 2007)	Botswana	Investigated the factors considered by firms when selecting alliance partners and the influence of trustworthiness in deciding the governance structures of alliances	E	C	Journal	Quantitative	Survey
5.	(Holt, Love, & Li, 2000)	UK	How alliances can provide a `means of survival' for construction organisations	E	C	Journal	Qualitative	Review
6.	(Langfield-Smith, 2008)	Australia	Relations between transactional characteristics, trust and risk in the start-up phase of a collaborative alliance	E	C	Journal	Qualitative	Case study
7.	(Laan, Noorderhaven, Voordijk, & Dewulf, 2010)	Netherland	The establishment and maintenance of cooperative, trusting relationships in alliance projects between client and contractor	E	C	Journal	Qualitative	Case study
8.	(Hobbs & Andersen, 2001)	Canada	Identify best practice within different areas of management of alliance projects	E	C	Journal	Qualitative	Case study
9.	(Abrahams & Cullen, 1998)	Australia	General project alliances theory in the construction industry	NE		Trade press	Qualitative	Review
10.	(Wang & Yang, 2000)	Australia	Examine business development strategy and Australian construction industry	NE		Journal	Qualitative	Review
11.	(Yin, Wang, Yu, Ji, & Ni, 2009)	China	Application of DEA cross-evaluation model in project dynamic alliance subcontractors selection	NE		Conference	Quantitative	Simulation
12.	(Bresnen & Marshall, 2000a)	UK	Bridge the gap between existing research and useful practical recommendations by exploring the issues of partnerships in construction	E	O	Journal	Qualitative	Interview
13.	(Scheublin, 2001)	Netherland	To obtain a complete picture of the project alliance concept	E	C	Journal	Qualitative	Interview
14.	(Sweeney, 2009)	Australia	Why there is no uniform project delivery selection method	E	C	Thesis	Quantitative	Survey
15.	(Walker, 2002)	Australia	Enthusiasm, commitment and project alliancing in an Australian experience	E	C	Journal	Qualitative	Case study
16.	(Hauck, Walker, Hampson, & Peters, 2004)	Australia	Collaborative processes are reviewed and numerous examples of the management of a project are cited	E	C	Journal	Qualitative	Case study

17.	(Grynbaum, 2004)	Australia	General alliance introduction	NE		Trade press	Qualitative	Review
18.	(Ngowi & Pienaar, 2005)	Botswana	To determine the role of trust on the propensity to pursue the competition aspect of the alliance	E	C	Journal	Quantitative	Survey
19.	(Xu, Smith, & Bower, 2005)	China	Critical success factors for strategic alliances between foreign contractors and design institutes	E	C	Journal	Mixed	Case study, survey
20.	(Koolwijk, 2006)	Netherland and Australia	Alternative disputes resolution methods applied in three project alliances	E	C	Journal	Qualitative	Case study
21.	(Rowlinson, Cheung, Simons, & Rafferty, 2006)	Australia	Reports the critical factors identified that influence the success of an alliance project	E	C	Journal	Qualitative	Case study
22.	(Lingard, Brown, Bradley, Bailey, & Townsend, 2007)	Australia	The post-hoc evaluation of a compressed work week	E	O	Journal	Mixed	Case study
23.	(El Asmar, Hanna, & Chang, 2009)	USA	Lays out the framework that facilitates selecting the best alliance team for a project by quantifying the evaluation factors and combining them into a single score	E	C	Journal	Quantitative	Simulation
24.	(Schreiner, Kale, & Corsten, 2009)	USA	To conceptualise alliance management capability as a multidimensional construct	E	C	Journal	Quantitative	Survey
25.	(Rezgui & Miles, 2010)	Spain, UK Norway, Slovenia,	The concept of an SME alliance and its key features, business relationships management in an SME alliance, SME alliance viability and sustainability, the role of information and communication technologies in an alliance	E	O	Journal	Quantitative	Survey
26.	(Love, Mistry, & Davis, 2010)	Australia	The success factors for price competitive alliances during their relationship development phases	E	C	Journal	Qualitative	Interview
27.	(Faisol, 2010)	Malasia and UK	adaptability of the relational contracting norms in different cultural setting	E	O	Thesis	Qualitative	Interview
28.	(Love, Irani, & Edwards, 2004)	UK & Australia	Model to integrate design and production in construction	E	O	Journal	Qualitative	Interview
29.	(Huemer, 2004)	Norway	Addresses trust in an international construction project, focuses on when actors, participating in an international construction project, begin working according to a new contract	E	C	Journal	Qualitative	Case study
30.	(Cheung & Rowlingson, 2005)	Australia	Identify CSF of alliance case study	E	C	Conference	Qualitative	Case study
31.	(Jefferies, Brewer, Rowlinson, Cheung, & Satchell, 2006)	Australia	Presents a framework of project success factors and discusses a case study of a recent Australian project alliance	E	C	Conference	Qualitative	Case study

32.	(Hampson & Kwok, 1996)	Australia	Reviews the literature and describes an analysis framework comprising attributes of strategic alliances	E	C	Conference	Qualitative	Review
33.	(Noble & Record, 2007)	USA	General information of alliance and IPD	NE	-	Trade press	Qualitative	Review
34.	(Love, Edwards, Love, & Irani, 2011)	HK and Australia	Review risk/reward compensation model in infrastructure alliance projects	NE	--	Journal	Qualitative	Review
35.	(Le Masurier, 2006)	NZ	Justify alliance advantages	E	C	Conference	Qualitative	Case study
36.	(Hampson, Peters, & Walker, 2001)	Australia	To report research undertaken into the nature of ethical negotiation and its impact upon conflict resolution	E	C	Conference	Qualitative	Case study
37.	(Scott, 1995)	UK	Explain alliance principles through example case study	E	C	Journal	Qualitative	Case study
38.	(Briscoe & Dainty, 2005)	UK	To empirically investigate the problems encountered in trying to integrate supply chains in construction	E	C	Journal	Qualitative	Case study
39.	(Maqsood, Walker, & Finegan, 2007)	Australia	To develop a synergy between the approaches of knowledge management in a learning organisation and supply chain management	NE	-	Journal	Qualitative	Review
40.	(Walker & Loosemore, 2003)	Australia	How learning culture is obtained through systematic problem solving approach	E	O	Journal	Qualitative	Case study
41.	(Das & Kumar, 2010)	UK	To propose a framework for understanding inter-partner sense making in cross-national strategic alliances	NE	-	Journal	Qualitative	Review
42.	(Quick, 2002)	Australia	Introduction to alliancing and relationship contracting	NE	-	Conference	Qualitative	Review
43.	(Ingirige & Sexton, 2006)	UK	To prove that alliances in the construction industry can be used as vehicles to achieve sustainable competitive advantage	E	C	Journal	Qualitative	Case study
44.	(Lönngren, Rosenkranz, & Kolbe, 2010)	Germany	To address the management of supply chains within the construction industry.	E	C	Journal	Qualitative	Case study
45.	(Cardell & Johnson, 1999)	NM	Where alliancing was born and how it has developed.	NE	-	Trade press	Qualitative	Review
46.	(Chan, Chan, Lam, & Albert, 2011)	HK	To identify the party most preferred to take the risks associated with the Target Cost Contracts and Guaranteed Maximum Price Contracts	E	C	Journal	Quantitative	Survey
47.	(Walker, Hampson, & Peters, 2002)	Australia	Describes partnering concept, alliance concept and difference between the two concept	NE	-	Journal	Qualitative	Case study
48.	(Walker & Keniger, 2002)	Australia	Describe the quality measure used in a project and how these were monitored and used as a feedback mechanism to achieve project objective	E	O	Journal	Qualitative	Case study
49.	(Clifton & Duffield, 2006)	Australia	Explores management and governance of private finance initiatives/public private partnership projects via the integration of	E	C	Journal	Qualitative	Review

			alliance concepts into the typical concession agreements					
50.	(Walker & Johannes, 2003a)	HK	Focuses upon the motivation of JV partners and the way they design their behavioural responses in project organisations to meet challenges and achieve their goals	E	C	Journal	Quantitative	Survey
51.	(Halman & Braks, 1999)	Netherland	Principles, structure and culture of a project alliance as applied within the off shore Industry are described	E	C	Journal	Qualitative	Case study
52.	(Jefferies, Gameson, Chen & Elliot, 2006)	Australia	Identifying and exploring the elements that influence the performance of project alliances	E	C	Conference	Qualitative	Case study
53.	(Wu, Greenwood, & Steel, 2008)	UK	To identify a spectrum of attributes of collaborative working	NE		Conference	Qualitative	Review
54.	(Ngowi, 2001)	Botswana	Determines the influence of private activities on the performance of construction alliances	E	C	Journal	Quantitative	Survey
55.	(Van & Kamminga, 2006)	UK	Optimising contracting for alliances in infrastructure projects	NE	C	Journal	Qualitative	Review
56.	(Ross & PCI Alliance services, 2009)	Australia	Alliance contracting in Australia: a brief introduction	NE		Guideline	Qualitative	Review
57.	(Victorian Government, 2006)	Australia	Project alliancing practitioners' guide	NE		Guideline	Qualitative	Review
58.	(Davies, 2008)	Australia	Alliance contracts and public sector governance	E	C	PhD thesis	Qualitative	Interview
59.	(Wood, & Duffield, 2009)	Australia	A benchmarking study into alliancing in the Australian Public Sector	NE		Guideline	Qualitative	Review
60.	(Gadens Lawyers, 2000)	Australia	Review on alliance contracting.	NE		Trade press	Qualitative	Review
61.	(Lin, 2005)	NZ	Value for money in Grafton Gully alliance project	E	C	Report	Quantitative	Simulation
62.	(Department of Treasury and Finance, 2009)	Australia	Guideline for insurance in alliance contracting	NE		Guideline	Qualitative	Review
63.	(Australian Constructors Association, 1999)	Australia	Relationship contracting guideline	NE		Guideline	Qualitative	Review
64.	(Ross, 2007)	Australia	Review of advantages and disadvantages of alliancing	NE		Guideline	Qualitative	Review
65.	(Queensland Government Chief Procurement Office, 2008)	Australia	Relational procurement options - Alliance and early contractor Involvement contracts.	NE		Guideline	Qualitative	Review
66.	(Commonwealth of Australia, 2011)	Australia	National alliance contracting guidelines	NE		Guideline	Qualitative	Review
67.	(Ross, 2009)	Australia	Project Alliancing: learning from the Australian experience	NE		Conference	Qualitative	Review

