Implementing selected lean management tools to achieve effective planning within a construction environment at a tertiary institution

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Mini-dissertation submitted in partial fulfillment of the requirements for the degree *Master* of Business Administration at the Potchefstroom Campus of the North-West University

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November 2016

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT

It all starts here ™

ACKNOLWLEDGEMENTS

I would like to express my sincere appreciation to my Supervisor, Mr Johan Jordaan, for his guidance and support throughout the course of this mini – dissertation.

I would also like to thank all my colleagues for their support and inputs throughout my studies, in particular to Mr Joep Joubert for granting me the opportunity to conduct my study at the Department: Physical Infrastructure and Planning at the North West University.

A word of thanks to MBA Ubuntu study group members Sonya Bekker, Johan Combrink and Bianca Fazakas for their support, assistance and friendship.

Thanks to my mother, brother and sister for their encouragement and guidance over the course of my studies. My thanks go out to my late father, Prof Tom Coetzee, for his unconditional love, friendship and motivation throughout the years.

Most importantly, I would like to express my love and appreciation to my wife Luzelle, daughter Marluzè and son Franco for all they did to support me in this endeavour.

ABSTRACT

This research study addresses the application of *lean* manufacturing principles and techniques to a construction environment at a tertiary institution. Assessing the implementation efforts and benefits of the *lean* approach to construction has become more critical to organisations in pursuit of continuous improvement. Therefore, the aim of this study was to propose selected *lean* management tools to achieve effective planning within a construction environment at a tertiary institution.

The objective of this study is to do a literature study to gain insight into those *lean* operations and *lean* construction principles that are applicable to a construction environment in a tertiary institution. Such insight will enable the researcher to identify what kind of activities cause construction process delays. Further objectives include the identification and description of the elements required for the effective implementation of selected *lean* management tools, and to incorporate those *lean* tools and techniques found in the literature study into the planning process. The final objective is to propose which *lean* tools should be introduced at the selected organisation.

Chapter one introduces the nature and scope of the study and contains the general introduction of the study and the problem statement. The aim, objectives, and significance of the research and the research methodology are also presented in this chapter.

The aim of chapter two is to provide an overview of *lean* manufacturing and *lean* construction as a management philosophy, in the form of a literature study. On the basis of the literature study, a theoretical description of *lean* manufacturing and lean construction is presented. It also highlights various *lean* manufacturing tools incorporated in *lean* construction with the emphasis on throughput, with some process improvement methodologies concentrating mainly on quality in order to establish effective planning in a construction environment at a tertiary institution.

Furthermore, chapter three presents the research process adopted and the rationale for using qualitative methodologies. The nature of the study examination and the method deemed most suitable for the research questions determined the choice of methodology, namely qualitative methodology. The qualitative methodology predominantly describes phenomena using words, while quantitative methodology measures them and describes results numerically. The reason for this is that quantitative methods tend to be broader and more easily generalizable, while qualitative methods can provide a much deeper, richer data set.

Finally, chapter four proposes recommendations and conclusions that are based both on previous case studies as well as the current case study and concludes with recommendations for future studies.

Keywords: *Lean*, *lean* construction, Last Planner System, Value Stream Mapping, 5S Principles, Six Sigma, Total Quality Management, effective planning

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GLOSSARY

CDOV	Concept, Design, Optimize, Verify
COPQ	Cost of Poor Quality
CTQ	Critical to Quality
DFSS	Design for Six Sigma
DHET	Department of Higher Education and Training
DMADV	Define, Measure, Analyse, Design, Verify
DMAIC	Define, Measure, Analyse, Improve, Control
FMEA	Failure Mode and Effect Analysis
ICOV	Identify, Characterize, Optimize, and Verify
IGLC	Group for *Lean* Construction
JIT	Just – in – time
KPIV	Key Process Input Variables
LPS	Last Planner System
MSA	Measurement System Analysis
PIDOV	Plan, Identify, Design, Optimize, and Validate
PIP	Physical Infrastructure and Planning
PPC	Per cent Plan Complete
SOP	Standard Operating Procedures
SPICE	Standardized Process Improvement for Construction Enterprises
TPS	Total Production System
TQM	Total Quality Management
VOC	Voice of the Customer
VSM	Value Stream Mapping
WBS	Work Breakdown Structure

CHAPTER 1: NATURE AND SCOPE OF THIS STUDY

1.1 INTRODUCTION

The design of facilities poses numerous management problems. While site construction can operate on a definition of quality as conformance to requirements, design must produce those requirements from the careful identification of customer needs and meticulous translation of those needs into engineering specifications. (Koskela & Ballard, 2006:163).

Research has shown that work structuring is extremely important in order to achieve effective planning. According to Ballard and Howell (2004:45), work structuring entails developing a project's process design, while simultaneously trying to align engineering design, supply chain, resource allocation, and assembly efforts. The goal of work structuring is to increase the reliability and speed of workflow while delivering value to the customer. In particular, work structuring views a project as consisting of production units and work chunks (Koskela & Ballard, 2006:163).

Womack and Jones indicate that *lean* thinking is *lean* precisely because it provides a way to do more and more with less (Koskela & Ballard, 2006:163). This implies less human industry, equipment, time and space are used with the aim of providing the customer with their exact requirements. According to Koskela (2004:17), *lean* construction is a method of design pertaining to production systems with the aim to minimise waste of materials, time, and effort in order to generate the maximum possible quantity of value.

Tsao (2005) states that work structuring involves determining:

- What chunks the work will be assigned to specialists.
- How the various work chunks will be sequenced.
- How the work will be released from one production unit to the next.
- If consecutive production units will execute work in a continuous flow processor or whether I their work will be de-coupled.
- Where de-coupling buffers will be needed and how should they be sized.
- When different chunks of work will be done.

It has become increasingly important to evaluate and investigate the concept of efective planning through the use of *lean* principles in the construction environment, given the current economic and political atmosphere within tertiary institutions in South Africa.

1.2 PROBLEM STATEMENT

Since the start of the 21st century, supply chain management has become progressively more important, especially in the construction industry. It has therefore become imperative for companies to build lasting partnerships in order to gain and maintain a competitive advantage. In order to achieve this, a company needs to constantly evaluate and improve the performance of its supply chain (Njoku & Kalu Alexanda, 2005:112). The supply chain includes a network of operations that purchase raw materials and processes them into transitional parts (Njoku & Kalu Alexanda, 2005:112). The final assembly and the delivery of these products through various distribution channels, are also part of the supply chain (Njoku & Kalu Alexanda, 2005:112). Companies are currently re-designing their supply chain management in order to increase organisational effectiveness to satisfy their key customers. There has been an increasing emphasis on supply chain management as a vehicle through which a company can achieve competitive market advantage (Njoku & Kalu Alexanda, 2005:112).

At least three different trends concerning the growts of logistics solutions within the construction industry, can be identified (Hakansson & Persson, 2007:41). Firstly, supply chain activities throughout an organisation are aimed at reducing costs in order to improve cooperation and coordination with suppliers and customers, resulting in increased integration (Hakansson & Persson, 2007:41). Secondly, individual companies increasingly specialise and outsource traditional activities such as logistics. Thirdly, it is becoming increasingly necessary for organisations to become more adept at change and innovation (Hakansson & Persson, 2007:41).

The construction environment makes use of various tools and techniques such as:

- feasibility studies;
- product design;
- project management etc.(Hakansson & Persson, 2007),

These techniques enable an organisation to duly deliver the final product within the budget and of the desired quality. In totality, the construction processis subject to both internal and external factors which may influence its effectiveness. These include factors such as project approval constraints, ineffective planning and the weather. Consequently, the logistics of a construction project need to be carefully addressed and this in itself implies that it is essential that enough time is set aside for accurate planning to ensure the punctual commencement of the project (Koskela & Ballard, 2006:163).

Previous research has found that in traditional construction projects, only one-half of the tasks assigned for a given week are actually completed in that week (Forbes & Ahmed, 2010:60). Flow variability, which refers to the presence of waste and the management thereof, greatly influences the work schedule since a delay in work completion by one trade directly affects the downstream activities of the next session (Forbes & Ahmed, 2010:60).

Budget constraints and selective approval of projects have become increasingly significant at tertiary institutions in South Africa. This causes a delay in the planning process for projects. Miscommunication may occur between departments and other role players such as professional engineers and quantity surveyors. This puts a strain on universities in terms of the funding model, according to which the Department of Higher Education (DHET) allocates grants. In many industries, the introduction of *lean* principles has been shown to improve effective project management (Forbes & Ahmed, 2010:60).

The purpose of this study is to investigate whether *lean* principles would in fact address the above-mentioned concerns. The aim is to achieve effective planning in order to eliminate wastage and to create a culture of effective planning.

1.3 RESEARCH QUESTIONS

- How can concepts of *lean* thinking improve project planning productivity?
- What concepts of *lean* thinking are relevant in a construction environment?
- What are the reasons for tardy commencement of projects?
- What recommendations could be made for future research and practice?

1.4 EXPECTED CONTRIBUTION OF THE STUDY

1.4.1 Contribution towards the individual

The individual is expected to profit from this study since *lean* production delivers value to him/her, whilst at the same time eliminating those aspects that do not.

1.4.2 Contribution towards the institution

It will help the company perfect its process and create a reliable flow by means of line stoppages, inventories and the decentralisation of information and decision – making.

1.4.3 Contribution towards the literature

The study will re-examine current conceptualisaiton and measurement issues pertaining to the implementation of selected *lean* management tools. This re-evaluation is aimed at achieving effective planning within a construction environment, specific to tertiary institutions. Suggestions will be made, regarding the improvement of such planning. The benefits of the study could potentiallyextend beyond the exclusive domain of tertiary institutions.

1.5 RESEARCH OBJECTIVES

1.5.1 General objective

The general objective of this study was to propose selected *lean* management tools to achieve effective planning within a construction environment at a tertiary institution.

1.5.2 Specific objectives

- To complete a literature study in order to gain insight into *lean* operations and *lean* construction principles that are applicable to a construction environment in a tertiary institution;
- to identify what kind of activities instigate delays in the construction process;
- to determine which elements are required for the effective implementation of selected lean management tools, and to describe them.;

- to incorporate the *lean* tools and techniques identified in the literature study into the planning process;
- to propose which *lean* tools should be introduced to the selected organisation.

1.6 RESEARCH DESIGN

1.6.1 Research Approach

There are currently two broad research approaches, namely quantitative and qualitative research. The nature of this study dictates the use of a qualitative research method.

Denzin and Lincoln (2003:55) define qualitative research as a situated activity that locates the observer to the world. It consists of a set of explanatory material practices that allow the domain to become evident and then alter it. It also changes the domain into a series of demonstrations including the following:

- field notes;
- interviews;
- conversations;
- photographs;
- recordings; and
- memos to the self.

Qualitative research involves an interpretive, naturalistic approach to the world and this implies that this study will be conducted in the natural setting of the institution. The study also attempts to make sense of, or interpret, occurrences in terms of the meaning people bring to them (Denzin & Lincoln, 2011:27).

According to Schurink (2008), establishing an agreed-upon meaning for qualitative research has been far from simplistic, if at all feasible. Schurink (2008) states that qualitative research involves the use and collection of a variety of empirical tools including case studies, personal experiences, introspections, life stories, interviews, artifacts, cultural texts and productions, observational, historical, interactional and visual texts that describe routine and problematic moments and meanings in individuals 'lives. Accordingly, qualitative researchers display a wide range of interconnected interpretive practices, always striving to better understand the subject matter at hand. For them, each practice makes the world visible in a different way, as pointed out by Schurink (2008).

According to Schurink (2008) there are different points of view as to how reality should be understood and these views tend to vary on a continuum ranging from an objective reality that exists independent of human conception to the notion of multiple, subjective realities that are socially constructed.

1.6.2 Research Strategy

The nature of this study is case study research due to the environment in which the research was done. Two previous case studies within the construction environment are re-examined, in order to identify specific elements present in both case studies. This will enable the researcher to draw comparisons between the case studies and the current construction environment at a tertiary institution. The research at the tertiary institution will serve as a third case study.

The study is comprised of the following three case studies:

- the Oscar J. Boldt Construction Company case (previous study);
- the PARC Project case (previous study); and
- the Department of Physical Infrastructure and Planning at the North West University (current study).

1.6.3 Research Method

1.6.3.1 Literature review

Journals and publicised literature, along with previous research conducted on *lean* manufacturing and *lean* construction, were reviewed in order to formulate the literature study.

1.6.3.2 Research setting

This research was conducted at the offices of the Department of Physical Infrastructure and Planning, at the Institutional Office of the North-West University, building number G14, located on the University's Potchefstroom campus.

1.6.3.3 Access and establishing of researcher roles

Permission was granted by the Chief Director: Physical Infrastructure and Planning, to conduct interviews with various participants and to observe them within their natural working environment.

1.6.3.4 Sampling

The participants of this research were purposefully selected, based on their involvement in the construction environment. The number of participants is viewed as being sufficient.

1.6.3.5 Data collection Methods

Semi-structured interviews allows for the following, with regards to data collection:

- Positive rapport between interviewer and interviewee;
- High Validity;
- Complex questions and issues can be discussed and or clarified; and
- Easy to record interview (Denzin & Lincoln, 2011:415).

1.6.3.6 Recording of data

Recordings were analysed for common themes and these themes were then subsequently used in the analysis of the data.

1.6.3.7 Data analyses

A content analysis method was used during this study. Certain keywords in the recordings were identified and analysed. These keywords were then categorised, after which conclusions were made.

1.6.3.8 Reporting

A narrative writing style was used in this study. This style allows reporting to include postmodern theory and related epistemology (Denzin & Lincoln, 2011:415). It also allows the researcher to:

- experiment with the 'plotting', the author's stance and the characters of the participants, voices and rhetoric.

- attempt to reflect the complex nature of research and power issues that surround social research.