68.	(Ross, 2003)	Australia	Introduction to project alliancing	NE		Conference	Qualitative	Review
69.	(Walker & Hampson, 2008b)	Australia	Discussion of project alliance member selection	NE		Book section	Qualitative	Case study
70.	(Miles,1998)	USA	Alliance Lean design/ construction on a small high tech project	E	O	Conference	Qualitative	Case study
71.	(Morwood, Scott, & Pitcher, (2008)	Australia	Alliancing a participant's guide	NE		Guideline	Qualitative	Review
72.	(Henneveld, 2006)	Canada	Alliance contracting	NE		Conference	Qualitative	Review
73.	(McIntyre, 2005)	Australia	Project alliance contracts harness commercial imperatives	NE		Conference	Qualitative	Review
74.	(Chen & Zhang, 2010)	Australia	A proposed research area in alliancing: cost management	NE		Conference	Qualitative	Review
75.	(Dainty, Briscoe, & Millett, 2001)	UK	Sub-contractor perspectives of supply chain alliances	E	O	Journal	Qualitative	Interview
76.	(Das, & Teng, 1998)	USA	Resource and risk management in the strategic alliance making process.	E	C	Journal	Qualitative	Review
77.	(Das., & Teng, 2001)	USA	A risk perception model of alliance structuring	E	C	Journal	Qualitative	Review
78.	(Green, 1995)	UK	Partnering and alliances: Theory and practice	E	C	Conference	Qualitative	Case study and interview
79.	(Henderson & Cuttler, 1999)	Australia	Description of North side storage tunnel project	E	O	Conference	Qualitative	Case study
80.	(Lacey, 2007)	Australia	Examine the law regarding the interpretation of a selection of issues that may affect an alliance agreement	E	C	Journal	Qualitative	Case study
81.	(Kumaraswamy,Rahman, Ling & Phng , 2005)	HK	Reconstructing cultures for relational contracting	E	C	Journal	Quantitative	Survey
82.	(Chew, 2004)	Australia	Alliancing in delivery of major infrastructure projects	E	C	Journal	Qualitative	Review
83.	(Ingirige & Sexton, 2006)	UK	to prove that alliances in the construction industry can be used as vehicles to achieve sustainable competitive advantage	E	C	Journal	Qualitative	Case study
84.		Australia	Discussion of formation of partnering and allaincing	NE	C	Book section	Qualitative	Review

Note: *Research stance: NE- Non empirical studies and E: Empirical studies

**Research focus: O: Operational related, C: Contractual related

Appendix C: Analysis of wasted time in past productivity studies

	Cited in	Publication type	Country	Data collection	Project type	Operation	VA	NVA	NVAU
1.	Bandyopadhyay and Smith (2004)	Conference	USA	Work sampling	Residential project	Exterior masonry and steel	41	35	24
					Commercial project	Reinforcing, and pouring concrete slab	46	30	24
2.	Lee et al. (1999)	Journal	India	Work sampling	Residential project	Rebar placement 6th floor	60.02	20.98	19.0
						7th floor wing a	71.27	17.10	11.63
						7th floor wing b,	61.75	18.82	19.43
						7th floor wing c	71.22	15.51	13.27
						Roof level wing a	68	17.7	14.3
						Roof level wing b	70.53	14.00	15.47
						Roof level wing c	70.08	15.48	14.44
3.	Garas et al. (2001)	Workshop report	USA	Work sampling	-		40		60
4.	Watson & Carillion, (2003)	Workshop report	USA	Work sampling	-	Steelwork	0.3		99.7
		Workshop report	USA	Work sampling	-	Concrete pouring	8		92
5.	Construction Excellence (2003)	Report	UK	Work observation	Commercial building	Day 2 – pipes & rods	38	27	35
						Day 1 – pipes & rods	55	25	20
						Day 2 – trays & trunking	42	43	15
						Day 1 – conduit	29	56	15
6.	Bhuiyan and Baghel (2005)	Report	USA	Work sampling	Residential project	Formwork remove	44	39	17
7.	Antony et al. (2012)	Journal	USA	Time study	Pre cast yard	Steel shop work	10		90
8.	Oprime et al. (2011)	Conference	USA	Time study	Commercial building	Steel erection	58	21	21
9.						Concreting	36	33	31
10.	Dubois and Gadde (2002)	Report	Canada	Work sampling	Oil and Gas projects	Commercial building site	53		47
11.	(Bessant & Caffyn, 1997)	Thesis	USA	Work sampling	Modular home builders	Module production	41	59	
12.	Oreg (2006)	Journal	USA	Work sampling and time study	Road construction	Asphalt paving	64	36	
13.	Morton (2002)	Report	USA	Work sampling	Bridge construction	Deck construction	59	41	
14.	Ma et al. (2011)	Report	Saudi Arabia	Work sampling	Commercial building	Slab on Grad Concreting o	37	18	45

15.	Kalsaas (2010)	Conference	Norway	Boss method (Secondary data)	Commercial building	Carpenters	19	33	38
						Concrete	49	43	18
16.	Josephson and Saukkoriipi (2007)	Report	Sweden	Observation	Building project	Plumbing			
17.	Bossink and Brouwers (1996)	Journal	USA	Work sampling	-	-	34	9	57
							40		60
							69		31
							45	22	33
18.	Diekmann, Krewedl, Balonick, Stewart, and Wonis (2005)	Report	USA	Work sampling and time study	Commercial building	Steel erection	24.89	21.9	53.2
							10 .54	35.45	54
							9.77	24.8	65.4
						Piping	10.43	21.4	68.7
							8.19	19.2	72.7
19.	Alarcón and Ortiz (1995)	Report	Chile	Work sampling	Multi-storey cast in-place reinforced concrete	Nonspecific construction operations			54.5
20.	Baxendale (1987)	Conference	UK	Work sampling	Housing development; retail; factory	Multiple construction operations			49.0
21.	Chan and Kumarasamy(1995)	Journal	Hong Kong	Work sampling;	Multi-storey cast in-place reinforced concrete	Tower cranes; concrete truck mixers			38.4
22.	Chan and Kumarasamy(1995)	Journal	Hong Kong	Work sampling	Multi-storey cast in-place reinforced concrete	Formwork rigging; bar-bending; steel-fixing; concreting			33.6
23.	Christian and Hachey(1995)	Journal	USA	Multiple	Multi-storey cast in-place reinforced concrete	Concrete worker			67.0
24.	Handa and Abdalla (1995)	Journal	Canada	Work sampling	Medium density housing development	Framing operation, carpentry			53.8
25.	Horner et al. (1989)	Conference	UK	Direct measurement	Supermarkets; car park; water treatment	Concrete; formwork brickwork; activities steel reinforcement;			19.8
26.	Liou and Borcherding (1999)	Journal	USA	Work sampling	Nuclear power plant; fossil fuel power plant	Concreting			59.3
27.	Logcher and Collins(1986)	Journal	USA	Direct observation	Medium density buildings; new and renovated	Carpentry; tile laying activities			63.9

28.	Low and Chan(1978)	Book	Singapore	Direct observation	Multi-storey public housing apartments	Concreting activities	49.2
29.	Low and Chana(1997)	Book	Singapore	Direct observation	Multi-storey condominium tower blocks	Insulation laying; bricklaying activities	49.9
30.	Oglesby et al. (1997)	Book	USA	Work sampling	Multiple project types	Multiple construction trades	44.4
31.	Oglesby et al. (1989)	Book	USA	Continuous time lapse	Multi-storey cast in-place reinforced concrete	Concreting crew	39.4
32.	Olomolaiye et al. (1989)	Journal	Nigeria	Work sampling	Varied	Bricklaying, joinery; steel fixing activities	38.7
33.	Olomolaiye (1987)	Published report	UK	Work sampling	Varied	Bricklaying; joinery; steel fixing activities	30.8
34.	Parker et al. (1996)	Conference	Tanzania	Work sampling	Medium-density housing	Multiple construction trades	62.3
35.	Peer and North(1987)	Journal	Australia	Continuous time lapse	Multi-storey office building; institutional; supermarket housing	Multiple construction operations	52.6
36.	Peer and North(1971)	Report			Multi-storey office building institutional; supermarket; housing;	Multiple types of equipment	55.4
37.	Salim and Bernold (1994)	Journal	USA	Work sampling	Mid-height multi-storey office building	Concrete reinforcement activities	40.4
38.	Serpell et al(1995)	Conference	Chile	Work sampling	Commercial buildings	Multiple construction activities	71.6
39.	Stevens (1987)	Conference	UK	Work sampling	Medium and high density housing	Multiple construction operations	58.8
40.	Rogge and Tucker (1982)	Journal	USA	Work sampling	Nuclear power plant	Carpenters; electricians; ironworkers; pipefitters	67.7
41.	Thomas(1991)	Journal	USA	Work sampling	Nuclear power plant	Carpenters; electricians; pipefitters	54.5
42.	Thomas(1991)	Journal	USA	Work sampling	Nuclear power plant	Pipefitters	49.0
43.	Thomas(1991)	Journal	USA	Work sampling	Nuclear power plant	Nonspecific construction operations	38.4

Appendix D: Worker participation practices – chronological Source (Doody, 2007)