1.6.3.9 Ethical considerations

According to Gorman and Clayton (2005:3), ethical considerations are essential to research, regardless of the approach adopted. All research subjects have ethical rights and these rights include the right to be consulted, to give or withhold consent, and the right to confidentiality (Saunders *et al.*, 2009:187).

Researchers should adhere to the following ethical guidelines during research:

- Informed consent should be obtained since.voluntary participation is a prerequisite. Participants should be given sufficient information pertaining to the research to enable them to make an informed decision. The participants were given a comprehensive synopsis of the nature of the research, after which the necessary consent was obtained in writing (Leedy & Ormrod, 2015:120);
- Participants should be protected from harm. All interviews were conducted in circumstances which facilitated comfortability and eliminated any stress or embarrassment on the participants' behalf (Leedy & Ormrod, 2015:120);
- The participants' right to privacy should be respected. Participants' responses were disclosed in such a manner as to not expose the specific individuals. In particular instances in which they were willing to agree in writing to such disclosure, the participants were allocated a code number, in order to honour their privacy (Leedy & Ormrod, 2015:120);
- Honesty with professional colleagues was a necessity. The researcher did not fabricate data to support a specific finding and also was cognisant of the requirement to ensure that all sources were acknowledged, to refrain from committing plagiarism (Leedy & Ormrod, 2015:120);
- The sources that were consulted were referenced, as required. Reference was made to all sources incorporated in the research by incorporating them into the list of references (Leedy & Ormrod, 2015);

- In practice, the study population is a close–knit group with whom the researcher has a good working relationship. To observe the ethical prerequisites was easy since the level of trust is high.

1.7 CHAPTER DIVISION

The chapter layout for this mini-dissertation is as follows:

Chapter 1 Nature and scope of the study: This chapter contains the general introduction of the study and the problem statement. The aim, objectives and significance of the research along with the research methodology are presented in this chapter.

Chapter 2 Literature Study: This chapter examines *lean* manufacturing and *lean* construction through the review of literature.

Chapter 3 Empirical Study: In this chapter, a methodology is proposed for measuring *lean* conformance of previous case studies of construction companies and a current study within a construction environment at a tertiary. The overview of the research methodology and structure of the interviews are explained. The results, after an analysis, are provided and discussed.

Chapter 4 Recommendations and Conclusion: This chapter summarises the overall research process that was adopted, discloses the conclusions derived from the overall research findings and, lastly, provides recommendations and suggestions for further research.

CHAPTER 2: LITERATURE STUDY

2.1 INTRODUCTION

This chapter will focus on a literature study conducted through the use of *lean* manufacturing principles adopted in the construction environment. This chapter will start by providing an overview of the history of *lean.*

Even though *lean* construction and *lean* manufacturing are considered to be two separate theoretical subjects, they do have some similarities in that *lean* construction was inspired by *lean* manufacturing and both utilise the same basic principles such as, to identify value, to map the value stream, create flow, establish pull, and to seek perfection. Consequently, this chapter further distinguishes between the two by supplying certain definitions pertaining to *lean* manufacturing and *lean* construction, respectively.

In accordance with the main objective of this dissertation, which is to apply certain *lean* construction tools within a university environment, an overview of *lean* construction tools will be discussed. These tools include the Last Planner System, Value Stream Mapping and 5 S Process.

This chapter will also identify and decribe certain process improvement methodologies, namely Six Sigma and Total Quality Management, which do not strictly form part of either *lean* manufacturing or *lean* construction tools, but which have been proven to be interconnected with *lean* construction methodology. These process improvement methodologies are important methods to support and help *lean* principles to achieve product quality.

2.2 HISTORY OF *LEAN* MANUFACTURING

The foundations of *lean* production were developed post-World War II, a period in which the Japanese manufacturing industry was completely reconstructed (Womack *et al.*, 2007:15). The *lean* pioneers, Kiichiro Toyoda, Eiji Toyoda and Taiichi Ohno of the Toyota Motor Company, developed many of the underlying principles of *lean* production in response to pragmatic considerations and existing geographic circumstances (Womack *et al.*, 2007:15).

Ohno (1988:17) created a set of system design criteria that prevented sub-optimisation and promoted continuous improvement, these system designs allows for a multi-dimensioned standard of perfection. To meet customer requirements in limited delivery time and with nothing in the inventory, strict oordination was essential between the movement of each car down the line and the arrival of parts from the supply chains. Rework due to errors was not tolerated. This lead to an increase in the time it took to manufacture a car from beginning to end, which lead to unreliable workflow. If workflow is unreliable, the coordination of the arrival of parts would be impossible. Ohno (1988:17) even instructed the workers to stop the line if there were any defective parts or products coming from the upstream because he recognised that reducing the cost or increasing the speed could add further waste if variability was injected into the flow of work. This decicion was based on eliminating the various types of variations that lead to development of Kanban and Just–in–time production (JIT). Conseqently, it became possible for Toyota Motor Corporation to compete with global competitors in terms of quality and variety.(Ohno, 1988:17)

According to Booz *et al.* (2002), *lean* manufacturing has followed three development phases over the last forty years. These phases are presented beneath:

- Phase 1: Three sub–principles were concentrated on that focused solely on production, during the the early philosophy, namely:
    - The focus was shifted to embedding quality assurance into the manufacturing process, rather than inspecting the end production;
    - Minimising waste along with increased awareness to reduce surplus inventory and low value activity; and
    - Stabilising production in order to decrease variability caused by the production system.

- Phase 2: The introduction of *lean* principles resulted in a set of five sub–principles, namely:

    - Cost drivers and not cost buckets, are reduced;
    - Quality, speed and cost is improved in a combined method, rather than focusing on cost alone. This allows improvements in both quality and speed which subsequently yield greater cost;
    - Managing processes from start to finish in order to recognise the benefits;
    - Empowering frontline staff with ownership of work to ensure *lean* production is achieved; and
    - Removing complex product design and product outline.

- Phase 3: After evaluating the work of the foremost *lean* manufacturing corporations, this phase arose dealing with all the principles and sub–principles merging into the following three main factors:

    - Product architecture, facilitating the managing of structural difficulty to ensure the balancing of cost and variety by focusing on the commonalities in many different products,. This in turn, leads to the development of product architecture;
    - Decision-correct architecture with an extensive review on decision making, to steer speed, quality and costs; and
    - Technological architecture to develop a process to aid support product and decision architecture.

2.3 Defining le*an*

This study determines to examine various definitions of *lean* which are applicable to construction.

Various definitions presented in Table 1 below, show that the common themes central to all definitions are customer, value, and waste. In the context of this study, *lean* is defined as a philosophy and a production management-based system that uses tools and techniques to create a change in organisational culture and maximise value to the customer by identifying and eliminating waste, and pursuing perfection in the execution of a construction project.

Table 1: Definitions of *lean*

Sources	Definition
Manrodt *et al.* (2008)	*Lean* is a systematic approach to enhancing value to the customer by identifying and eliminating waste (of time, effort and materials) through continuous improvement by the flow of the product at the pull of the customer, in pursuit of perfection.
Ballard *et al.* (2007)	*Lean* is "a fundamental business philosophy – one that is most effective when shared throughout the value stream".
Womack *et al.* (2007)	*Lean* construction is a production management-based project delivery system emphasising the reliable and speedy delivery of value,
Radnor *et al.* (2006)	*Lean* is a philosophy that uses tools and techniques to create a change of organisational culture in order to implement the "good practice of process/operations improvement that allows the reduction of waste, improvement of flow, more focus on the needs of customers and which takes a process view",

Tsao (2005)	"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."
Shah and Ward (2007)	"An integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimising supplier, customer, and internal variability."

There are seven types of waste identified under *lean,* namely overproduction, overstocking, excessive motion, waiting time, delay and transportation, extra-processing, defect and rework. Tsao (2005) states that *lean* offers significant benefits in terms of waste reduction and increased organisational and supply chain communication and integration. The various methodologies for attaining *lean* production include just-in-time (JIT), total quality management, concurrent engineering, process redesign, value-based management, total productive maintenance and employee involvement as indicated by Womack *et al.* (2007:71), to name but a few.

2.4 DEFINING *LEAN* CONSTRUCTION

The *Lean* Construction Institute (2004) defines the term *lean* construction as a production management-based approach to project delivery, a new way to design and build capital facilities. *Lean* production management has revolutionised manufacturing design, supply and assembly. When applied to construction, *lean* changes the way work is done throughout the delivery process. *Lean* construction extends from the objectives of a *lean* production system, maximising value and minimising waste, to specific techniques and applies them in a new project delivery process.

Lean production concepts support the development of a methodology for managing construction planning by emphasising process efficiency and focusing on achieving objectives (Womack *et al.*, 2007:15).

According to Koskela (2004), the concepts and principles of *lean* generally aim to make the onstruction process "*lean*er" by the removal of waste, which is regarded as a non- value-generating activity. This concept of *lean* construction is a new production philosophy which has the potential of bringing about innovative changes in the construction industry, according to Koskela and Ballard (2006:163).

According to Shah and Ward (2007:805), itis vital to differentiate between studies in view of *lean* from a philosophical perspective relating to guiding principles or overarching goals, and studies examining the concept from a practical angle as a set of management practices, tools or techniques that can be witnessed directly,.

Tsao (2005) indicates the aforementioned differentiation is necessary since the implementation of *lean* construction has been directed towards certain specific tools and principles, without a full integration on different aspects such as supply chain, safety, planning and control, production design and management, culture and human aspects. According to Tsao (2005), outlining a comprehensive definition that covers all aspects of *lean* is seen as a difficult task..

Tsao (2005) also states that there are many different meanings of *lean* when applied to construction. *Lean* construction is similar to the current practices in the construction industry by way of pursuing to meet customer needs while reducing waste of all resources. However, the difference between the current practices and *lean* construction is that *lean* construction is based on production management principles, and Tsao (2005) indicates that it will have better results in complex, uncertain, and quick projects.

In the last four decades, numerous tactics have been developed to improve the efficiency and effectiveness of *lean* construction methods in order to minimise, non-value-adding work. Since the early 1990's, the construction research community has been analysing the possibility of applying the principles of *lean* production to construction. The idea of understanding construction as production was first introduced by Koskela and Ballard (2006:163). Formulation of the theoretical foundation for *lean* construction by conceptualising the core concepts of *lean* production and applying them to the management of construction, were aided by the contribution of the International Group for *lean* Construction (IGLC) (Koskela & Ballard, 2006:163).

The nature of the operation, planning and execution are the key categories that emphasise the differences between manufacturing and construction, according to Tsao (2005). The tools of *lean* production cannot be directly applied to manage construction processes and a new set of tools is required, attributable to fundamental differences between construction and production processes. The Last Planner system of production control which was introduced in 1992, emphasises the relationship between scheduling and production control and is generally seen as the most completely developed *lean* construction tool (Ballard & Howell, 2004:45).

One of the priorities of *lean* construction is the elimination of waste since *lean* construction tools have evolved to contribute to sustainable construction (Koranda *et al.* (2012:707). Similarly, sustainable construction focuses on the removal of waste from the construction process (Koranda *et al.* (2012:707). Therefore, it could be said that both concepts share the same goal of waste reduction. However, as Koranda points out, organisations struggle to integrate the concepts (Koranda *et al.* (2012:707).

There is sufficient evidence to support the view that the following principles will significantly and rapidly improve the efficiency of flow processes, as explained by Koskela and Ballard (2006:163):

- "Reduce the share of non-value adding activities, also known as waste;
- Increase output value through systematic consideration of customer requirements;
- Reduce variability;
- Reduce cycle times;

- Simplify by minimizing the number of steps, parts, and linkages;
- Increase output flexibility;
- Increase process transparency;
- Focus control on the complete process;
- Build continuous improvement into the process;
- Balance flow improvement with conversion improvement; and
- Benchmark" Koskela and Ballard (2006:163).

Research shows that the above-mentioned principles are universal and apply to almost any production process, for example physical production, informational production (design), mass production, and one-of-a-kind production (Koskela & Ballard, 2006:163).

2.5 *LEAN* CONSTRUCTION TOOLS

The following *lean* construction tools will be discussed:

- Last Planner System (LPS)
- Value Stream Mapping; and
- 5S process.

2.5.1 Last Planner System (LPS)

Ballard and Howell (2004:45) indicate that the Last Planner System (LPS) refers to the process of creating a master schedule, a look-ahead schedule and a weekly work-plan through front-end planning, look-ahead planning, and commitment planning, respectively, using *lean* Construction Planning techniques.

Ballard and Howell (2004:45) also note that the traditional construction management approach is to define activities and schedule work that is required to be done, prior to the start of construction. The assumption is made that resources are always available when needed (Ballard & Howell, 2004:45). This assumption leads workers to believe that the work is "do-able" and that the desired result is guaranteed. It is then up to the production crews to gather the necessary resources on hand and to adhere to the schedule as effectively as they can. It is generally expected that these production crews can do the work, regardless of resource availability (Ballard & Howell, 2004:45).

The term called can–do attitude, refers to instances in which the person or organisation responsible for producing the schedule, not having the appropriate ability or understanding of the work to be performed (Ballard & Howell, 2004:45). The reason for this is that they do not have the desired work-related experience required to perform optimally. It is difficult for for these employees to define the full scope of work and many do not possess the ability to assess the real nature of work to be done, methods to be used, and the required capacity of the resources to be applied (Ballard & Howell, 2004:45). They also struggle to anticipate the specific circumstances relating to work-execution. Consequently, the work cannot be planned in advance at the level of detail that is required to best perform the work and to control the production (Ballard & Howell, 2004:45).

Previously, employees were told what goals they were required to achieve at a specific point in time, and it was left up to them to determine how to accomplish those goals (Ballard & Howell, 2004:45) . The reality, however, is that although the schedule reflects anticipated resource availability, actual resource availability can differ significantly from the anticipated availability (Ballard & Howell, 2004:45). This leads to subsequent variations in the original schedule (Ballard & Howell, 2004:40).

Ballard and Howell (2004:38) therefore proposed the LPS to improve this situation, which focuses on adding reliability in planning by stabilising workflow at production level. According to Ballard and Howell (2004:38), the main purpose of the LPS is to shield workers from the uncertainties which they cannot control (Ballard & Howell, 2004:45). The scholars also propose that weekly work-plans should be implemented if assignments do not meet specific quality requirements as identified by the following questions below (Ballard & Howell, 2004:45):

- **Definition:** Are assignments specific enough so that the right type and amount of materials can be collected? Can work be coordinated with other trades? Is it possible to tell at the end of the week if the assignment has been completed?

- **Soundness:** Are all assignments workable? Are all materials on hand? Is design complete? Is prerequisite work complete? The intent is to do whatever can be done to get the work ready a week before the deadline.
- **Sequence:** Are assignments' selected in order of priority and in terms of there constructibility? Are additional, lower-priority assignments identified as workable backlog? In other words, are additional quality tasks available in the event that assignments fail or productivity exceeds expectations?
- **Size:** Are assignments sized to the productive capability of each crew or sub-crew, while still being achievable within the plan period?
- **Learning:** Are assignments that are not completed within the week tracked and the reasons for the deviation identified?

Having a plan meet the LPS quality criteria does not guarantee that there will be no plan failure at all (Ballard & Howell, 2004:45). A plan could always fail upon execution. However, the purpose of the LPS is to help minimise plan-quality failures in order to avoid unnecessary execution failures. Ballard and Howell (2004:45) therefore suggest that only assignments that meet the desired quality criteria be put on a weekly work-plan (Figure 1).

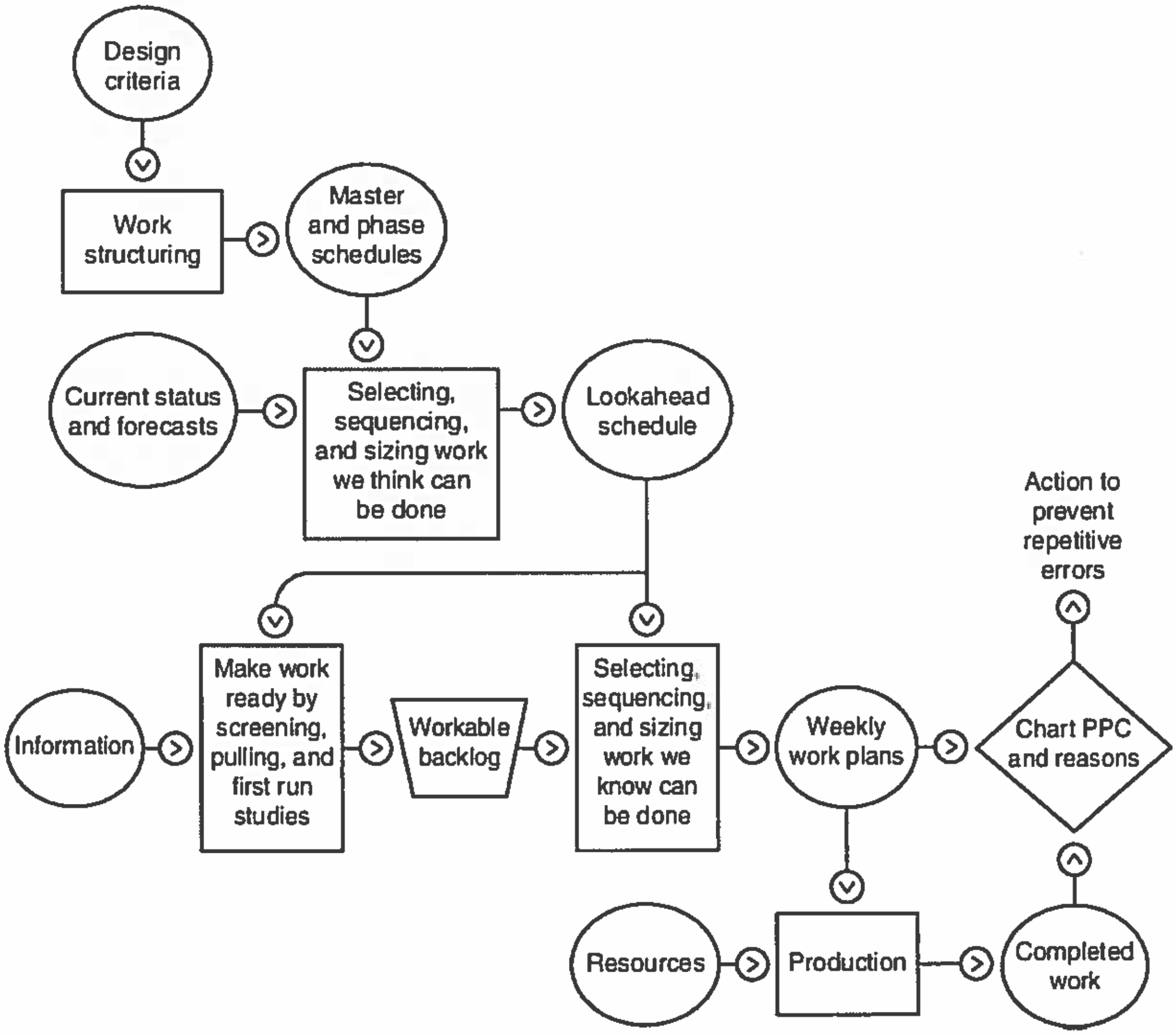
The LPS, which began as a methodology for generating quality assignments in weekly work-planning, has been extended to the current form of LPS, that includes front-end planning (Ballard & Howell, 2004:45) and look-ahead planning (Ballard *et al.*, 2009:500), as indicated in Figure 2. According to Ballard and Howell (2004:40), each level of the LPS has a very specific purpose.

The purpose of the master schedule (Figure 1) is to :

- Demonstrate the feasibility of completing the work within the available time;
- Display an execution strategy that can serve as a basic coordinating device; and
- Determine when long lead items will be needed.

Figure 1: Last Planner System

Source: Ballard and Howell (2004:45)



The purpose of the look-ahead schedule is to (Figure 2):

- Shape workflow in the best achievable sequence and rate for achieving project objectives that are within the power of the organization at each point in time (Ballard & Howell, 2004:45) ;
- Match labour and related resources to workflow (Ballard & Howell, 2004:45);
- Produce and maintain a backlog of assignments for each frontline supervisor and crew, screen the backlog for design, materials, and completion of perequisite work (Ballard & Howell, 2004:45);

- Group together work that is highly interdependent, so the work method can be planned for the whole operation (Ballard & Howell, 2004:45); and
- Identify operations that require joint planning by multiple trades (Ballard & Howell, 2004:45).

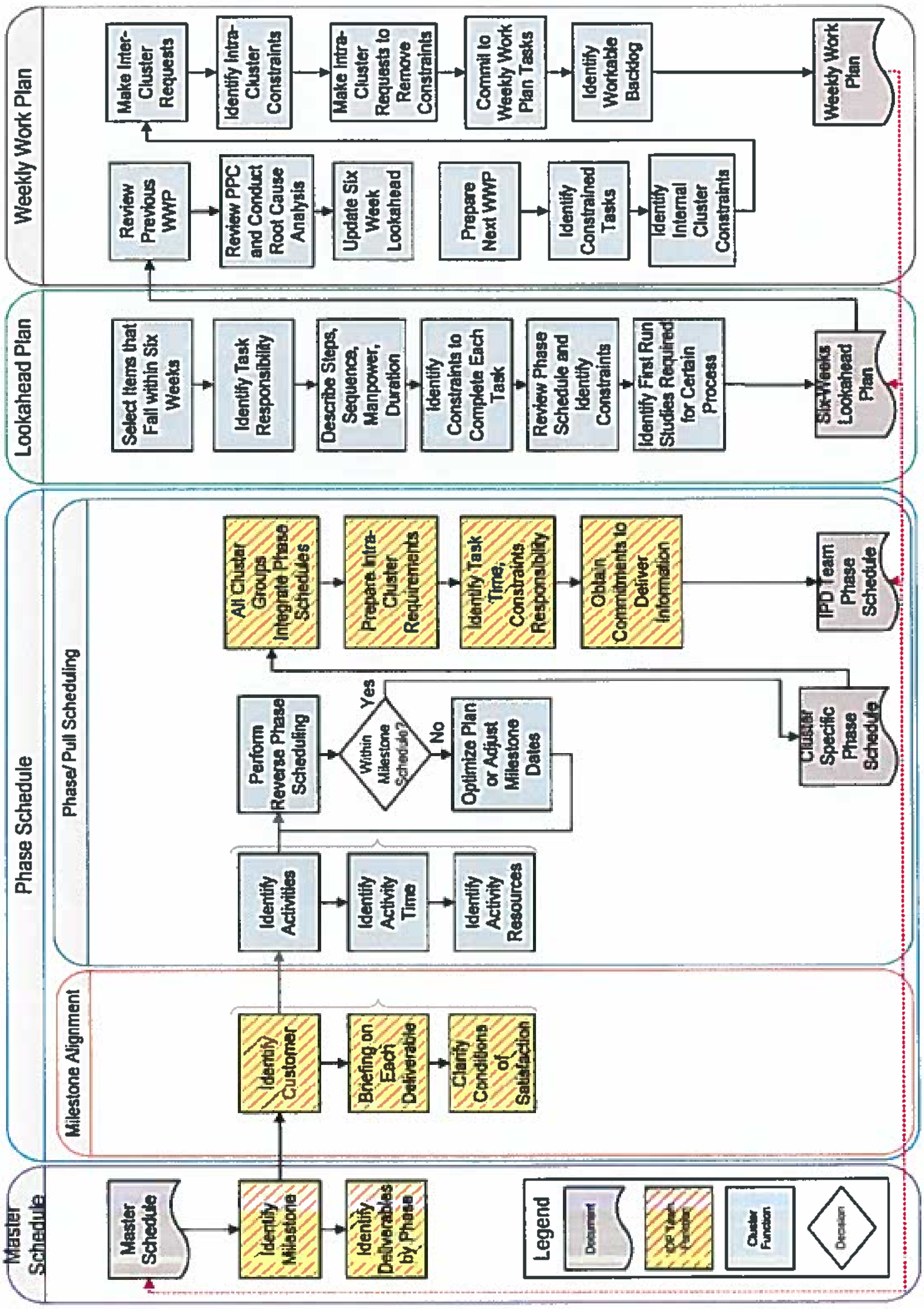
The purpose of the weekly work-plan as shown in figure 2, is to:

- Identify make ready actions and assessing their feasibility prior to making assignments so as to shield production units from uncertainty (Ballard & Howell, 2004:45) ; and
- Make best use of the production unit's capacity and acknowledge individual's differences in light of the schedule loads (Ballard & Howell, 2004:45).

Ballard and Howell (2004:45) also propose a new metric, namely PPC (Per cent Plan Complete), for measuring the reliability of the planning system. Unlike other project performance criteria or variance analyses that measure whether the project is on schedule or on budget, PPC measures whether the planning system is able to reliably anticipate what will actually be done (Ballard & Howell, 2004:45). Determining whether an assignment was completed or not according to the plan is mandatory in calculating PPC, but elaborating on reasons for failure to complete the work as planned is even more important (Ballard & Howell, 2004:45). These learned reasons will serve as valuable knowledge in elaboration of constraints in future planning efforts (Ballard & Howell, 2004:45).

Figure 2: Process Map Depicting the Planning Process

Source: Ballard *et al.* (2009)



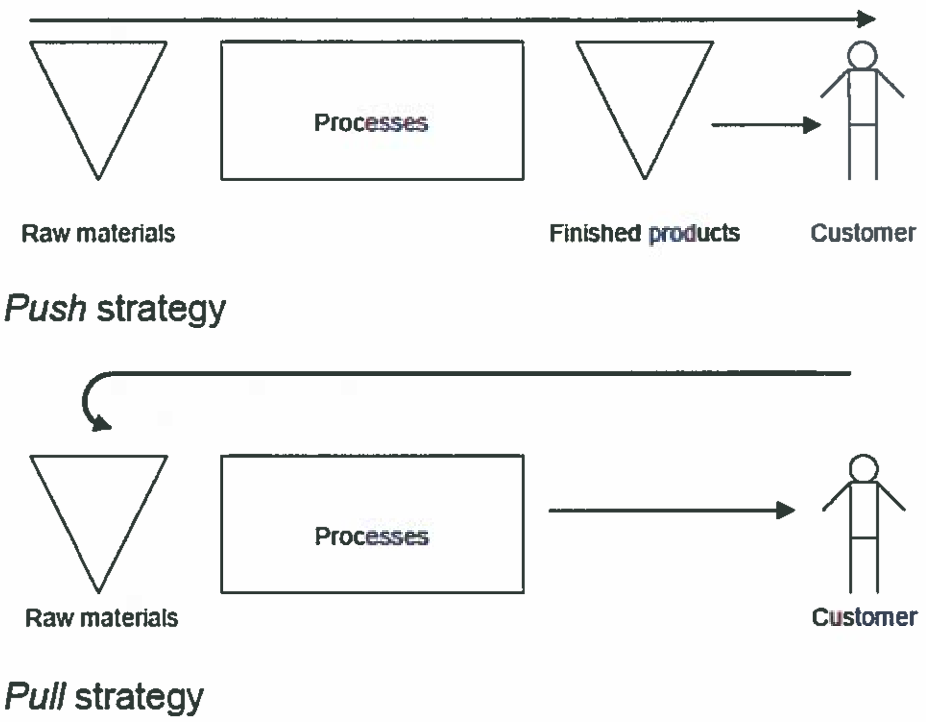
2.5.1.1 Front-end Planning

According to Tao (2005), the master schedule is developed based on the design criteria using work structuring (Figure 3). Tsao (2005) defines work structuring as "a process of breaking work into pieces, where pieces will likely be different from one production unit to the next, so as to promote flow and throughput". These pieces are termed "work chunks", which are "the unit(s) of work that can be handed off from one production unit to the next", as indicated by Tsao (2005). According to Ballard & Howell (2004:45), work chunks may change as they move from one production unit to the next. The notion of "breaking work into pieces" is consistent with "grouping work" or "subdividing" as is done in the development of a Work Breakdown Structure (WBS) (Ballard & Howell, 2004:45) .