Publication \ Practices	Teams/teamwork	Job rotation	Social activities	Problem solving	Conflict resolution	TQM/quality circles	Participative decision	Information Sharing	Suggestion systems	Selection processes	skill based reward	Performance appraisal	Initial training	Mulit-skill training	On-going training	Hiring (from within)	Opinion surveys	Promotion rules	Feedback on goals	Low status barriers
Lawler III (1986)	-	-	√	√	-	-	-	-	-	√	√	-	-	-	√	-	-	√	√	-
Ledford & Mohrman (1993)	-	-	√	√	-	-	√	-	-	√	√	-	-	-	√	-	-	-	-	-
Osterman (1994)	√	√	-	-	-	√	-	-	-	-	-	-	-	-		-	-	-	-	-
Macduffie (1995)	√	√	-	√	-	√	-	-	√	√	√	-	√	-	√	-	-	-	-	√
Huselid (1995)	-	√	-		-	-	-	√	-	√	√	√	-	-	√	√	√	√	-	-
Pil et al. (1996)	√	√		√	-	√		-	-	-	-	-	-	-	-	-	-	-	-	-
Fenton-O'Creevy (1998)	√	-	√	√	-	√	√	√	√	-	-	-	-	-	-	-	-	-	-	-
Gollan & Davis (1999)	√	√	√	- -	-	√	√	√	√	-	-	√	√	√	√	-	-	-	-	√
Vanderberg et al.(1999)	-	-	√	√	-	-	√	√	-	-	√	-	-	√	√	-	-	-	-	-
Sanchez et al. (1999)	√	√	√	-	-	-	√	-	-	√	√	√	√	√	-	-	-	-	-	-
Ramsay et al.(2000)	√			√		√	√	√	√	√	√	√	√	√	√	√	-	-	-	-
Whitfield (2000)	√	√		√			√	√			√	-	-	√	-	-	-	-	-	-
Freeman & Kleiner (2000)	√	-	-	-	-	√	√	√	√	-	-	-	-	-	-	-	√	-	-	-
Lloyd (2000)	√	-	-	-	-	-	-	√	√	-	-	√	√	√	-	-	-	-	-	√
Godard et al. (2000)	√	-	√	√	-	-	-	-	-	√	√	-	√	-	-	-	-	-	-	-
Cappelli & Neumark (2001)	√	-	-	-	√	√	-	-	-	-	-	-	-	√	√	-	-	-	-	-
Guthie (2001)	√	-	√	-	-	√	-	-	-	-	-	-	√	√	√	-	-	-	-	-
Bacon & Blyton (2001)	√	-	-	-	-	√	√	- -	√	-	-	-	-	-	-	-	-	-	-	√
Edwards & Wright (2001)	√	-	-	√	-	√	-	√	√	-	-	-	-	√	√	-	-	-	-	-
Guthie et al. (2002)	√	√	-	-	-	√	-	-	-	-	-	-	-	-	-	-	√	-	-	-
Way (2002)	√	√	-	-	-	√	-	√	√	√	-	-	-	√	√	-	√	-	-	-
Kaufman (2003)	√	- -	-	-	-	√	√	√	-	√	-	-	-	-	-	-	-	-	-	-
Guy (2003)	-	√	√	-	√	√	√	-	-	-	-	-	-	√	-	-	√	-	-	-
White et al. (2003)	√	-	-	-	-	√	√	-	-	-	√	√	-		√	-	-	-	-	-
Ordiz-Fuertes et al. (2003)	√	-	-	-	-	√		√	-	-	√	-	√	√	√	-	-	-	-	√
Carvariella (2003)	√	√	√	√	-	-	√	√	√	-	√	-	√	√	√	-	-	-	-	-
Felsted & Gallie (2004)	√	-	-	√	-	-	√	√	√	-	-	-	-	-	-	-	-	-	-	-
Long & Shields (2005)	√	√	√	-	-	-	√	√	√	-	√	-	-	√	√	-	-	-	-	√
Gollan (2005)	√	√	√	-	-	-	√	√	√	-	-	√	- -	√	-	-	-	-	-	√
Konrad (2005)	√	-	-	√	-	√	√	-	-	√	-	-	√	√	-	-	-	-	-	-
Richards (2006)	√	-	√	-	-	√	√	√	√	-	√	-	-	-	√	-	-	-	-	√
Scotti et al. (2007)	√	-	√	-	-		√	√	√	-		-	-	-	√	-	-	-	√	-

Key √ ***Relevant*** – - ***Irrelevant***

Appendix E: Web based questionnaire surveys

Strategic Initiatives in Alliance Contracts

1. General information

Alliance contracts encourage reducing cost and time. However the full potential of project performance is not always achieved through alliance contracts. The following survey is designed to evaluate the alliance culture and identify possible areas for improvement.

This survey is conducted among middle level management within the "Newmarket Viaduct Replacement" project. You are identified as someone who can provide valuable input into this research. Completion of this questionnaire is considered as indicating your consent to participate.

All responses will be held anonymous. The data will be used only for my PhD research. The raw data will be seen only by myself and my primary supervisor. Once the research is completed the data will be deleted. This survey has a total of 17 questions and should only take 30-40 minutes to complete. This questionnaire consists of 5 sections.

Part A - Process improvement initiatives
Part B - Employee participative culture
Part C - Sub-contractor management practices
Part D - Improvements in alliance projects
Part E - Background information

In order to progress through this survey, please use the following navigation links:

Click the Next >> button to continue to the next page.
Click the Previous >> button to return to the previous page.
Click the Exit the Survey >> button if you need to exit the survey early.
Click the Done >> button to submit your survey.

The survey is open for three weeks. Within this time if you need any further information or clarification, please feel free to contact me or the my supervisor via the contact details given below. A follow-up reminder will be sent one week prior to closing of the survey.

Thank you in advance for taking time to complete this research survey.

Researcher contact details:

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Strategic Initiatives in Alliance Contracts

2. Part A - Process improvement initiatives

Process improvement initiatives systematically seek to achieve changes in processes in order to improve efficiency and quality. This part of the questionnaire survey has been designed to identify the process improvement initiatives ir alliance projects.

Select the extent of the following features of process improvements hapenning during the project.

1. How do you determine the process improvement opportunity? (mark all relevant fields)

- ☐ Discussing with peers
- ☐ From variation of expected outcome (Time, cost, quality, safety)
- ☐ From worker suggestions
- ☐ Through periodic site visits
- ☐ From complaints made by other stakeholders (eg. Suppliers, community)
- ☐ Through lesson learned workshops

Other (Specify here)

____

2. Select the objectives of the process improvements taken in your project. (mark all relevant fields)

- ☐ Eliminate the duplication of handling materials
- ☐ Minimise travel distances – from store-room to the place of use
- ☐ Minimise the storage of materials
- ☐ Provide a uniform flow of materials and equipment
- ☐ Provide controls to eliminate material wastage, breakage and theft
- ☐ Provide a safe work environment
- ☐ Maintain tools and equipment for zero downtime
- ☐ Develop crews with multi-craft capabilities
- ☐ Minimise redundant inspections
- ☐ Break the chain of repeated rework
- ☐ Other (specify here)

____

Strategic Initiatives in Alliance Contracts

3. Identify the most common way that you make a decision on process improvement.

- You solve the problem or make the decision yourself using the information available to you at the present time.
- You obtain any necessary information from team members and then decide on the solution to the problem yourself.
- You share the problem with the relevant team members individually and get individual suggestions. Then you make the decision.
- You share the problem with your team members and obtain their suggestions. Then, you make the decision.
- You share the problem with your team members. Then generate, evaluate alternatives and attempt to reach agreement on a solution.

4. Identify the involvement frequency of the following groups in the process improvements.

	Very rare	Rare	Sometimes	Often	Very often
Site worker					
Sub-contractor/supplier					
Supervisor/ Foreman					
Site engineer					
Project engineer					
Alliance leadership team					

5. Select the level of the influence of the following factors on the success of in process improvement initatives and the difficulty of overcoming these factors.

	Strength of influence	Level of difficulty
High work load and project pressure		
Difficult to change behaviour and attitude		
Schedule and cost being the main priorities		
Lack of perceived need for improvements		
Lack of incentives to encourage process improvements		
Lack of mechanisms for operational improvement suggestions		
Lack of evaluations of the middle management based on improvement effort		
Lack of education and training to drive the improvement process		
Tendency for temporary solutions rather than addressing the root cause of a problem		
Other (rate here)		

Other (specify here)

Strategic Initiatives in Alliance Contracts

3. Part B - Enhancing employee participative culture

Encouraging employee participation could be conceived as a strategy for improving alliance performance. This part of the questionnaire is designed to identify the employee participation culture of an alliance project.

6. Select the relative importance assigned in this alliance project for each of the following factors.If particular practice is not available mark it as "NA" in the scale.

(NA- Not available, 1 - Not at all important, 2 - Slightly important, 3 - Moderately important, 4 - Very important, 5 - Extremely important)

	NA	1	2	3	4	5
Treat the entire workforce as equals	○	○	○	○	○	○
Conduct social activities	○	○	○	○	○	○
Conduct relationship workshops	○	○	○	○	○	○
Formal appraisal system to assess training needs	○	○	○	○	○	○
Supervisors/ team in charge trained in people management skills	○	○	○	○	○	○
Site workers have the job training opportunities	○	○	○	○	○	○
Regular site workers performance appraisal	○	○	○	○	○	○
Site workers receive performance related rewards	○	○	○	○	○	○
Site workers receive performance related recognitions	○	○	○	○	○	○
Management gives project performance information to employees (Eg.one team session)	○	○	○	○	○	○
Standard job related induction programme other than safety	○	○	○	○	○	○
Opinion survey of employees by third party	○	○	○	○	○	○
"Feedback box" to make suggestions for improving work methods	○	○	○	○	○	○
Worker involvement in lesson learned workshops	○	○	○	○	○	○
Requests for employees' ideas and input on upcoming changes	○	○	○	○	○	○
Other (rate here)	○	○	○	○	○	○

Other (specify here)

7. It was realised that there had been an unsuccessful feedback box/ feedback form system in this project. Select causes for the failure (mark all relevant fields).

- ☐ Lack of management interest
- ☐ Lack of employee interest
- ☐ Slow or no response to the suggestions
- ☐ Unclear suggestion making and evaluation procedure
- ☐ Lack of publicity and promotions of the system
- ☐ Lack of followup
- ☐ Lack of reward and recognition
- ☐ Other (specify here)

8. Select the level of the influence of the following factors on the success of the employee participation initiatives and the difficulty of overcoming these obstacles.

	Strength of influence	Level of difficulty
Inability to overcome mind set		
Short-term nature of employee contract		
Lack of leadership of top management		
Pressure of routine work		
Lack of trust between workers and management		
Lack of communication between workers and management		
Lack of confidence in employee participation programme		
Lack of training on participative management culture		
Special interest groups (Eg.Union)		
Difficult to measure individual performance		
Short term nature of projects		
Organizational politics		
Personal agendas		
Little organisational commitment		
Fear for decentralisation of power		
Lack of HR policies		
Other (rate here)		

Other (specify here)

Strategic Initiatives in Alliance Contracts

4. Part C - Improving sub-contractor management practices

Sub-contractors play an important role with regard to the success of a project. This part of the questionnaire survey has been designed to evaluate the current performance of sub-contractors.