The main difference, however, is the goal of the breakdown. According to Tsao (2005), the current criteria determining work structuring practices are the contracts, the history of the trades, and the traditions of the craft. In work structuring, a conscious effort is made to structure the work to facilitate throughput with a goal to "make work flow more reliable and quick while delivering value to the customer" (Ballard & Howell, 2004:45).

The relationships between work chunks are defined by the following deliverables: *when* the work chunks are required, *how much* work is required, *in which* sequence the work is broken up into , and *what* the other chunks require (Ballard & Howell, 2004:45). Tsao (2005) indicates that it is important to note that these deliverables do not conclusively determine sequencing, as relationships might be shared. However, in the current methodology activities are linked by precedence relationship, which presumes that as long as the sequencing of those activities is right, the output of the forerunner will be compatible with the requirement of the beneficiary asmentioned by Tsao (2005). This may, however, not always be the case as mentioned by Milberg and Tommelein (2003). Tsao (2005) indicates that the timing and sequencing of handoffs by simulating a given sequence of activities with different handoff scenarios are of utmost importance, as indicated by pull versus push, as seen in Figure 3.

Figure 3: Pull vs. Push
Source: (Tsao, 2005)



Nevertheless, Milberg and Tommelein (2003) indicates that as the very definition of work structuring suggests, it is not limited to only developing master schedules, but extends to developing operations and process designs in alignment with product design, the structure of supply chains, the allocation of resources, and the design-for-assembly efforts.

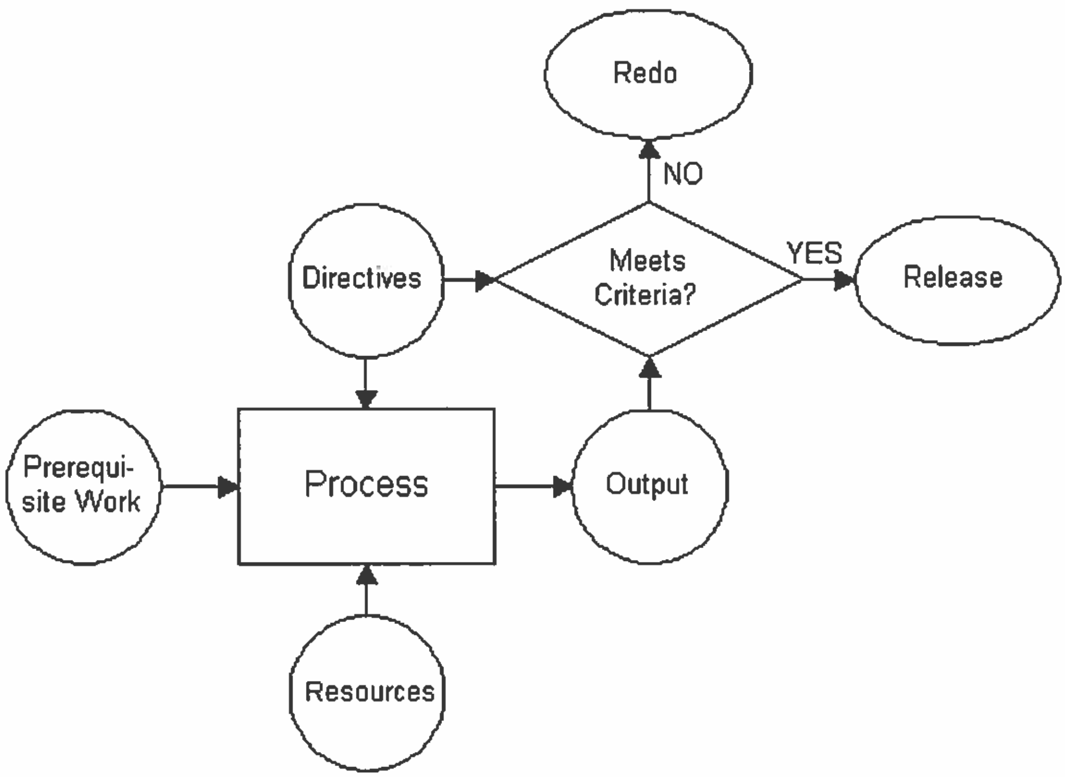
2.5.1.2 Look-ahead Planning

Ballard *et al.* (2009:500) defines "control" as "causing a desired future rather than identifying variances between plan and actual." This is the main reason the LPS differs from traditional planning and control practices (Ballard *et al.*, 2009:499). The control practices of the LPS comprises of workflow control and production unit control (Ballard *et al.*, 2009:499). Look-ahead planning is mainly responsible for workflow control, while commitment planning (weekly work planning) is mainly related to production unit control, as seen in Figure 4 (Ballard *et al.*, 2009:499).

According to Ballard *et al.* (2009:500), the following takes place during look-ahead planning:

- **Explosion**: Detailing master schedule activities, using the Activity Definition Model (ADM) before they enter the look-ahead window.
- **Screening**: Determining the status of tasks in the look-ahead window relative to their constraints, and choosing to advance or delayed tasks based on their constraint status and the probability of removing constraints. An important tool in screening is constraint analysis. This analysis comprises of identifying constraints that prevent activities from starting and ending without unplanned interruptions.
- **Make ready**: Confirming lead-time, pulling and expediting.

Figure 4: Look ahead Planning
Source: (Ballard *et al.*, 2009)



2.5.1.3 Commitment Planning

Commitment planning in the LPS differs from the traditional weekly work planning in that it explicitly identifies uncertainties and tries to shield employees from uncertainties over which that they do not control (Ballard & Howell, 2004:45). It is also important to note that commitment plans also have to meet specific quality requirements, namely :

- Definition;
- Soundness;
- Sequence;
- Sizing; and
- Learning (Ballard & Howell, 2004:45).

2.5.2 Value Stream Mapping (VSM)

2.5.2.1 Value Stream

Osterling and Martin (2013:135) define value stream as the sequence of activities required to design, produce, and deliver a good or service to a customer, and includes the dual flow of information and material.

The activities forming part of a value stream include the work done by the organisation, work done by outside parties, and the consumer of the end product (Osterling & Martin, 2013:135).

2.5.2.2 Value Stream Mapping

Liker (2004:27) suggests that value stream mapping has grown from what Toyota calls the material and information flow diagram, which was used to teach total production system (TPS) to suppliers.

Rother and Shook (1998:41) were the first to transform Toyota's way of working with value stream mapping to a practical guide, called Learning to see. This approach focuses on mapping in production, but the method has since been adapted and used in other disciplines such as administration, office processes, healthcare and supply chain (Graban, 2009:58).

Value stream mapping assists in the understanding of the flow of material and information required to make the final product and also for analysing how that flow can be improved by using *lean* principles (Rother & Shook, 1998:41). By focusing on the customer, value creation and the removal of waste, an effective and efficient flow in the process can be created (Rother & Shook, 1998:41).

Pictorial representations with process maps may be used to communicate with different parties in an organisation (Rother & Shook, 1998:41). In this way, value stream maps can provide a whole view of how work are done through the entire systems (Rother & Shook, 1998:41).

Osterling and Martin (2013:135) summarises the benefits of value stream mapping as follows.

- The visual unification tool can help in visualising non-visible work such as information exchanges. Visualising non-visible work is a key step in understanding how work gets done.
- Value stream maps can create connections to the customer that assist an organisation to focus more on the customer's perspective and thereby deliver more value to the customer.
- Value stream maps can provide a complete system view by connecting different parts into a more collaborative organisation, with the objective of providing higher value to customers.
- Value stream mapping can help in visualising and simplifying the work process on a macro level, which may help in making strategic improvement decisions better and faster.
- Value stream maps are an effective means to orientate newcomers by assisting them develop a holistic view of the organisation and its management as well asunderstand where they fit in, inan organisation product (Osterling & Martin, 2013:135).

Value stream mapping provides a graphic, all–inclusive view of how work progresses from a customer request to the final fulfilment of that request product (Osterling & Martin, 2013:135). The process of value stream mapping is aimed at providing effective ways to establish strategic directions for better decisionmaking and work design (Osterling & Martin, 2013:135).

2.5.2.3 Creating a Value Stream Map

According to Rother and Shook (1998:41), the process of creating a value stream map can be briefly summarised as follows:

- Firstly, the target product, process family or service has to be identified. The process family is a group of products or services that go through similar or the same processing steps, or is the most problematic process family requiring improvement.
- Secondly, the current state value stream map is drawn. The current state map should illustrate how the exact activities are performed in a real working context. To create a current state map, collect data and information by walking the flow and interviewing the people who perform the tasks.
- Next, the current state value stream map is analysed. After the current state map is completed, the team may go through the process of assessing the current state value map in terms of creating flow by eliminating waste.
- A future state value stream map is then drawn. The purpose of value stream mapping is to highlight sources of waste and eliminate them within a short period of time. The future state map should be based on an assessment of the current state map and make achievable. Through implementing a future-state value stream, the goal can become a reality.
- Finally, work towards the future state condition. A plan for achieving the future state is crucial. Without one, value stream maps are pointless. The plan for achieving the future state value stream can be a future state map, detailed process map, a yearly value stream plan or a combination of these documents (Rother & Shook, 1998:41).

2.5.2.4 Value Stream Mapping Tools

Before acquiring the tools used in Value Stream Mapping to eliminate waste, an understanding is necessary of the types of waste that may. Monden (2011:197) states that there are three types of processes that are carried out, namely:

- **Non-value adding**: This process can be defined as pure waste with unnecessary actions that should be completely eliminated.
- **Necessary but non-value adding**: This process involves actions that are necessary but may be wasteful.
- **Value-adding**: This specific process converts raw materials into finished products, through the use of manual labour.

In a study conducted by Hines and Rich (1997:46), seven new tools are presented regarding waste. The first tool, **process activity mapping**, helps in generating solutions to reduce waste. Figure 5 is a map drawn by Hines and Rich (1997:46), indicating the process to follow:

- Firstly, analyse and study the flow of processes, then record in detail all items required in each process. Secondly, list each process and categorise it into activity types such as operation, transport, inspection and storage _(the darker shade box indicates the type of activity). Finally, identify any waste in the processes and consider a better and more efficient way to rearrange the process(Hines & Rich, 1997) .

Figure 5:Process Activity Mapping

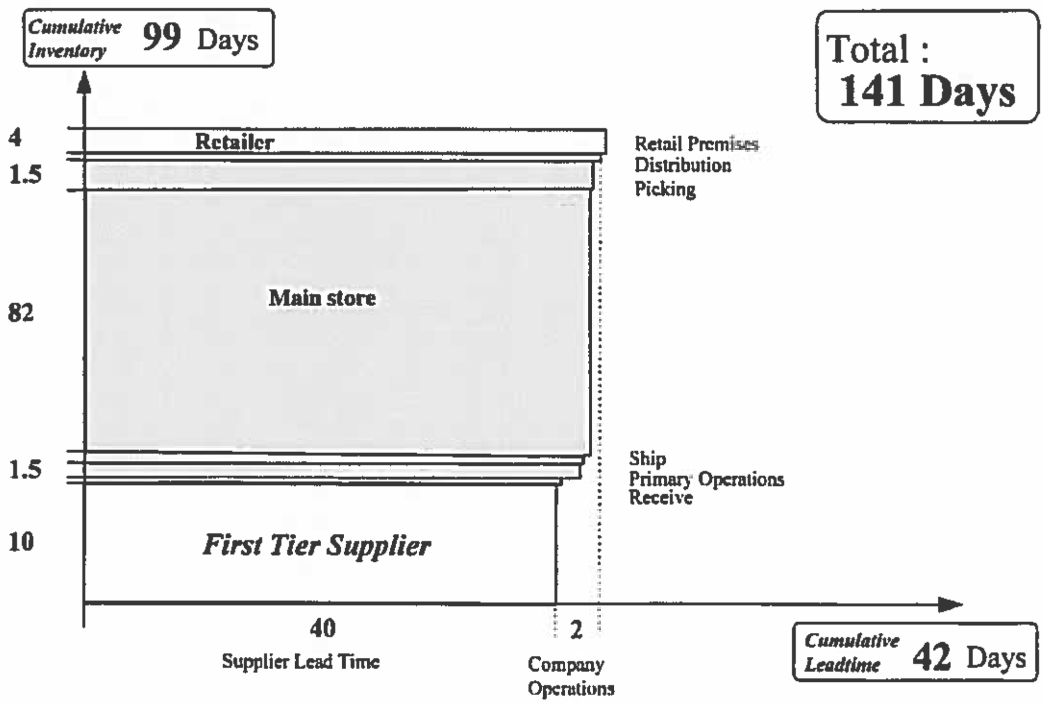
Source: (Hines & Rich, 1997)

#	STEP	FLOW	MACHINE	DIST(M)	TIME(MIN)	PEOPLE	OPERATION	TRANSPORT	INSPECT	STORAGE	DELAY	COMMENTS
1	RAW MATERIAL	S	RESERVOIR				O	T	I	**S**	D	ADDITIVES
2	KITTING	O	WAREHOUSE	10	5	1	**O**	T	I	S	D	
3	DELIVERY TO LIFT	T		120			O	**T**	I	S	D	
4	OFFLOAD FROM LIFT	T			0.5	1/2	O	**T**	I	S	D	
5	WAIT FOR MIX	D	MIX AREA		20		O	T	I	S	**D**	
6	PUT IN CRADLE	T		20	2	1/2	O	**T**	I	S	D	
7	PIERCE/POUR	O	MIX AREA 12		0.5	1	**O**	T	I	S	D	
8	MIX(BLOWERS)	O			20	1/2	**O**	T	I	S	D	BASE MATERIAL BLOW& ADDITIVES
9	TEXST #1	I			30	1+1	O	T	**I**	S	D	SAMPLE/TEST
10	PUMP TO STORAGE TANK	T	STORE TANK	100		1	O	**T**	I	S	D	DEDICATED RESERVOIR
11	MIX IN STORAGE TANK	O	STORE TANK		10	1	**O**	T	I	S	D	
12	J.R. REST	I			10	1+1	O	T	**I**	S	D	STAMP& APPROVE

The second tool, the **supply chain response matrix**, helps identify the critical lead-time activities constraining the process, aiming to target these activities for improvement. Figure 6 shows an example of a supply chain response matrix by Hines and Rich (1997:64). The horizontal axis relates to the lead-time for the product. In this example, the cumulative lead time is 42 days. The vertical axis shows the cumulative inventory in the supply chain, which represents an additional 99 working days. Therefore, the total lead time can be calculated as 141 days. Each of the activity lead-times can be targeted for improvement (Hines & Rich, 1997:64).

Figure 6: Supply Chain Response Matrix

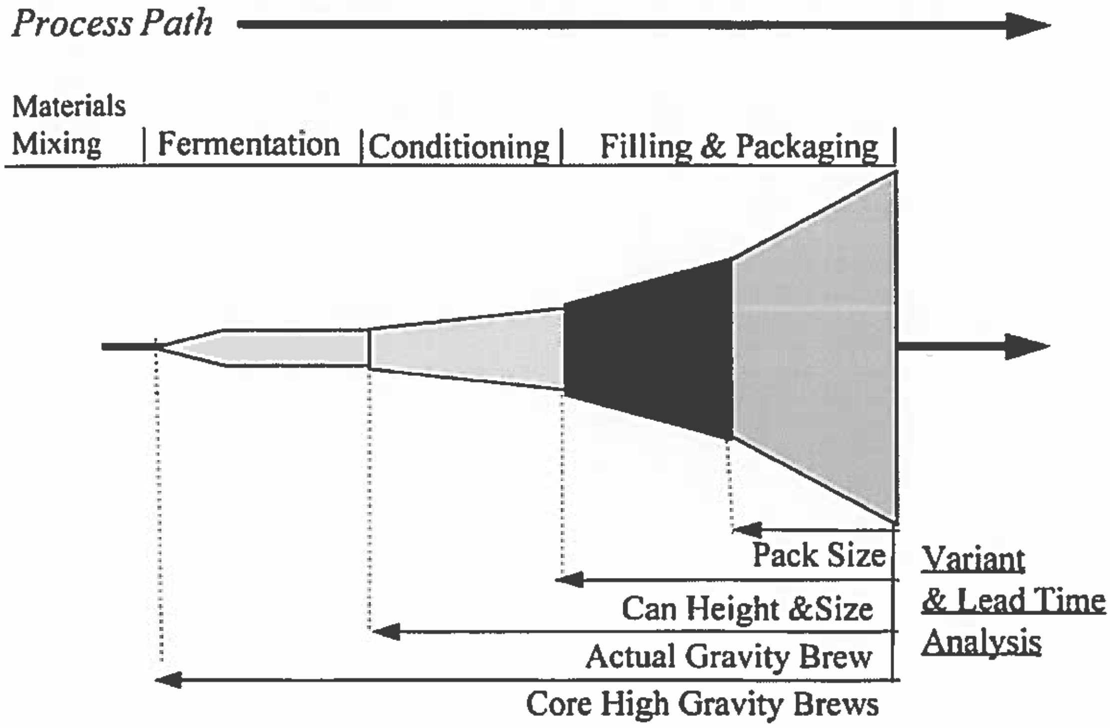
Source: (Hines & Rich, 1997)



The third tool, the **production variety funnel**, assists in understanding how products are produced and how a company or supply chain operates. According to Hines and Rich (1997:46), this tool helps the mapper to target inventory reduction and gain an overview of the company. Figure 7 shows the production variety funnel of a brewing industry case.

Figure 7: Production Variety Funnel

Source: (Hines & Rich, 1997)



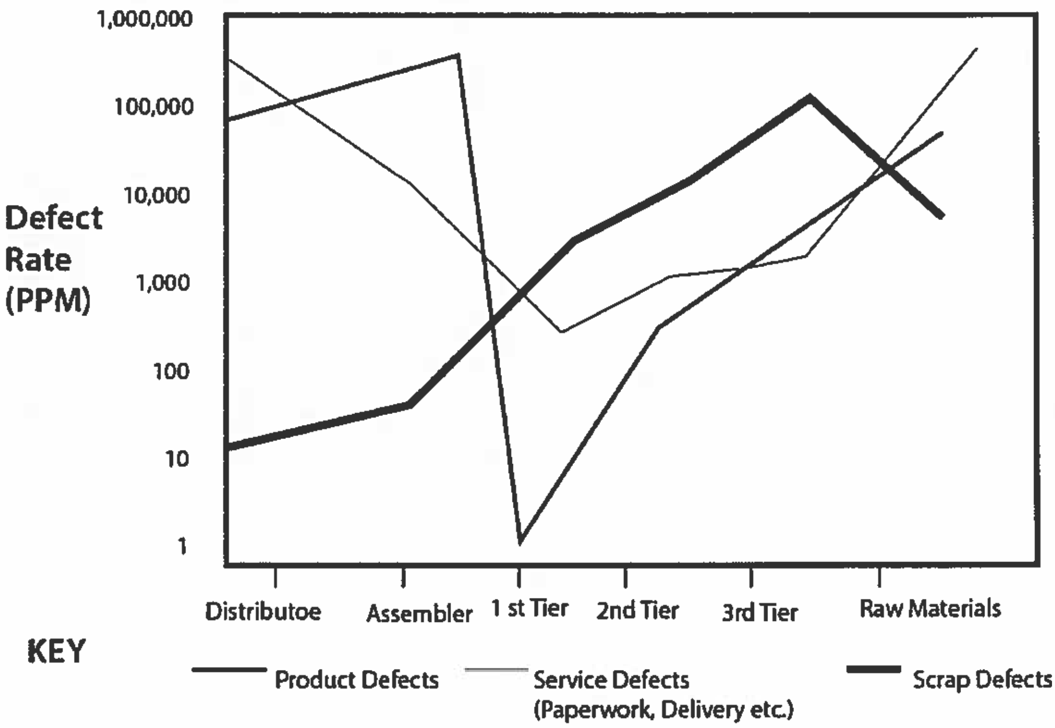
The fourth tool, **quality filter mapping**, helps to identify where quality problems occur. Hines and Rich (1997:46) indicate that there are three types of defects, namely:

- Product defects, which occur when defects are not timeously identified by inspections and are passed to customers.
- Quality or service defects can be identified in examples such as inappropriate delivery (early or delay), or any defect associated with customer experience.
- Internal scraps, which refer to product defects that have been pinpointed by inspection checks.

It is easier to identify where defects are occurring and to make improvement to minimise waste when using the mapping process. These three defects are then mapped out in a manner similar to the example in Figure 8.

Figure 8: Quality Filter Mapping

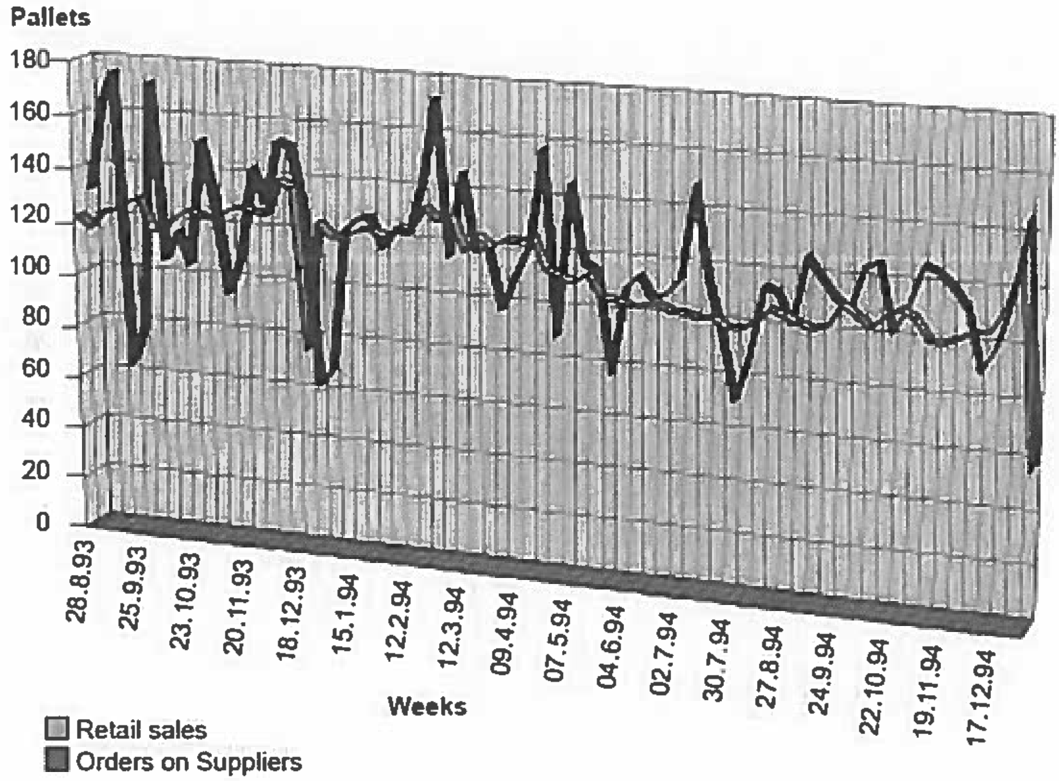
Source: (Hines & Rich, 1997)



The fifth tool, **demand amplification mapping**, assists in analysing demand variability. A demand amplification map indicates how demand varies along a supply chain, an analysis is conducted and decisions can be made using the information. Figure 9 is an example of a demand amplification map. Two curves are plotted on a graph with the lighter shade curve representing actual customer sales while the darker curve represents orders placed with the supplier to fulfil the order. From the map, one can ascertain that the variability of supplier orders is much higher than the consumer sales. Analysing the demand changes along the supply chain assists in managing the fluctuations or in redesigning the value stream (Hines & Rich, 1997:64).

Figure 9: Demand Amplification Mapping

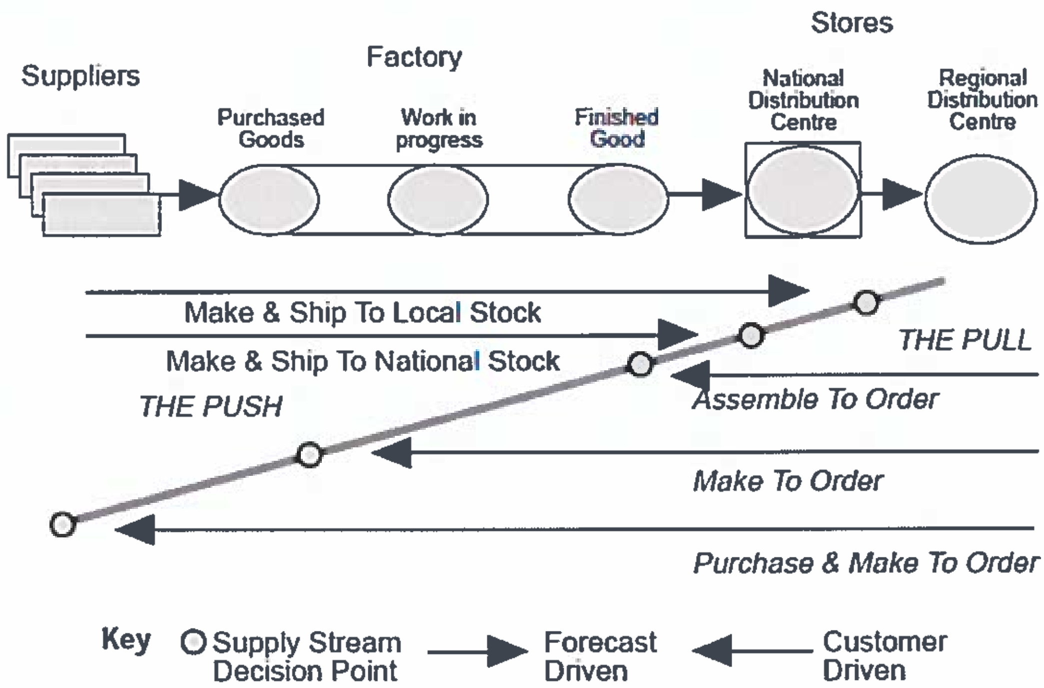
Source: (Hines & Rich, 1997)



The sixth tool, **decision point analysis**, aids in identifying "the point in the supply chain where actual demand-pull gives way to forecast-driven push" (Hines & Rich, 1997:51). In other words, the tool shows the point where products stop being made according to actual demand and are made according to the forecast. Figure 10 is an example that shows the decision point analysis. Knowing where the point is, enables the planner to assess the processes operating upstream and downstream from this point. The purpose is to make sure they are working under the same pull or push philosophy. From a long-term perspective, it provides various scenarios to in an attempt to ascertain what the result would be, if the point is moved (Hines & Rich, 1997:51).