9. Rate the importance and satisfaction level of sub contractor's performance in your process (es).

	Importance	Satisfaction
Quality of workmanship		
Technical competence		
Timeliness of performance		
Accuracy and completeness of documentation		
Labour force coordination		
General site management practices		
Conformance to safety program		
Conformance to the project budget		
Flexibility for changes		
Level of innovation		
Cooperation and coordination with other trades		
Overall craft productivity		
Adherence to environmental programe		
Housekeeping at the site		
Effective communication		
Decision making in field activities		
Periodic onsite evaluation		
Adherence to project alliance decisions		
Other (rate here)		

Other (specify here)

Strategic Initiatives in Alliance Contracts

10. Improving sub-contractor performance could be viewed as a strategy for improving alliance performance. How important are each of the following factors in sub-contractor management.

If particular practice is not available in this project mark it as "NA" in the scale.

(NA - Not available, 1 - Not at all important, 2 - Slightly important, 3 - Moderately important, 4 - Very important, 5 - Extremely important)

	NA	1	2	3	4	5
Long term relationship	○	○	○	○	○	○
Mutual trust	○	○	○	○	○	○
Frequent communication	○	○	○	○	○	○
Collaborative culture	○	○	○	○	○	○
Consistent objectives	○	○	○	○	○	○
Win-win attitude	○	○	○	○	○	○
Risk-reward sharing	○	○	○	○	○	○
Regular performance monitoring	○	○	○	○	○	○
Early contract involvement	○	○	○	○	○	○
Defined responsibilities	○	○	○	○	○	○
Selection criteria other than price	○	○	○	○	○	○
Knowledge of supplier capabilities	○	○	○	○	○	○
Information transparency	○	○	○	○	○	○
Training and development by alliance	○	○	○	○	○	○
Opinion survey	○	○	○	○	○	○
Other (rate here)	○	○	○	○	○	○

Other (please specify)

Strategic Initiatives in Alliance Contracts

5. Part D - Views on improvement initiatives in an alliance contract

How strongly do you agree that the following techniques in each initiative would improve the overall project performance?

11. Techniques for incremental process improvement initiative:

	Completely disagree	Disagree	Neither agree nor disagree	Agree	Completely agree
Frequent site visits made by top/middle managers to see the actual process					
Identify process wastes (unnecessary motion, rework, idle of workers etc)					
Evaluate possible ways to reduce waste activities					
Analyse the root cause of the waste activities					
Share the findings of process improvements with the other process owners					

12. Techniques for employee participation initiative:

	Completely disagree	Disagree	Neither agree nor disagree	Agree	Completely agree
Use a feedback box/ feedback form system					
Worker involvement in lesson learned workshops					
Discuss process improvements at pre-start meeting					
Worker involvement in process improvement studies					
Rewarding mechanism for suggestions made by workers					

13. Techniques for sub-contractor management initiative

	Completely disagree	Disagree	Neither agree nor disagree	Agree	Completely agree
Involvement of sub-contractors at the early stage of alliance					
Include the waste reduction plan as a contractual agreement					
Implement a sub-contractor specific KPI system					
Sub-contractor involvement in process improvement initiatives					
Rewarding mechanism for process improvements made by sub-contractors					

14. What are the "missed opportunities" which may accrued further benefits for the project and participants? (mark all relevant fields)

- ☐ Strategies to encourage continuous process improvements
- ☐ Continuous improvements not fully encouraged among workers
- ☐ Continuous improvements not fully implemented among sub- contractors
- ☐ Key participants were not included as sub-alliance
- ☐ Unstructured approach to acknowledge the process improvement effort
- ☐ Higher number of alliance participants leads to operational level difficulties
- ☐ Higher number of key results areas (KRAs)
- ☐ Complexity of the key performance indicators (KPIs)

Other (specify here)

Strategic Initiatives in Alliance Contracts

6. Part E - Background information

15. Your job title (Optional):

- ○ Project engineer
- ○ Site engineer
- ○ Supervisor
- ○ Foreman

Other (please specify)

16. The average number of years of experience:

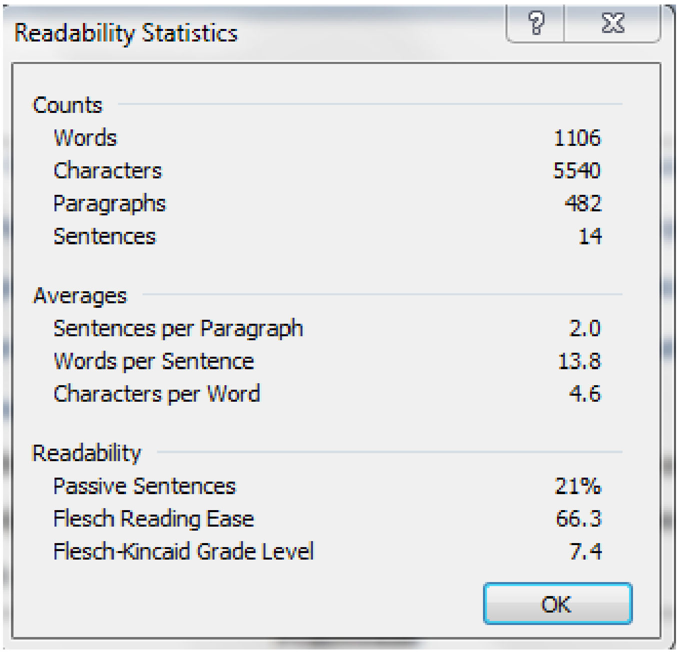
	Less than 5 years	More than 5 but less than 10 years	More than 10 but less than 15 years	Over 15 years
In the construction industry	○	○	○	○
In alliance projects	○	○	○	○

17. Are there any insights or information you would like to share on improvement opportunities in an alliance contracts?

End of questionnaire

You have now reached the end of the survey. Thank you very much for taking time to complete this questionnaire. If you have any queries, please do not hesitate to contact me by phone or mail. If you would like to have a copy of my final analysis or have any comments / suggestions, please drop me an e-mail and I will respond ASAP. Thanks again.

Appendix F: Readability test for the questionnaire



Appendix G: Feedback for the questionnaire at pilot study

Strategic Initiatives in Alliance Contracts

On a final note I would like to consider the following points and add your comments in the following box.

Is the wording of the survey clear? If not which ones?

Feel comfortable answering the questions?

Do any of the items require the respondent to think too long or hard before responding?

Do you think there were too many questions?

Which items produce irritation, embarrassment, or confusion?

Any other important issues been overlooked?

Do you have any other comments or suggestions for improvement?

Time taken to fill the questionnaire (min)

Appendix H: Participant information sheet for interviews

Participant Information Sheet

AUT UNIVERSITY TE WĀNANGA ARONUI O TAMAKI MAKAU RAU

Top Management Interviews

Date Information Sheet Produced: 2011-08-25

Project Title

Generating Value in Alliance Projects through Productivity Improvement

An Invitation

My name is Nimesha Vilasini, and I am a doctoral student in Construction Management, through the School of Engineering, at Auckland University of Technology. My PhD research is in the area of Lean construction in alliance projects. I have no employment, consulting, governance or other business relation with the Newmarket Viaduct project. You are cordially invited to participate in this research because your contributions could be helpful for performance improvement in the construction industry. Your participation is entirely voluntary. You can refuse to participate, and decline to answer any questions at any time without any penalty or adverse consequences to you.

What is the purpose of this research?

This study reviews the causes for factors those hinder the performance of alliance projects from a Lean construction perspective. Lean construction principles assist to minimise waste of materials, time, and effort in order to generate the maximum possible value for the construction project. This research is for the researcher's doctoral studies and will result in a thesis, journal articles and conference presentations. Your name or any identifiable references to you will not be included.

How was I identified and why am I being invited to participate in this research?

You have been invited to participate because you are a top manager who has knowledge and experience of alliance projects and Lean construction principles. Your name has been passed on to me by your company as someone who may wish to participate. I am only seeking to interview 5 participants so no one will know if you are participating or not.

What will happen in this research?

I will invite you to participate in an interview with me in which I will ask you a set of questions related to current practices in alliances. This interview will be at a pre-agreed place convenient to you. It will be audio recorded and then transcribed. I will bring the transcript back to you so that you can remove anything that you do not wish to disclose. The data will be analysed by using content analysis techniques. The collected data will be used in the development phase of the conceptual model of the study.

What are the discomforts and risks?

You may experience some discomfort about raising any deficiencies in an alliance project. However everything you say will be treated with the highest of confidence. There is a small risk of being able to be identified in the final report but all possible steps will be taken to protect your anonymity. The final report will contain only de-identified aggregated data to assure the commercial sensitivity .

How will these discomforts and risks be alleviated?

Participation is voluntary. You can refuse to participate at any time without any penalty, and you can also refuse to answer any questions at any time. There is a very remote possibility of traceability of participants in the final report. Only a fraction of participants out of a large number of project employees will be selected for the purpose of this research. The final list of participants for the study will be kept confidential and the management does not know who has been invited to participate in the interviews. A draft of the interview report based on digital voice recordings and notes taken will be given to you to check for factual errors. Furthermore, you can remove any information from the transcript if you wish to do so. If you experience any emotional issue or other discomfort, you will be able to use the AUT online counselling service, if you consider it necessary.

What are the benefits?

The research findings would be helpful to develop a comprehensive Lean integration road map for alliance contracts and to improve the performance of the construction industry. The knowledge could also be applicable to other countries who are engaged in alliance contracts. This study will advance the knowledge of alliances and Lean construction principles. Your contribution will also contribute to the completion of my PhD thesis

How will my privacy be protected?

This research does not seek to gather personal information of participants. Your identity will be known only to the researcher and to the supervising professor Thomas Neitzert. The final list of participants of the study will be kept confidential and the management including my industry supervisor, Alan Powell will not know who has been invited to participate in the interviews. Your identity will be kept confidential. The following practices will be followed to ensure the confidentiality of the collected data.