Figure 10: Decision Point Analysis

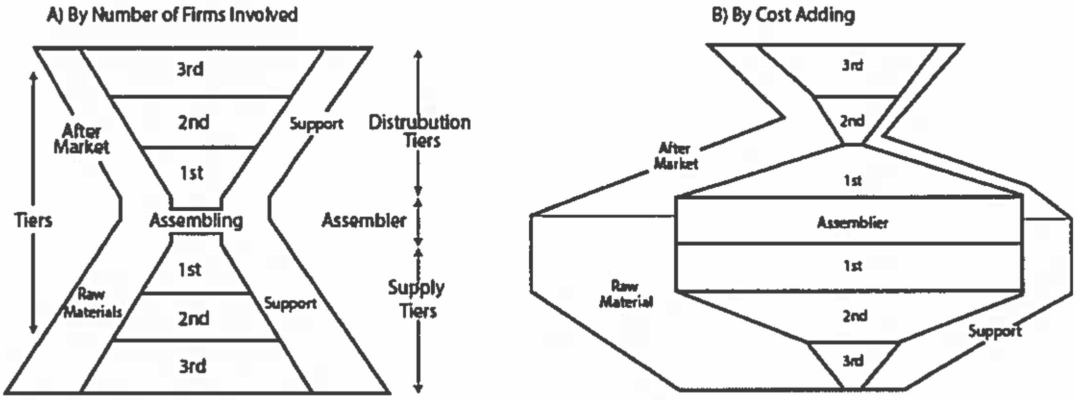
Source: (Hines & Rich, 1997)



The seventh tool, **physical structure**, provides an overview of the supply chain at an industry level. It helps with understanding related to how an industry operates and draws attention to areas that may need improvement. Figure 11 illustrates the physical structure mapping tool, which can be split into volume structure and cost structure.

Figure 11: Physical Structure

Source: (Hines & Rich, 1997)



The seven tools introduced above can be applied in combination or singularly, based on the requirements of the individual value stream (Hines & Rich, 1997:64). Hines and Rich (1997:64) maintain that it is vital to choose the most relevant of these tools in a bid to effectively eliminate the waste in any value stream.

2.5.2.5 Value Stream Mapping in Construction

The application of the value stream mapping tool, which represents the main principles of *lean* production, has also been introduced to the construction industry, although it has not yet been fully circulated in this field (Fontanini & Picchi, 2004:587). Value Stream Mapping studies with regard to construction are rare, and place more emphasis on construction supplies rather than on productive process (Fontanini & Picchi, 2004:587).

Yu *et al.* (2009:790) states that there are a number of factors that hinder the application of value stream mapping to the construction industry. These factors include:

- The repetition of the production process, that is an underlying precondition for VSM. The nature of VSM as a quantitative tool that uses a list of process data to depict the current state of the process as well as to determine what the future state will be. However, most of construction companies usually do not comprehensively track the construction processes and data.

- Key concepts and or elements used in VSM, such as inventory, cycle time, takt time (the maximum amount of time in which a product needs to be produced in order to satisfy customer demand) and change-over time that are defined in the manufacturing context and seem not applicable to construction.

Due to vast differences between manufacturing and construction, Pasqualini and Zawislak (2005:124) conclude that the modification of Value Stream Mapping is necessary since they found that the results, which appeared to be possible, are:

- The production in a continuous (or almost continuous) flow,
- Supplies reduction,
- Reduction of stoptimes,
- Better exploitation of the workforce,
- The possibility to reduce lead-time in masonry production,
- Executing work in a shorter time than what was initially programmed.

This way, the production process in apartment building construction would be possible with lower costs, higher quality and speed, and the abilityto respond to the demands of its market in terms of costs, deadlines and quality.

2.5.3 5S Principles

The 5S principles are a simple tool for organising the workplace in a clean, efficient and safe manner to enhance your productivity, visual management and to ensure the introduction of standardised working (Salem *et al.*, 2006:176).

The 5S principles are generally intended to eliminate waste as stated by Osada (1991:134). Working in disorder is neither productive, nor safe. According to Osada (1991:135), the 5S principles are a simple and practical method to instil a quality-orientated culture in the workplace. It is relatively easy to undertake, and requires minimal additional resources (Osada, 1991:135).

According to Osada (1991:134), the main benefits of implementing the 5S principles are:

- The workplace becomes *clean*er, safer, well-organised and more pleasant;
- The improvement of floor space utilisation;
- Workflow becomes smoother and more systematic and non-value added activities are reduced;
- Time spent searching for tools, material and documents is significantly reduced.;
- Machine breakdowns are reduced since *clean* and well-maintained equipment breaks down less frequently and problems also become easier to diagnose and repair before actual breakdowns occur, thereby extending equipment life;
- Errors are minimised, leading to making defect-free products;
- Consumables and material wastage are minimised;
- The morale and satisfaction of employees improves; and
- The productivity of the organisation improves, together with the quality of products and services.

The principle behind this method is visual control, which relates to surface problems and aims to improving the work environment. The idea is to *clean* and organise the workplace to the point where problems would be visually obvious (Osada, 1991:134).

When applied to construction, the following is applicable (Salem *et al.*, 2006:176):

- "Sort" refers to separating necessary tools, parts, and material from the unneeded ones (waste).
- "Straighten" refers to organising those tools, parts, and materials in stacks or bundles, making them easier to find and use.
- "Shine" refers to simply *clean*ing up the stacks of tools, parts, and materials.
- Standardise" refers to maintaining the first three S's.
- "Sustain" refers to making the 5S process both habitual and consistant.

According to Salem *et al.* (2006:176), this tool is similar to the 5S housekeeping system found in *lean* manufacturing. The material layout is commonly used for the acceleration of 5S implementation on construction sites (Salem *et al.*, 2006:176).

Ogunbiyi et al. (2014:107) refers to the fact that the 5S principles are an area-based system of control and improvement. The benefits of the implementation of 5S in the construction environment include improved safety, productivity, quality, set-up-timesand creation of space, reduced lead times, cycle times, increased machine uptime, improved morale, teamwork, and continuous improvement (Salem *et al.*, 2006:176).

2.6 PROCESS IMPROVEMENTS METHODOLOGIES

It is important to note that Process Improvements Methodologies do not form part of *lean* manufacturing or *lean* construction, but interlock with these two concepts. Process Improvements Methodologies focus on the quality of the output, while the lean form of management and construction focuses on the amount of materials or items passing through a system or process.

The Process Improvements Methodologies to be discussed, are as follows:

- Six Sigma; and
- Total Quality Management

2.6.1 Six Sigma

Six Sigma, which was initiated by Motorola, received huge interest by professionals after General Electric and Allied Signal overcame cultural challenges within their organisations (Peng & Hui, 2004:489). Many studies have defined Six Sigma pertaining to their own viewpoints, as indicated in Table 2:

Table 2: Defining Six Sigma

Author	Definition
Harry and Schroeder (2000)	A disciplined method of using extremely rigorous data gathering and statistical analysis to pinpoint sources of errors and ways of eliminating them.
Snee and Hoerl (2003)	"A strategic approach that works across all processes, products, company functions and industries."

Antony and Banuelas (2002)	A business strategy and systematic methodology, the use of which leads to breakthrough quantum gains in product/service quality, customer satisfaction and productivity.
Kwak and Anbari (2006)	A business strategy that focuses on improving customer requirements understanding, business systems, productivity, and financial performance.
Peng and Hui (2004)	A "cultural and belief" system and "management philosophy" that guide the organisation in repositioning itself in world-class business performance by increasing customer satisfaction considerably and enhancing bottom lines based on factual decision-making.

Six Sigma has two key methods, namely (Kwak & Anbari, 2006:715):

- DMAIC process (Define, measure, analyse, improve, control);
- DFSS methodology (Design for Six Sigma).

2.6.1.1 DMAIC Process

This method relates to existing processes which require significant improvement due to falling below expected quality specification, according to Forbes and Ahmed (2010:76).

Stamatis (2004:45) notes that DMAIC methodology and its main steps can be summarised as follows:

- **Define.** The first stages of DMAIC relate to forming teams, determining the responsibilities of team members, establishing team goals and reviewing the process steps which are (Stamatis, 2004:45):

- Define the problem: The problem should be based on measurable data and be specific;
- Identify the customer: Identification of the customer includes the analyses of problem impacts and a detailed analysis of COPQ (Cost of poor quality);
- Identify CTQ characteristics: Identification of CTQ (Critical to quality) is the determination of the important issues concerning customers;
- Map the process: A visual representation of the existing process should be prepared in order to look beyond functional activities and the core process;
- Scoping the project: Reduction of project scope is the main focus of this step. Specific project issues are determined with a problem statement and brainstorm session being the purpose of scoping the project.

- **Measure.** This is the second stage of DMAIC and relates to having a plan for data collection, preparing a sufficient data sample and preliminary analysis of this sample. In this stage, Six Sigma analyses current performance through valid data in order to understand improvement opportunities and identify KPIV (Key process input variables). The basic steps of this stage are (Stamatis, 2004:45):

  - Identify measurement and variation: Types, sources, causes and detailed impacts of variation on process should be defined by the establishment of measurement;
  - Determine data type: Six Sigma team should define the data types that will be collected. The main focus is to decide what kind of data and knowledge are required for process improvement;
  - Develop a data collection plan: Data collection plans provide data collection and are responsible for data-displaying formats;
  - Perform a measurement system analysis: Graphical and baseline analyses should be performed through MSA (Measurement System Analysis) to ensure that the data collection plan works accurately and the collected data are kept confidential;

- Collect the data: Collected data should be properly gathered and provide enough information to the Six Sigma team to enable them to determine the root causes of the particular problem.

- **Analyse**, the third stage of DMAIC, is aimed at finding the root causes of defects and identifying the right approach styles to data and improvement opportunities. The basic steps found in this stage are (Stamatis, 2004:45):

    - Perform a capability analysis: Baseline capability should be realised in order to understand performance level of the process;
    - Select analysis tools: The Six Sigma team should control the graphical analysis and decide which tools will be used in order toidentify the various details of variation and performance;
    - Apply graphical analysis tools: A visual performance indication should be realised through graphical analysis techniques;
    - Identify the sources of variation: Statistical tools are used in order to define the variations sources. The main focus in this step is to locate and repair significant variations.

- **Improve**, the fourth stage of DMAIC, pertains to designing, implementing and validating the improvements. This stage includes FMEA (Failure Mode and Effect Analysis), a preliminary cost/benefit analysis and preparation of necessary actions. The basic steps that make up this stage are as follows (Stamatis, 2004:45):

    - Generate improvement alternatives: The focus of this step is to define, generate and evaluate tpossible improvements;
    - Create a "should be" process map: This entails the mapping of the best improvement opportunities by the Six Sigma team;
    - Conduct FMEA (Failure Mode and Effect Analysis): This analysis is used in order to analyse the “before the failure” situation;
    - Perform a cost/benefit analysis: A Ccst/benefit analysis consists of a comparison between expected benefits and improvements costs;

- Conduct a pilot implementation: The implementation of planned improvements should be conducted on a small scale;
- Validate improvement: Sigma values before and after "Improve Stage" should be compared in order to understand the effect of process improvement.

- **Control**, the final stage of DMAIC, relates to the institutionalisation of process/product improvements and following performance. This is a transition phase of process from the Six Sigma team to the original executers, by means of a detailed control plan. The basic steps are (Stamatis, 2004:45):

  - Mistake-proofing: The main focus of this step is toremove any error possibilities. It is important to remove the possibility of errors before they are able to elicit defects in the process;
  - Long-term MSA (Measurement System Analysis): Data collection should be distributed over the long-term in order to measure and monitor inputs/outputs of process improvements through Measurement System Analysis;
  - Appropriate and applicable charts (statistical process control): Graphical representation of process should be produced in order to control processes with lower and upper limits;
  - Reaction plan: This is a detailed plan pertaining to controlling issues and implementing necessary actions, shouldthe revised process be no longer under control;
  - The new or revised SOPs (standard operating procedures): The Six Sigma team should periodically revise the existing documents and procedures in order to reflect improvement results (Stamatis, 2004:45).

2.6.1.2 DFSS Methodology

DFSS can be defined as a systematic methodology used for designing new products and/or processes at Six Sigma quality levels (Kwak & Anbari, 2006:715). If the existing products or processes have inherently faulty designs, DMAIC methods cannot successfully repair them. However, DFSS can prove successful on new products or process developments, and meet customer expectations for performance, quality, reliability and cost (Sleeper, 2006:261).

Due to being relatively new, DFSS has more than one road-map in use, for example(Sleeper, 2006:261):

- ICOV (Identify, Characterise, Optimise, and Verify) ;
- CDOV (Concept, Design, Optimise, Verify) ;
- DMADV (Define, Measure, Analyse, Design, Verify);
- PIDOV (Plan, Identify, Design, Optimise, and Validate).

For the purpose of this study, PIDOV is summarised as follows (Sleeper, 2006:261):

- **Plan**: Developing goals and metrics for Six Sigma projects considering VOC (Voice of the Customer) is the main focus of this phase. DFSS team should decide which ideas will be developed and how they will be structured;
- **Identify**: Identification of product concepts that satisfy customer requirements is the main purpose. Focusing on VOC (Voice of the Customer) by the way right tools, is the prerequisite of success;
- **Design**: New products and processes should be designed by engineers, based on functions and statistics. Drawings and specifications have to be developed in this step;
- **Optimise**: The main issue is one of creating a balance between quality and cost. Statistical methods are used in this phase to make products and processes less sensitive to variations;
- **Validate**: Data should be collected from prototypes and appropriate tests should be conducted in order to validate customer requirements. The balance between quality and cost has to be controlled through Statistical Process Control tools and methods.

2.6.2 Total Quality Management (TQM)

The purpose of process improvement in the construction industry is to produce something of equal or better quality at a lower cost. However, there are various systematic approaches which are looking to attain total quality and lead to process improvement in the construction industry (Stewart & Spencer, 2006:348).