- All the interviews will be conducted off-site and in a convenient place for you
- You will have the opportunity to review the transcript of your interview and remove any data that you do not wish to be included
- The alliance management including the industry supevior will have no access to any of the raw data or the participant's identity

- Study codes will be assigned for each participant prior to collecting data. The interview notes labelled by using these study codes rather than of recording identifying information.
- Data documents will be securely stored in locked locations.
- The recorded interview tapes with assigned security codes will be stored in the supervising professor's office for six years and then will be destroyed permanently.
- The hardcopies of interview notes will be destroyed permanently immediately after the data analysis stage.

What are the costs for participating in this research?

The only cost associated with your participation is the time involved and it is about 1 hour which will be covered by the alliance.

What opportunity do I have to consider this invitation?

If you would like to take part in this study could you please e-mail me within two weeks of receiving this invitation. Please do remember that your participation is voluntary. If you need further information or clarification of any aspects of the project, please contact the researcher or the researcher's supervisor. Contact details are given below.

How do I agree to participate in this research?

You will be able to agree to participate by signing the consent form which is provided to you with this information sheet.

Will I receive a feedback on the results of this research?

Yes. The researcher will distribute the final thesis report to the case study organisation.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the project supervisor, Prof. Thomas Neitzert.

Concerns regarding the conduct of the research should be notified to the Executive Secretary, AUTEC, Madeline Banda, madeline.banda@aut.ac.nz, telephone 921 9999

Whom do I contact for further information about this research?

Researcher Contact Details:

Nimesha Vilasini, Room 311, Construction Management, WS Building, School of Engineering, Auckland University of Technology, telephone 09 921 9999, ext- 6635 e-mail:nimesha.vilasini@aut.ac.nz. Or nimeshav@yahoo.com

Project Supervisor Contact Details:

Prof. Thomas Neitzert, Room 310, WS Building, School of Engineering, Auckland University of Technology, E-mail: thomas.neitzert@aut.ac.nz , telephone 09 921 9258.

Approved by the Auckland University of Technology Ethics Committee on 11 October 2011 *was granted*, AUTEC Reference number *11/126*.

Appendix I: Participant information sheet for questionnaire

Participant Information Sheet

Questionnaire

Date Information Sheet Produced: 2011-08-25

Project Title

Generating Value in Alliance Projects through Productivity Improvement

An Invitation

My name is Nimesha Vilasini, and I am a doctoral student in Construction Management, in the School of Engineering, at Auckland University of Technology. My PhD research is in the area of Lean implementation in alliance projects. I have no employment, consulting, governance or other business relation with the Newmarket Viaduct project. I would like to invite you to take part in this anonymous online survey. Your participation is entirely voluntary and you can choose to withdraw at any time up until submitting the survey electronically.

What is the purpose of this research?

This study reviews the causes for factors that hinder the optimum performance of alliance projects from a Lean construction perspective. Lean construction principles assist to minimise waste of materials, time and effort in order to generate the maximum possible value for construction projects. This research is for researcher's doctoral studies and will result in a thesis, journal articles and conference presentations.

How was I identified and why am I being invited to participate in this research?

I like to get the views of all employees below the top management level and above the worker level with regard to quality, sub-contractor performance and employee participation. I am therefore inviting you to participate as you are a member of one of these groups. You are invited to participate in this questionnaire since you are a potential contributor to this research. Your details have been obtained from the employee list of the Newmarket viaduct replacement project.

What will happen in this research?

If you choose to participate, you are invited to complete an anonymous online survey (SurveyMonkey) via a link provided. There are three sections in the questionnaire. Once the information has been collected, data will be analysed using descriptive statistics. You can choose to withdraw at any time up until submitting the survey. Completing and submitting the survey will be considered as consent.

What are the discomforts and risks?

There are no anticipated risks to completing the anonymous survey. The survey itself blocks the IP address of users and the results will be aggregated so that no individual will be able to be identified. There is no possibility of tracing participants in the final report. The final report will contain only de-identified aggregated data to assure the commercial sensitivity.

How will these discomforts and risks be alleviated?

You can decline to answer any question at any time and can withdraw at any time up until submitting the survey. There are no anticipated risks to completing the anonymous survey.

What are the benefits?

The research findings would be helpful to develop a comprehensive Lean integration road map for alliance contracts and to improve the performance of the construction industry. The knowledge could also be applicable to other countries who are engaged in alliance contracts. This study will advance the knowledge of alliances and Lean construction principles. Your contribution will also contribute to the completion of my PhD thesis.

How will my privacy be protected?

This research does not seek to gather personal information from participants. You will remain anonymous to the researchers and will not be able to be identified in any way through your responses.

What are the costs of participating in this research?

You will not receive any financial compensation for your participation nor will you incur any cost in monetary value as a result of your participation in this research. The only cost associated with your participation is the time involved and it is about maximum of 20 minutes.

What opportunity do I have to consider this invitation?

You are invited to respond and the survey link will be available to you for two weeks. If you wish to participate, you only need to click on the link and start completing the survey. Please do remember that your participation is voluntary. If you need further information or clarification in any aspect of the project, please contact the researcher or the researcher's supervisor. Contact details are given below.

How do I agree to participate in this research?

If you participate in the on-line survey tool, this will be deemed as consent.

Will I receive a feedback on the results of this research?

Yes. The final thesis report will be presented to the case study organisation and participating groups in the study. The summary of the research findings will be published in the www. constructionproductivity.org.nz website.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the project supervisor, Prof. Thomas Neitzert, thomas.neitzert@aut.ac.nz, telephone +64 9 921 9258.Concerns regarding the conduct of the research should be notified to the Executive Secretary, AUTEC, Madeline Banda, madeline.banda@aut.ac.nz, telephone 921 9999 ext 8044.

Whom do I contact for further information about this research?

Researcher Contact Details:

Nimesha Vilasini, Room 311, Construction Management, WS Building, School of Engineering, Auckland University of Technology, telephone 09 921 9999, ext- 6635 e-mail: nimesha.vilasini@aut.ac.nz. Or nimeshav@yahoo.com

Project Supervisor Contact Details:

Prof. Thomas Neitzert, Room 310, WS Building, School of Engineering, Auckland University of Technology, E-mail: thomas.neitzert@aut.ac.nz , telephone: +64 9 921 9258.

Approved by the Auckland University of Technology Ethics Committee on *11 October 2011*, AUTEC Reference number *11/126*.

Appendix J : Data collection sequence of the study

Work element	2010	2011	2012
Process study-A			
Process study B			
Process study C			
Process study D			
Process Study E			
Process study A follow up			
Process study B follow up			
Process study C follow up			
Process study D follow up			
Process study E follow up			
Interviews			
Questionnaire Pilot			
Questionnaire			
Validation Interviews			

Appendix K: Pre mapping data collection

Section- Rebar fabrication process Interviewee- In charge of rebar fabrication

Date-18/02/2010

Customer Data

- Who is the customer? *Mould /Production section*
- What is the actual customer demand/day? *2 cages/day (depends on pouring efficiency, but not a pull system)*
- What is the product mix? *No flexibility to define product mix, already informed by programme (schedule)*
- How often is a customer order received? *Weekly update programme received from Site engineer, include next 1 month production schedule*
- Do they provide a forecast? *Weekly update programme received from Site engineer, include next 1 month production schedule*
- How often do you deliver to the customer? *2 cages /day, Example If steel delivered on 1 st, cage is ready on 3 rd and lift to mould on 9 th*

Supplier data

- Who is the supplier? *Steel provided by Fletcher's steel factory, concrete blocks provided by site engineer*
  Fletcher steel factory situated in Otahuhu, 20 min drive from PCCY. Communicated through e-mail and phones
- How often do you order? *No placement of order*
- Do you provide a forecast? *Site engineer already send weekly updated monthly programme to Fletcher steel factory , According to that they delivered raw materials*
  How often does the supplier deliver? *Daily 1 truck, Occasionally 2 trucks/ day (30% probable)*

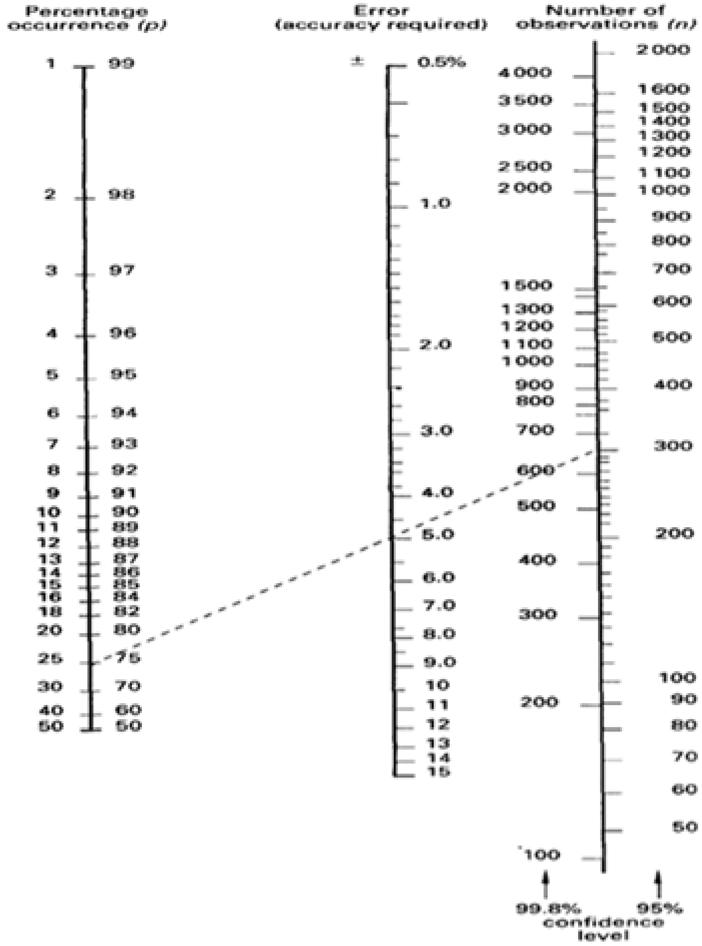
Value Stream Data

- How many shifts are worked with in this section? What hours are these shifts? *2 shifts , 7.00 am- 5.30 pm and 1.30pm to 11.30 pm*
  How many breaks and for how long? *Per shift 2 breaks each 30 min long*
- Do manual processes stop during the breaks? *yes*
- Are there any pre or post shift meetings and for how long? *Avg 2 blocks- 10 min each*
- Is there cLean up time scheduled during the shift and for how long? *Not scheduled, after end of cage production cLeaning is done, 10 min long*

Value Stream Control Data

- Who, what controls the production? *Site engineer*
- What are the documents used in your department? *Green folder provided by site engineer, programme, workers updates*
- Workers specialization identified? *No all workers equally skilled*
- How many production facilities available? Is it over/ under capacity? *4, not over capacity*
- Mistakes /errors identified at inspections? *Cannot spot specific error*
- HR requirement for products-
  Pier- 2 days= 5 workers 2 days*9 hrs = 90 hrs*
  Normal segment- 1 day=5 workers 1day* 9 hrs=45 hrs*
  Deviator segment=1.5 days=5 workers 1.5day* 9 hrs=68 hrs*

Appendix L: Nomogram for determining number of observations

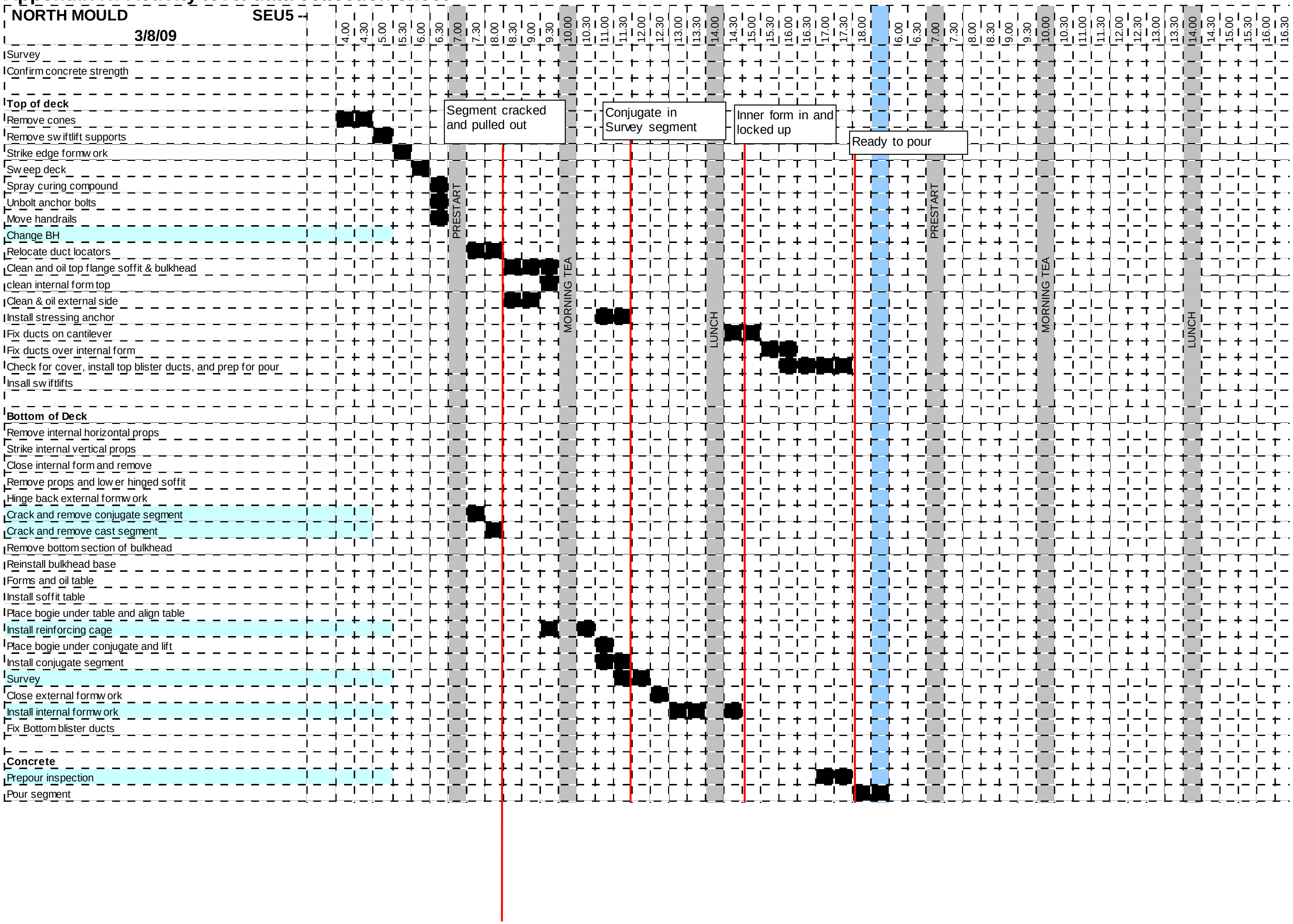


Appendix M: Time observation sheet

Time Observation Sheet	*Takt* time		Observer		Leader Review (initial)
Operation Name		Product Name / #		Observation Date	

Step #	Step Description	Observation Point	**Observation Number** *(Stopwatch time above dash, task time below)*										Avg Time	Low Time	Adjust-ment	Step Time
			1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***				
1																
2																
3																
4																
5																
6																
7																
8																
9																
10																
11																
12																
		Observed Cycle Time											SW Cycle Time			

Appendix N: Activity level data collection sheet



Appendix O: Waste record form

Waste Recording Form

Page 1 of 1

Process Observed:	Parapet & temporary barrier construction
Start Point:	
End Point:	
Observer:	Nimesha
Observation Date:	

		Category of Waste							Priority			Expected Ease to Correct		
Process Step (Name or #)	**Description of Waste**	Defects	Overprocessing	Transportation	Motion	Waiting	Inventory	Overproduction	High	Medium	Low	Easy	Medium	Hard
All	Transportation of material & equipment													
temporary barrier construction	Transportation of concrete for temporary barrier construction													
Finishing	Seam deconstruction													
Before placing formwork	Al plate cutting													
Rebar installation	Rework on tie bar													
Rebar installation	Inserting dummey bar													
Remove formwork	High waiting time due to concrete settling time													
All	Searching material													
All	Set up material													
All	Late arrival & early departure													
All	Difficulty in locating equipment													
All	Switch on generator continously													

Appendix P: Standard work combination sheet

Standard Work Combination Sheet				Operation Name	Temporary barrier construction	Product Name / #	South bound construction
Takt Time		Units/ Shift	Day	Work Group	Auckland Formwork	Operator	_____ of _____
Cycle Time		Time					

Manual	Automatic	Walking	Waiting
————	– – – – –	~~~~~~	═════

Step #	Step Description	Manual	Auto	Walk	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	0
	cleaning the floor																							
	Talking																							
	Clean timber plate																							
	attach pef packing materail																							
	inspection																							
	Clean timber plate																							
	place on barrier																							
	walking																							
	attach pef packing materail																							
	place timber plate																							
	fixing timber plate																							
	bring timber &cut																							
	fixing timber plate																							
	tighting timber plate																							
	apply glue																							
	search material																							
	insert timber wedges																							
	Clean timber plate																							
	apply glue																							
	attach pef packing material																							
	cleanning																							
	search material																							
	clean timber plate																							
	attach pef packing materail																							
	search material																							
	attach pef packing material																							
	walking																							

Appendix Q: Plus Delta sheet for process study B

Plus/Delta Sheet

+	Δ
Identify the things that are working first	*opportunities for improvement*
* TEAM COMPOSITION * LIFT PLAN & TECHNIQUES * USE OF A PRECAST ½ BARREL SHELL * PRECAST SUPPLIERS PROVIDE GOOD QUALITY PRODUCTS (MOST OF THE TIME) * SHIFT SEPARATION AND THE COMPOSITION OF THE WORK ON EACH SHIFT. * GENERAL METHODOLOGY FOR INSTALLATION & CASTING * SETOUT & SURVEY * ALIGNMENT TECHNIQUE * USE OF STANDARDISED STEEL SHUTTERS AND TEMPORARY WORKS * PRE-PAINTING BARRIERS PRIOR TO DELIVERY.	* POSSIBLE PRE-PLANNING OF REINFORCEMENT STARTER BAR LOCATIONS * USE OF PORTABLE STORAGE SYSTEMS ON SITE TO PREVENT EXCESSIVE TRAVEL * GREATER EMPHASIS / PLANNING ON DELIVERY & STORAGE LOCATIONS * PROVIDE ACCESS TO THE DECK CLOSER TO THE WORK FRONT * PROVIDE MORE SITE LEADERSHIP THROUGH THE PROVISION OF MORE EXPERIENCED LEADING HANDS. * BREAK OUT / SCABBLE JOINTS ASAP AFTER CASTING WHILST CONCRETE IS STILL GREEN * INVEST TIME TO PLAN SITE LAYOUT. * MAKE IMPROVEMENTS TO BARRIER PRE-CASTING TO AVOID RE-WORK ON SITE. * INTERFERENCE FROM OTHER SITE ACTIVITIES CAUSED DELAY, BETTER CONTROL / MORE REALISTIC TARGET DATES WOULD HELP THIS.

Appendix R: Explanation of variability matrix

The variability was examined based on available company data and through discussions with site management of the process studies.

Table E: Variability level scores for five processes

Process study	Demand variability	Processing variability				Route variability				Task variability
		Cycle time	Job of operator	Process standardization	Average	Number of routes	Interaction between routes	Frequency of route changes	Average	
A	3.0	3.0	3.0	3.0	3.0	3.0	2.0	3.0	2.7	5.7
B	2.0	4.0	2.0	3.0	3.0	2.0	2.0	2.0	2.0	5.0
C	2.0	3.0	2.0	2.0	2.3	2.0	2.0	2.0	2.0	4.3
D	3.0	2.0	2.0	3.0	2.3	2.0	2.0	2.0	2.0	4.3
E	2.0	4.0	3.0	3.0	3.3	3.0	3.0	2.0	2.7	6.0

Table F: Variability level scores Source (Redmond et al., 2011)

Score	1	2	3	4
Classification of demand variability				
Product mix variation	Low: less than 10%.	Medium low: 10% to 50%.	Medium high: 50% to 100%.	High: more than 100%
Classification of processing variability				
Work content (cycle time)	Difference between products less than 5%.	Difference between products 5% to 30%	Difference between products 30% to 50%.	Difference between products more than 50%.
Job of operator (tasks performed and in-process sequence)	Mostly the same (even when dealing with different products)	Somewhat different (1 or 2 operations change or are skipped)	Different (some operations and/or their sequence change)	Very different (most operations and/or their sequence change
Products repeat	Product offering is very limited and there is no customization. All products repeat and operators can easily become familiar with them.	Product offering is limited with very minor customization possible. All products repeat (a few may have minor changes), but some are made infrequently.	Wider product offering with some customization possible The majority of products repeat.	High customization, with the majority of products being made only once
Classification of route variability				
Number of routes	One route.	Few routes (2 or 3 max).	Some routes (about 10 or less).	Many routes
Interaction between routes	Zero interactions.	Low interaction (only material handling is shared).	Some interaction (1 or 2 processes shared).	High interaction (many processes shared).
Frequency of route changes	Steady routes (very few changes, once every few years if at all)	Mostly steady routes (few changes).	Frequently changing routes.	Constantly changing routes.