Process improvement methods under Total Quality Management include the following (Stewart and Spencer, 2006):

- Process Cost Model;
- Standardised Process Improvement for Construction Enterprises (SPICE);
- The Balanced Scorecard;
- Kaizen; and
- Statistical Process Control

Total Quality Management methods are defined as follows (Stewart & Spencer, 2006:348):

2.6.2.1 Process Cost Model

Quality costs are arguably the most important success factors of a quality management system. This means that poor quality impact on cost and performance should be measured in order to forewarn company management who can realise preventive actions and beneficial activities of potential losses (Tang *et al.*, 2004:275).

The main purpose of this model is to measure the quality costs of specific processes rather than the quality costs of total project (Tang *et al.*, 2004:275). The Process Cost Model, which uses financial theory, is a process–oriented perspective related to customer satisfaction and continuous process improvement (Stewart & Spencer, 2006:348).

The method's most significant weak point is the use of financial metrics, which cannot properly monitor and measure multiple dimensions of performance (Stewart & Spencer, 2006:348).

2.6.2.2 Standardised Process Improvement for Construction Enterprises (SPICE)

SPICE, as a process improvement framework, is proposed by Sarshar *et al.* (2004:82) in order to look beyond financial measures (Stewart & Spencer, 2006). The main focus of this method is to measure performance considering process maturity, their strengths and weaknesses (Sarshar *et al.*, 2004:82). SPICE was established on the principles of the Capability Maturity Model and evaluates process success as a function of organisation maturity (Stewart & Spencer, 2006:348).

The Capability Maturity Model, which was developed by Carnegie Mellon University, is a process improvement tool designed for software industry and has been reused within the construction context (Sarshar *et al.*, 2004:82).

2.6.2.3 The Balanced Scorecard

Kaplan and Norton (1992:79) introduced The Balanced Scorecard in order to link performance and measures. This method provides a balance, pertaining to project performance and measures various perspectives of performance (Stewart & Spencer, 2006:348).

The Balanced Scorecard evaluates business from four different perspectives (Kaplan & Norton, 1992:79), namely a:

- Customer perspective;
- Internal perspective;
- Innovation and Learning perspective; and finally
- A Financial perspective

Nevertheless, Sommerville and Robertson (2000:466) states that there is resistance to the adoption of holistic Total Quality Management approaches in the construction industry. For this reason, the implementation of this method may prove difficult in the construction industry.

2.6.2.4 Kaizen

Stewart and Spencer (2006:348) note that this process improvement perspective contributes immensely to the economic growth of Japan.

According to Stewart & Spencer (2006:348), eliminating waste, managing time and cost and reduction of services values are the main aim of Kaizen. However, the integration of Total Quality Management and Kaizen may be difficult to implement since their aims and ideas are similar to each other (Stewart & Spencer, 2006:348).

2.6.2.5 Statistical Process Control

Statistical Process Control is used to follow and improve the manufacturing processes and operations and plays an important role in quality improvement processes (Woodall, 2000:350).

This models attempts to analyse process defects and reduce them by root cause analyses and problem-solving methods (Stewart & Spencer, 2006:348). Statistical Process Control, which is based on data-oriented and decision-making analysis, has assisted the evolution of Six Sigma (Stewart & Spencer, 2006:348).

2.7 CHAPTER CONCLUSION

To conclude, a drive is necessary to implement the Last Planner System (LPS) in order to create a master schedule, a look-ahead schedule, and a weekly work-plan through front-end planning, look-ahead planning, and commitment planning. This will support an establishment such as a university by adding reliability in planning by means of stabilising workflow.

Given the current volatility of the tertiary sector in South Africa, value stream mapping as a *lean* construction tool should be introduced to allow the Department of Physical Infrastructure and Planning to process data in order to illustrate their current state of process and to determine what their future state will be.

By applying the 5S process, a culture of quality would be instilled in the employees, which would in turn help reduce waste and allow the incorporation of process improvement methodologies such as Six Sigma and Total Quality management, into their processes, with the goal of establishing effective planning.

2.8 SUMMARY

This chapter aims to provide an overview of *lean* manufacturing and *lean* construction as a management philosophy, in the form of a literature study. On the basis of the literature study, a theoretical description of *lean* manufacturing and *lean* construction is presented. It also highlights various *lean* manufacturing tools incorporated in *lean* construction with the emphasison throughput, with some process improvements methodologies focusing on quality in order to establish effective planning in a construction environment at a tertiary institution.

The following issues were identified with regards to the literature study, and similarities will be highlighted in the case studies:

- Poor development of the business case for *lean*;
- Insufficient understanding of *lean* principles and Process Improvement Methodologies;
- Insufficient top management focus and involvement;
- Insufficient communication: Too Little, Too Complex, Too Simple.
- Poor organisational and leadership development;
- Lack of proper metrics to determine performance and isolate challenges;
- Lack of middle-management buy-in;
- Weak deployment strategy;
- Insufficient or inappropriate training;
- Re–work;
- Unreliable workflow;
- Lack of appropriate scheduling and production control;
- Ineffective and time consuming circle time;
- Insufficient focus control on the complete process;
- Lack of bench-marking;
- Inappropriate match of labour and related resources to workflow;
- The inability to identify operations to be planned jointly by multiple trades;
- The lack of visualising non-visible work; and
- The absence of Process Improvements Methodologies.

3 CHAPTER 3: EMPIRICAL STUDY

3.1 INTRODUCTION

This chapter is comprised of three parts. The first part of the chapter focuses on research design in terms of the research approach, and it presents the research methods to be used, namely the research setting, initiating and establishing researcher roles, sampling, data collection method, recording of data, and data analysis. The second part of this chapter will review previous case studies pertaining to the objectives of this study. In addition to the aforementioned two parts, the third and final segment will evaluate the current study conducted at the Department of Physical Infrastructure and Planning of the North-West University. This final part will also assess the findings of the structured interviews held with the relevant stakeholders, in order to determine whether selected *lean* principles should be incorporated to establish effective planning at a tertiary institution.

3.2 RESEARCH DESIGN

3.2.1 Research Approach

There are currently two broad research approaches, namely quantitative and qualitative research. The nature of this study is such that a qualitative research method is applicable.

Denzin and Lincoln (2003:82) define qualitative research as a situated activity that locates the observer to the world. It consists of a set of explanatory material practices that allow the domain to become evident and then alter it. It also changes the domain into a series of demonstrations, including field notes, interviews, conversations, photographs, recordings and memos to the self.

Qualitative research involves an interpretive, naturalistic approach to the world. This implies that this study will be conducted in the natural setting of the institution. It also attempts to make sense of, or interpret occurrences in terms of the meaning people bring to them. (Denzin & Lincoln, 2011:56)

According to Schurink (2008), establishing a widely accepted meaning for qualitative research has been far from simplistic, if at all feasible. Qualitative research involves the use and collection of a variety of empirical tools. These include case studies, personal experiences, introspections, life stories, interviews, artifacts, cultural texts and productions, observational, historical, interactional and visual texts that describe routine and problematic moments and finaly, meaning in individuals' lives. Accordingly, qualitative researchers display a wide range of interconnected interpretive practices, always striving to better understand the subject matter at hand. For them, each practice makes the world visible in a different way, as pointed out by Schurink (2008).

According to Schurink (2008), we all have different views as to how reality should be understood and these tend to vary,ranging from an objective reality that exists independent of human conception to the notion of multiple, subjective realities that are socially constructed.

3.2.2 Research Method

3.2.2.1 Literature review

Journals and publicised literature, along with previously conducted research on *lean* manufacturing and *lean* construction were examined in order to formulate the literature study.

3.2.2.2 Research setting

The research setting can be seen as the physical, social, and cultural situation in which the researcher conducts the study. In qualitative research, the focus is mainly on meaning-making, and the researcher studies the participants in their natural setting. The contrast with post-positivist, experimental, and quantitative research settings lies in the fact that in qualitative research, the investigator does not attempt to completely control the conditions of the study in a laboratory setting, focuses instead on situated activities that place her or him in the context of the research setting (Welman *et al.*, 2011:142).

This research was conducted at the offices of the Department: of Physical Infrastructure and Planning at the Institutional Office of the North West University, building number G14, on the University's Potchefstroom campus.

3.2.2.3 Access and establishing of researcher roles

The Chief Director of the Department of Physical Infrastructure and Planning granted the researcher permission to conduct interviews with several participants and to observe them in their comfortable and natural environment.

3.2.2.4 Sampling

According to Cozy (2009:7), since the main purpose of sampling is to achieve representativeness; the sample should be assembled in such a way as to be representative of the population from which it is taken. Since the department is very small, a non-probability sampling procedure was used for the selection of knowledgeable and experienced participants (Cozby, 2009:7).

The participants of this research were purposefully selected according to their involvement in the construction environment. The number of participants (10) is viewed as being sufficient. The original research design was based on saturation principles but in practice, interviews were conducted with all relevant practitioners in the relevant department. This is the motivation for using a purposive sample in selecting this specific construction environment.

3.2.2.5 Data collection methods

- Interviews

The interview is a social relationship designed to facilitate the exchange of information between the participant and the researcher. The quantity and quality of the information exchanged depends on how astute and creative the interviewer is at understanding and managing the relationship (Monette *et al.*, 2008:428).

The goal of any qualitative research interview is therefore to see the research topic from the perspective of the interviewees, and to understand why they have a particular perspective (Schurink, 2008).

Research texts typically highlight three types of interviews used in educational research, namely standardised open-ended, semi-structured and structured interviews (Denzin & Lincoln, 2011:56).

Semi-structured interviews were used in this research with the following aspects in mind:

- Focus on greater interest in the interviewee's point of view;
- It will give insight into what the interviewee sees as relevant and important;
- As a result, qualitative interviewing tends to be flexible;
- The interviewee may be interviewed on more than one and sometimes even several occasions (Denzin & Lincoln, 2011:243).

3.2.2.6 Recording of data

In instances where preceding consent was given, qualitative data collected through interview schedules are voice-recorded. The purpose of the recording of the discussion was clearly explained to the respondents, and respondents were assured that the information recorded would only be used for the purpose of the study. Recordings were then analysed for common themes and these detected themes were incorporated into the analysis of the data

3.2.2.7 Data analyses

A content analysis method was used during this study. According to Blanche and Durrheim (2002:209), qualitative data analysis tends primarlity to be an inductive process of organising data into categories and identifying patterns. The most general guide to analysing qualitative data involves looking for similarities and variations. The focus should be on those patterns of interactions and events that are generally common to what the researcher is studying (Babbie, 2013:402).

Certain keywords on the recordings were identified, analysedand thensorted whereafter conclusions were made.

3.3 PREVIOUS CASE STUDIES

3.3.1 The Oscar J. Boldt Construction Company

This case study, as described by Diekmann *et al.* (2005:54), examined the following *lean* principles, methods and/or tools:

- Work structuring;
- Implementation of the "5-Whys" to determine root causes of problems/errors;

This case study focuses on the construction of the Red Ganite Correctional Institution in Wisconsin. The project consisted of two housing buildings that covered a total of 140000 square feet. The Oscar J. Boldt Construction Company was appointed as the construction manager with Venture acting as the project architect. The state awarded Boldt this project based upon a guaranteed price of $48 million Diekmann *et al.* (2005:54).

This case study provided the opportunity to explain how organisations may devise alternative ways to perform their work when not controlled by contractual agreements and trade boundaries. It also demonstrated the importance of dimensional tolerances in construction and how these affected the transfer of work chunks from one production unit to the next (Diekmann *et al.*, 2005:54).

While the "5 WHYs" is a good approach to the initial development of a better work structure, it is hardly enough to cover all aspects of work structuring. The "5 WHYs" addresses the following questions of work structuring:

- How will work chunks be divided and assigned to specialists?
- How will work chunks be sequenced?
- When will different chunks of work be done? Future research efforts will explore how to deal with the previously listed questions as well as the other work structuring questions.
- How will work be released from one production unit to the next?
- Will consecutive production units execute work in a continuous flow process or will their work be de-coupled?
- Where will de-coupling buffers be required and how should they be sized?

This case study, as an example of the use of the 5 Why method, indicates that the following five "why" questions were asked during this project in order to enhance works structuring:

- **Why did caulking and foam backer rods blow out?** Caulking and backer rods blew out because of the hydrostatic pressure developed by wet grout during the grouting process.
- **Why did grout leak through the cracks?** Grout leaked through the cracks because of the pump pressure and the thin grout mixture.
- **Why was the grouting of the hollow metal door frame required?** We do not know the origin of the grouting requirement but can speculate that grout adds to prison security firstly, by protecting the anchor bolts that connect the frame to the wall, secondly by providing a bond between the frame and the wall while also making the frame heavier should an inmate attempt to push out the frame, thirdly by preventing inmates from hiding objects in the hollow frame and lastly, by making it more difficult to disable the electrical lock mechanism inside the frame of certain security doors.
- **Why were there cracks between the door frames and precast panels?** Firstly, door frame installers require a 1/8" (3.2 mm) or so opening between the frame and the wall to make it possible to slide the frame into the panel opening and properly plumb it. Secondly, this opening may vary in size along the frame as a result of dimensional tolerances (stochastic variation relative to the design dimensions of a product) during manufacturing and the placement of the concrete walls and metal frames.
- **Why are door frames and panels manufactured separately?** These two parts are manufactured independently because they require different materials, knowledge, skills, and fabrication tools. Industry specialisation has further led to this division of labour.

Tradesmen such as construction managers, architects, fabricators and manufacturers, do not necessarily complain about site problems because of the following reasons:

- Contractually speaking, site problems may be considered theirs to resolve;
- They may have more important problems to address such as developing bargaining tactics and determining which battles to fight; and

- Complaining might reflect poorly on their trade skill and pride, ("tricks of the trade") so they are under the impression that workarounds are what they are supposed to do.