Appendix S: Improvement suggestions for process study B-E

Process study B

Pre - cast element installation – before inspection						
Objective	Recommendation	Management response			Comment made by management	Action taken by management
		Accept	Partially accept	Reject		
Reduce waiting time	Prior preparation at site before parapet delivery	√	-	-	Always advised to site management	Discuss during pre-start meeting
	arrange another temporary storage area middle of the bridge	-	√	-	An extra cost	Relocate the stores as job progress
	bring necessary, routine material/tool in advance	-	√	-	-	Prepare a checklist and distribute among workers
	Assign material and tool set up job responsibility to foreman	-	-	√	Always use the lowest paid member for material handling work	-
Reduce motion time	Provide movable cart to transport necessary equipment and material	√	-	-	Already provided but damaged	Use a cart or platform truck for material handling
Reduce transportation	Directly install parapet	-	-	√	Cannot wait long time due to traffic issues	unload parapet as close as to final location
Improve worker availability	Provide transport to work site(vertical lift)	-	-	√	An extra cost	-
	Provide sanitary facilities closer to work centre	√	-	-	Need to consider other crews requirements	Relocate the sanitary facilities as job progress
	Provide smokerooms closer to work centres	-	-	√	Rejected by ALT due to environmental issues	-
Pre - cast **element installation – After inspection**						
Reduce rework	Brackets need to be modified	√	-	-	-	Communicate with design team

	Eliminate defects of pre-cast segments	-	-	√	Already notified to PCCY management	-
	Create standard procedure to be followed by all workers	-	√	-	Absenteeism and labour turnover is a major issue	-
Improve communication	Conduct effective pre-start meeting	√	-	-	Only discuss safety issues	Communicate to charge in hand level
Parapet formwork installation						
Reduce waiting time	Effective communication system for crane booking	√	-	-	-	Implement log book system to shared resources
	Develop backlog activity list for workers	-	√	-	It is depend on the work package and supervisor	-
Eliminate material searching	Worksite standardisation (5S implementation)	√	-	-	Always encourage workers to organised the worksite	Provide tool box boxes.
Concrete pour						
Reduce waiting time	Defined interval between concrete mixers	-	-	√	Due to uncontrollable factors	-
	Provide backlog work to the site workers	√	-	-	-	Visually present week ahead programme
Reduce rework	Encourage self-successive checks	√	-	-	-	Increase supervision for unskilled workers and summarise method statements
	Provide standard operational procedure chart					
Improve safety	Good lighting condition	√	-	-		Provide extra lighting

Process C

Objective	Recommendation	Management response			Comment made by management	Action taken by management
		Accept	Partially accept	Reject		
Wire saw cut operation						
‘Reduce rework	Ensure complete cut	√	-	-	-	Add this as an item in the work handover checklist
	Aware the block arrangement in the trailer	√	-	-	-	Put identification mark to the blocks
Reduce waiting time	On time arrival of crane	√	-	-	-	-
	Eliminate above rework incidents	√	-	-	-	-
Improve communication	On time arrival of trailer	√	-	-	This issue is not a frequent one	-
Column piece load out						
Reduce rework	Ensure complete cut	√	-	-	-	Add this as an item in the work handover checklist
	Aware the block arrangement in the trailer	√	-	-	-	Put identification mark to the blocks
Reduce waiting time	On time arrival of crane	√	-	-	-	-
	Eliminate above rework incidents	√	-	-	-	-
Improve communication	On time arrival of trailer	√	-	-	This issue is not a frequent one	-
Platform removal						
Reduce waiting time	Extra yellow tapes	√	-	-	-	-
	Allocate other work to spotter at the fence Safety sign board near the fence	-	√	-	Due to safety requirement when crane is operating the watchman allocated near the fence	Implement safety sign board and supervisor is assigned at the gate

Eliminate unnecessary motion	Ensure all the screws are uptight before signalling to lift	√	-	-	-	-
	Eliminate searching for material	√	-	-	-	Proper toolbox arrangement
Remove transverse bracket						
Reduce waiting time	Closer supervision and empowered charge in hands	-	√	-	Supervisors are advised to be at the site	-
	Preventive maintenance of machinery	√	-	-	Not only to this activity	Pre-check machinery condition
Core drilling						
Reduce set up time	Tube extension at the initial stage	-	-	√	This was tried but cause delay in early stage	-
Reduce waiting time and extra processing time due to machine failure	Follow the machine specification in speed, coolant volume/pressure and drill life	√				Provide training to workers on drilling
	Introduce machine design improvements	√				Use “Water swivel adapter” to run high pressure of coolant
	Visual management boards at elevated working platform to ensure workers are well equipped	√	-	-	-	-
Remove temporary props						
Waiting time	Proper maintenance of machinery	-	√	-	-	Implement pre-start checklist for all machinery
Unnecessary motion	Visual management boards at elevated working platform to ensure workers are well equipped	√	-	-	-	-
Platform installation						
Reduce set up time	Bring necessary materiel	√	-	-		-
Reduce waiting time	Visual management boards at elevated working platform to ensure workers are well equipped	√				
	Prior notice to crane					

Process D

Stressing operation						
Objective	Recommendation	Management response			Comment made by the management	Action taken by management
		Accept	Partially accept	Reject		
Reduce waiting time	Waiting for equipment	-	√	-	Always advice workers to preparations	Discuss in toolbox meeting
	Waiting for equipment due to calibration issue: make a due date log and calibrate on time	√	-	-	We did not check our equipment for calibration due dates Spent on air freight to get these done.	To avoid this in the future, check calibration dates early enough
	Due to clashes with other work: do finishing work concurrently with segment erection	√	-	-	Most of the finishing works (internal and external) did not happen concurrently	Update the schedule
	Due to clashes with other work: Stormwater work should complete before concreting manholes	√	-	-	Waited for the stormwater people and other crews to get stuff inside the bridge before concreting of manholes	Update the schedule
	Only during set up change time high work requirement ;Work balancing		√		Difficult to change worker composition within one cycle	Conduct floating balancing with one worker from other processes
	Accelerate setup time specially in point 4-5	-	√	-	Need extra beam for the down positions	Discuss with the foreman and do some changes
Unnecessary walking	Looking for tools and equipment : keep track of equipment or keep the tool shed tidy	√			Always advice workers to preparations	Discuss in toolbox meeting
	Closer storage place		√		Always advice workers to preparations	Discuss in toolbox meeting
Reduce worker unavailability	Extended personal breaks	-	-	√	Difficult to keep track	Closer rest room
	Good supervision			√	Supervisors required to go out from the site for meetings	-

	Provide target work for the day			√	No motivation for them to finish work early	Rewarding mechanism
Reduce setup time	Have everything ready for the changeover next to the machine ahead of time	√			Always advice workers to preparations	Discuss in the toolbox meeting
	Use a checklist	√			Always advice workers to preparations	-
	Accelerate setup time specially in point 4-5	-	√	-	Need extra beam for the down positions	Discuss with the foreman and do some changes
Improve safety	During stressing time show safety hazard mark in front of tendons	√			Always advice workers on standing positions	-
Reduce rework	Tendons installed in wrong location (C and D): use a checklist by foreman	√			Update QA procedure	Implement checklist
Grouting						
Reduce set up time	Sort out the grout mix in advance	√			Spent 1-2 weeks to sort out the grout mix	Should be done well in advance
	Waiting due to testing work	√			-	Ask charge in hand to do all testing during smoking time
Reduce waiting time	Conduct all the testing in advance	√			-	
	Prepare with all necessary material and equipment				Always advice workers to preparations	Discuss in the toolbox meeting
	Machine breakdown	√			Occasional situation	Extra machine or regular maintenance of the machine
Reduce rework	Eliminate cantilever grouting vents damages during transferring segments	√			Spent lot of time and money on this.	Truss crew and other crew to be reminded about this
	Void creation between the void former and the MDPE pipe in continuity grouting: Due to the Denso tape	√	-	-	Use Sika Top Seal 107 to seal this void.	Avoid this denso tape for the diaphragms or scrabble around the area as soon as diaphragm is cured.

	Grouting of swift lift pins and holes did not happen with the cantilever grouting operation.	√	-	-	-	
	Partially grouted cantilever duct : Ensure QA procedure	√	-	-	-	Modify the QA supervision
	Work clashes : Pier diaphragm needs to be grouted prior to asphalt being laid	√	-	-	The 25mm vertical hole above the external tendon at the pier diaphragm	Hole needs to be grouted prior to asphalt being laid
	Designed with incorrect tolerances or manufactured with direct faults in the prefabrication plant.	-	√	-	-	-
Reduce machine failure	Grout pump breakdown	√	-	-	-	Fix these pumps before works
	Material waste due to leakage of the machine	√	-	-	Calculate to identify grout loss	Immediate fixing of machine
Air testing						
Reduce walking time	Keep track of equipment or keep the tool shed tidy		-	-	Always advice workers to preparations	Discuss in toolbox meeting
	Near storages	√	-	-	Always advice workers to preparations	Discuss in toolbox meeting
Reduce rework	Inexperienced workers search leakages	-	-	-	-	Trained with experienced workers
Reduce unavailability	Extended personal breaks	-	-	√	Difficult to keep track	Closer rest room
	Good supervision	-	-	√	Supervisors required to go out from the site for meetings	-
	Provide target work for the day	-	-	√	No motivation for them to finish work early	Rewarding mechanism
Anchorage setting						
Reduce waiting time	Only during set up change time high work requirement ;Work balancing	-	√	-	Difficult to change worker composition within one cycle	Floating balancing with one worker
	Good supervision	-	-	√	Supervisors required to go out from the site	-
	Looking for tools and equipment : keep track of equipment or keep the tool shed tidy	-	√	-	Always advice workers to preparations	Discuss in toolbox meeting

Process E

Objective	Recommendation	Management response			Comment made by the management	Action taken by management
		Accept	Partially accept	Reject		
Installing DLF						
Reduce setup time	While truss workers having their tea break gantry operator operating Gantry and bring DLF	√		-	-	-
	Longer setup time to crane	√			Due to potential unsafe lifting	Hiabs to be used if crane cannot be used safely
	Wrong setup of cutting machine due to miscommunication with survey marks	√			Already addressed and talked in prestart meeting	Again discuss this matter in the pre-start meeting
Reduce worker unavailability	Extended personal breaks	-	-	√	Difficult to keep track	Closer rest room
	Good supervision			√	Supervisors required to go out from the site for meetings	-
	Provide target work for the day			√	No motivation for them to finish work early	Rewarding mechanism
Cutting operation						
Reduce waiting time	Truss workers having their tea break gantry operator operating Gantry and bring DLF	√	-	-	-	-
	Clashes with other work :power line mostly interrupt by ground work	-	√	-	Mainly due to safety issue	Preparation of the work
	Work balance due to some issues among works	√	-	-	Charge in hand aware these issues	-
Reduce machine failure	Follow the machine specification in speed, coolant volume/pressure and drill life	√	-	-	-	Provide training to workers on drilling

Reduce rework	Set up machine again due to misunderstanding of survey marks				Due to poor communication with the ‘position markers’ they faced this issue	Since the segment is closer to pier, the cutting machine setup workers always advised to the cutting machine away from the pier.
Setup for lowering cut segment						
Unnecessary walking	Provide movable cart to transport necessary equipment and material	√	-	-	Already provided but damaged	Use a cart or platform truck for material handling
Reduce waiting	Work balance due to some issues among works	√	-	-	Charge in hand aware about these issues	Work balance due to some issues among works
Lowering cut segment						
Reduce rework	Lowering the segment to ground and then transport: eliminate double handling	√	-	-	This is due to payment issue with transporting company	
	Misalignment of DLF vertical screw	√	-	-	-	QA by workers after completing their work

Appendix T: Agenda discussion points in the pre-start meeting

Process	Agenda discussion points						
	Schedule	Quality	Safety	Planning	Worker training	Worker's voice	Total
A	1	0	2	3	1	0	7
	2	1	1	2	0	1	7
	1	1	2	3	1	1	9
Average	1.33	0.67	1.67	2.67	0.67	0.67	7.67
Percentage	17%	9%	22%	35%	9%	9%	100%
B	1	0	0	2	0	0	3
	1	1	1	1	0	1	5
	2	1	0	1	0	0	4
Average	1.33	0.67	0.33	1.33	0.00	0.33	4.00
Percentage	50%	25%	0%	25%	0%	0%	100%
C	2	0	1	2	0	1	6
	2	2	0	3	0	0	7
	1	1	1	1	0	0	4
Average	1.67	1.00	0.67	2.00	0.00	0.33	5.67
Percentage	29%	18%	12%	35%	0%	6%	100%
D	2	0	1	2	0	1	6
	3	1	2	2	0	0	8
	1	1	1	1	0	0	4
Average	2.00	0.67	1.33	1.67	0.00	0.33	6.00
Percentage	33%	11%	22%	28%	0%	6%	100%
E	1	0	1	2	0	0	4
	2	1	2	3	0	0	8
	1	1	1	1	0	0	4
Average	1.33	0.67	1.33	2.00	0.00	0.00	5.33
Percentage	25%	13%	25%	38%	0%	0%	100%

Appendix U: Interview guide for the behavioural waste due to site workers

PURPOSE OF THIS INTERVIEW

The purpose of this interview is to gather current worker participation practices of the project.

Guidance notes

Section A asks some information about your background information and Section B covers the worker participation practices relate to particular project.

Section A

Please provide the following information:

a) Your job title

____

b) Years of experience in construction industry

____

c) Years of experience in alliance projects

____

Section B

1. What are the practices used to improve the level of relationship with site workers?
   a. Conduct social activities among workers
   b. Conduct relationship development workshops
   c. Any initiatives to remove low status barrier and move to single status
   d. What is the level of importance of abovementioned practices in an alliance project
   e. How would you rate the relationship between management and employees generally at this project?
   f. Has it changed during the project life cycle? Why?

2. How you achieved the 'skill KPI- personal development plans' for site workers?
   a. Formal on the job training opportunities
   b. Formal off the job training opportunities
   c. Multi skilling training programme
   d. What proportion of supervisors here has been trained in people management skills?
   e. Formal appraisal system to assess training needs
   f. What is the level of importance of abovementioned practices in an alliance project?

3. Are there any reward and recognition related practices for site workers?
    a. Individual or group performance related rewards
    b. Receive profit related payments
    c. Receive non-financial recognition for performance
    d. Periodic employees performance appraisal
    e. What is the level of importance of abovementioned practices in an alliance project

4. What are the information sharing practices exists in this project?
    a. Job related information- Job related induction programme other than safety
    b. Opinion survey of employees by third party
    c. Management gives employees information about the project performance
    d. Why this one team session did not implement earlier?
    e. Do you think these practices are beneficial to project?

5. What are the channels through which workers can make suggestions for improving working methods?
    a. 'Feedback box' to make suggestions
    b. Worker involvement in lesson learnt workshops
    c. Requests for employees' ideas and input for project changes
    d. Do you think these systems are beneficial?

6. Do you think worker participation will increase the project performance in terms of:
    a. Reduce time
    b. Reduce costs
    c. Improve quality
    d. Improve Innovation
    e. Improve relationships
    f. Overall project performance

7. Are there any barriers to implement above worker participation practices in worker level?

Appendix V: Interview guide for the behavioural waste due to sub-contractors

Purpose of this interview

The purpose of this interview is to gather current sub-contractor management practices of the project.

Guidance notes

Section A asks some information about your background information and Section B covers the sub-contractor management practices related to particular project.

Section A

Please provide the following information:

a) Your job title

____

b) Years of experience in construction industry

____

c) Years of experience in alliance projects

____

Section B

1. What are the reasons for selecting sub-contracting option in the alliance project?

Reason	Yes	No
Cost reduction		
Stable and predictable environment		
Expert knowledge		
Eliminate duplication		
Improve flexibility		
Improve quality		
Reduce time		
Increase innovation		
Reduce stock holding		
Improve site coordination		
Minimise site congestion		
Lack of capacity of the contractor		
Other (Please specify)		

2. How you select suitable sub- contractors? Any usage of following mentioned criteria?

2.1. Primary selection criteria

Cooperation quality	Financial situation	Construction capability
Enterprise culture compatibility	Production capacity	Enterprise qualification standards
Management cooperative desire	Financial indicators (Net assets debt rate, operation capital return	Quality assurance system
Sustainable development ability		Construction experience/ performance
Enterprise cooperative spirit		Social reputation
Resources complementarity		Equipment and technical force

2.2. Secondary selection criteria

Commercial bid	Technical bid	Historical performance
Bidding price	Quality objective and guarantee measures	Cooperation cost
Bidding documents completeness	Construction methods	Cooperation years
	Construction schedule and period	Cooperation project success
	Enterprise qualification standard	
	Site project manager qualification	
	Similar project experience and performance	
	Resource allocation	
	Site safety assurance plan	
	Waste reduction plan	

2.3. Any session conducted for unsuccessful sub-contractors?

3. What are the strategies used to improve inter-company interaction of the alliance sub-contractor

Previous working experience of working together
Expectation of continuing involvement
Sub-contractor involvement in the alliance set up workshops
Any weekly planning meetings
Onsite performance evaluation
Sharing of cost -savings
Provision of worker training
Early involvement of product design
Sharing of data (openness)
Consideration of mutual impact of decisions
Clear agreement from the beginning, responsibilities, price…
High level of trust
Pursue perfection by continually improvements
Very frequent interaction at operational level
Providing finance, technical assistance
Shared pain/gain incentivisation

4. How do you measure the sub-contractor performance?

5. What measures do you used to promote the level of performance of the sub-contractor?

6. Are there any incentives to deliver tangible improvements in the quality of the construction and reductions in time and whole-life cost for sub-contractors?

7. Why do you do not or are not able to use suppliers/sub-contractors in an expanded role?

Appendix W: Interview guide for validation interviews

Table G: Validation of the study recommendations

Validation questions	Disagree	Neither agree nor disagree	Agree
To eliminate process waste			
Since procurement type alone is not enough for process waste elimination, there should be a process to detect and eliminate process waste.	-	-	5
• Implement process improvement framework by site management	-	-	5
• Frequent 'waste walk' by site management	-	-	5
• Discuss the issues identified in site walk at the pre-start meetings (like quality circle meeting)	-	-	5
• Motivate workers to provide suggestions to eliminate waste activities through reward and recognition system	1	1	3
To improve worker participation as this research suggests			
• Assess site workers/teams based on selected KPIs which are linked with alliance project KPIs	-	1	4
• Provide training in managerial skills/problem solving skills to foreman level	-	-	5
• Involve site workers in lesson learnt workshops	1	-	4
• Extend the performance appraisal system to worker level	1	1	3
• Implement bottom - up practices at the early stage of the project	-	-	5
• Explain the alliance principles to the worker level in the initial stage of the project	-	-	5
To improve sub-contractor involvement as this research suggests			
• Involve critical sub-contractors in the early stage	-	-	5
• Conduct value engineering workshops and request sub-contractors to provide their suggestions	-	-	5
• Conduct frequent coordination meetings with sub-contractor management who are not on site	2	-	3
• Extended assessment protocols and techniques to improve sub-contractor base	-	-	5
• Identify sub-contractor specific KPIs and implement a system that measures KPIs	-	-	5
• Offer any tangible incentives for sub-contractors linked to the measured KPIs	-	-	5