3.3.1.1 Summary

The case illustrates the consequences of poor decision-making pertaining to work structuring. The involvement of specialist suppliers and service providers in design is supported by *lean* practices (Gil *et al.*, 2000).

The architect decided on the work structure by designing the system of walls and doors, with regards to this project. Collectively, the wall fabricator and door frame manufacturer might have developed a better system design, had they not been contractually restrained.

The following factors were identified as key areas for project improvement:

- The use of design and construction project delivery does not ensure integrated product–process design.
- Traditional work breakdown structure (WBS) prevents project participants from seeing opportunities for systemic change. Consequently, project participants failed to see the walls and door frames as a single enclosure system of significant value to the owner.
- Local optimisation can be detrimental to global optimisation. It is possible that installers may not see that process design problems are linked to insufficiencies in product design. They do not provide frequent feedback to project planners to encourage modifications of the product design to better support process design.

The following interrelated aspects pertaining to the 5S process can be seen by asking the "5 Why" questions:

- Sort: The "5 why" questions resulted from distinguishing between the needed items and the unneeded items;
- Strengthen: It was found that the correct items were to be designed, sourced and/or stored in the correct place for easy access;

- Shine: From the "5 why" questions, it can be concluded that the work place should have frequent feedback;
- Standardised: It is clear that from the results of the questions that a method of habitually implementing the above-mentioned three was required;
- Sustain: In order to accomplish their desired result, required sustainable procedures had to be established.

3.3.2 PARC Project

This case study examined the following *lean* principles, methods and/or tools:

- Increased production planning;
- Work method design;
- Decrease variability - increase reliability;
- Continuous improvement; and
- Increased project coordination.

The PARC project was a refinery expansion costing approximately $2.1 billion. In 1994, consultants Mike Casten, Greg Howell and Glenn Ballard initiated a productivity improvement program at the PARC project following an initial site visit and diagnosis. An increase in labour force of 10 000 to 18 000 was required due to poor labour productivity but this was not an option because of a lack of skilled workers and the inability of the project to accelerate the supply of work (Diekmann *et al.*, 2005:54). As a result, this project focused on production planning since their current planning methods were deemed insufficient to complete the job. They had to change their project management model from a contract management model to a production management model, which would be adapted to the way work is done (Diekmann *et al.*, 2005:54).

The following three factors were highlighted as key areas for project improvement:

- How well the project is supplying the basic elements of work to the crews. These elements include information, materials, tools, equipment, etc.
- The method used by the crew to perform the work.
- How well the accomplishment of the work itself meets the needs of the workers.

3.3.2.1 Summary

This case study indicated that the implementation of production planning in order to increase the reliability of the sub-contractors' work-plans, allowed them to better match labour to their work and identify reasons why work was not being completed (Diekmann *et al.*, 2005:54).

The findings of this case study coincide wwith the literature study on the Last Planner System (LPS). It was established that in order for the PARC project to increase planning reliability, the team of professional consultants had to introduce sub-contractors to the Last Planner System, which was developed to improve production planning. The LPS includes the following (Diekmann *et al.*, 2005:54):

- Using six-week look-ahead schedules;
- Screening processes for creating workable assignments;
- Sizing assignments to crew capacity;
- Charting and acting on reasons for not doing planned work; and
- Using percentage of planned weekly assignments completed (PPC charts).

This case study also reinforced the need to improve their work method design regarding plan reliability in their design processes and also suggested improvements to the production control system required to achieve better plan reliability. This needs to take place through an incorporation of the Last Planner System (LPS), as discussed in the literature study on the basis of the following:

- Make sure project management understands the production control system and its objectives;
- Provide additional training to participants;
- Include a 'puller' on the action item log;
- Establish a look-ahead window with screening criteria for advancement;
- Track the status of assignments as they move through the look-ahead window;
- Adopt a sizing standard for assignments that consistently demand less output from production units than their estimated capacity in order to accommodate variability incapacity.

3.4 CURRENT STUDY

3.4.1 Department: Physical Infrastructure and Planning

This case study will examine the following *lean* principles in order to achieve effective planning:

- Last Planner System;
- Value Stream Mapping, and
- The 5S principles.

The planning and execution of refurbishments, large scale maintenance and new infrastructure related projects is the responsibility of The Department: Physical Infrastructure and Planning at the North West University. This is a centralised function, operating from the Potchefstroom Campus of the University which delivers this function to two more offsite Campuses, namely the Mafikeng and Vaal Triangle Campus.

On average, they handle approximately one hundred projects per year with a combined estimate of R150 million per year over the last five years. These funds are allocated from a number of sources such as capital funding of the institution and The Department of Higher Education and Training (DHET). Owing to the current economic climate and financial distress, in which South Africa, and for that matter all tertiary institutions, finds itself, it is necessary for all expenditure be carefully monitored. Therefore, all infrastructure projects must be prioritised and approved by either the Council of the North West University or the DHET.

In an environment where escalating labour and material cost can potentially deplete the entire project budget, it is important to reduce wastage to as low a level as possible. The entire Department consists of 32 employees with 6 employees reporting to the planning office. The following individuals were purposefully selected to be interviewed based on their involvement in the construction environment at the North West University and are refered to according to their current job titles:

- Architectural Technologist (3);
- Project Manager (2);
- Manager (2);

- Project Planner,
- Tender Administrator; and
- Senior Project Administrator.

3.4.2 Results of the interviews

The interviewees raised the following issues when asked to list the inefficiencies pertaining to the project approval process:

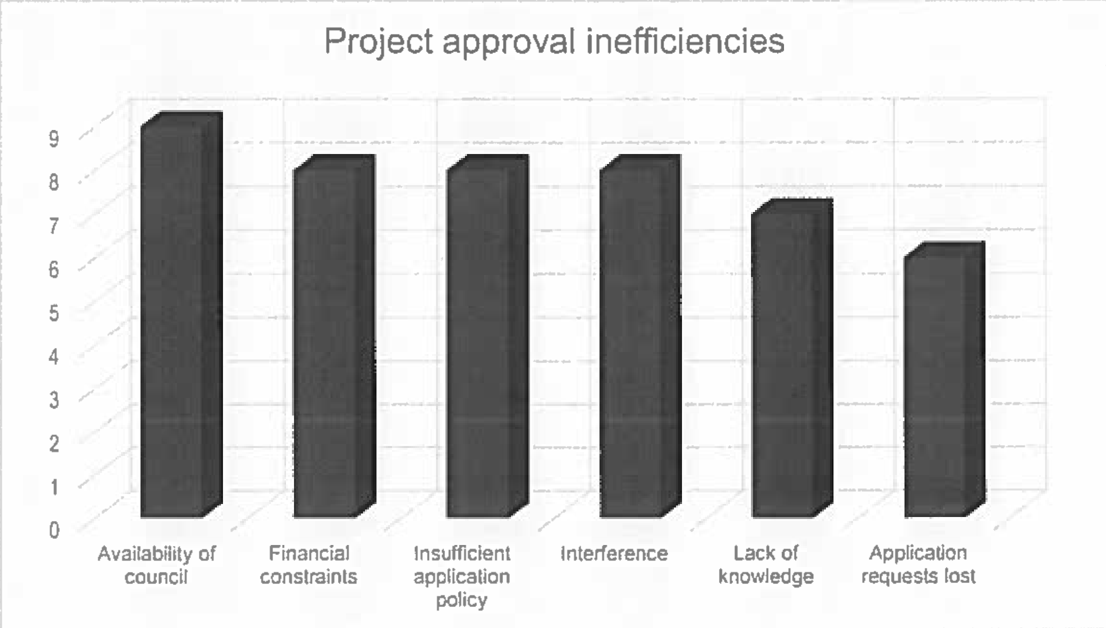
- Financial constraints;
- Lack of knowledge related to infrastructure;
- Insufficient application policy;
- Lost application requests;
- Availability of council; and
- Interference.

The above-mentioned *non–lean* factors can be identified in the literature study through the following inefficiencies:

- Insufficient understanding of *lean*;
- Insufficient top management focus and involvement;
- Communication barriers;
- Poor organisational and leadership development;
- Weak deployment strategy; and
- Insufficient or irrelevant training.

Figure 12 indicates the number of interviewees agreeing with the above-mentioned inefficiencies. It clearly shows that 90% of the interviewees agree that the availability of the council to approve projects is seen as the main contributing factor. The lowest scoring contributor is applications that get lost, scoring only 60%.

Figure 12: Project approval inefficiencies

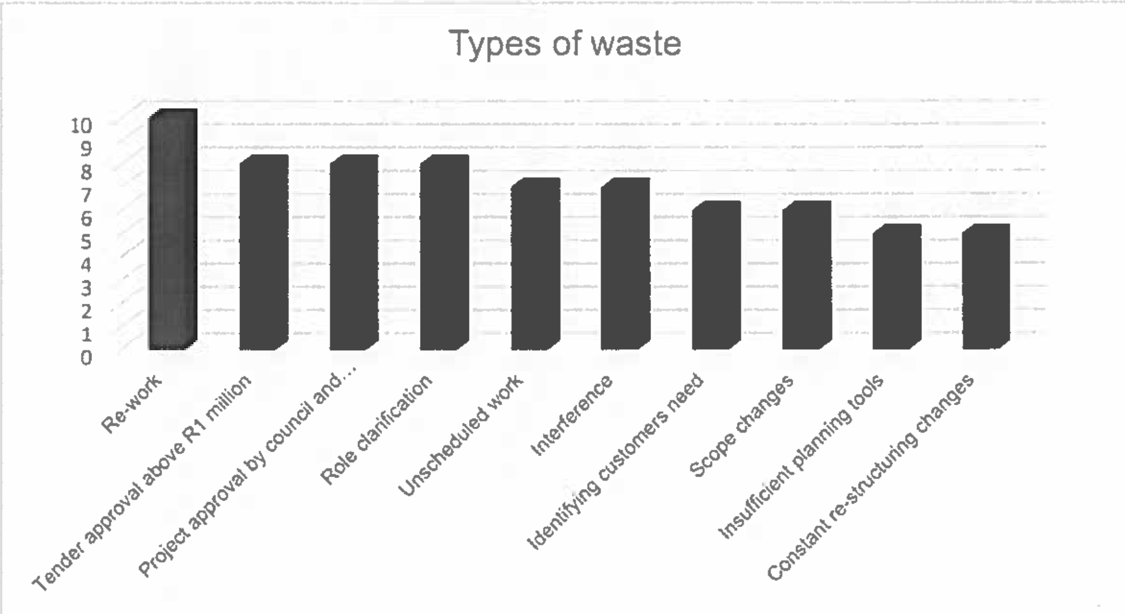


The participants raised the following issues when questioned about the types of waste experienced within their environment:

- Re-work;
- Tender approval for over R1 million;
- Identifying customer needs;
- Project approval by council and DHET;
- Unscheduled work;
- Interference;
- Lack of role clarification;
- Constant re-structuring changes;
- Insufficient planning tools; and
- Scope changes.

Figure 13 graphically illustrates the findings,indicating that 100% of the interviewees agree that re-work is the biggest contributor to wastage. The lowest contributing factors as indicated in figure 13 below are constant restructuring and insufficient planning tool, both scoring 50% of the interviewees responses.

Figure 13: Types of waste

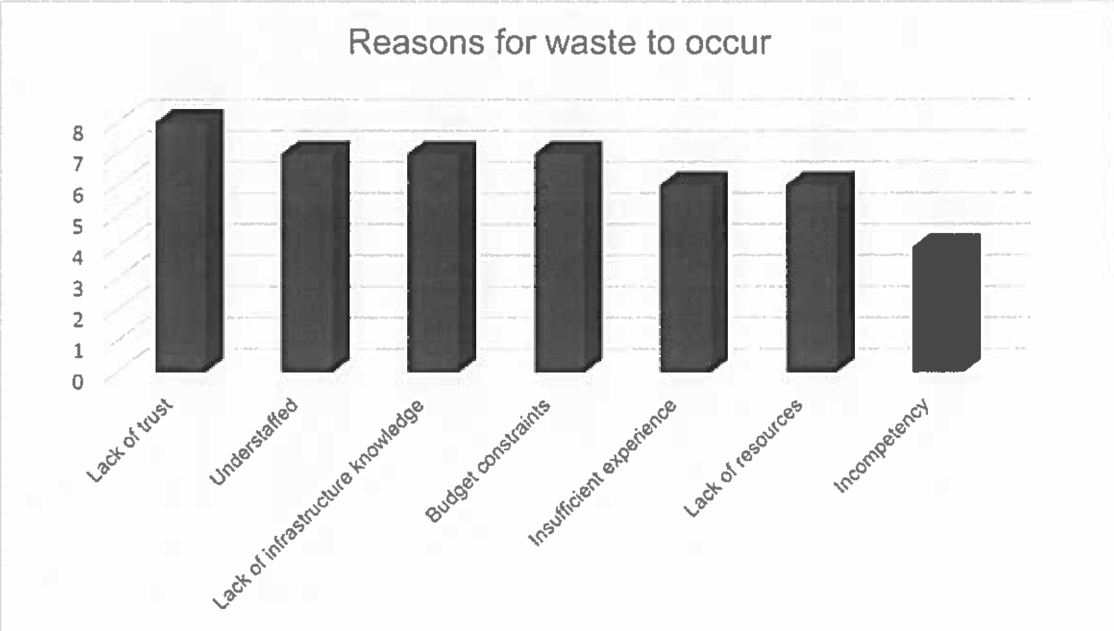


The participants indicated the following reasons for the occurence of these wastes:

- Understaffing;
- Insufficient experience;
- Incompetency;
- Lack of trust;
- Lack of resources;
- Lack of infrastructure knowledge; and
- Budget constraints.

Figure 14 demonstrates that that the main reason for occuring wastage is lack of trust, which scores 80% while thelowest contributing factor is incompetency which scores only 40%.

Figure 14: Reasons for waste to occur

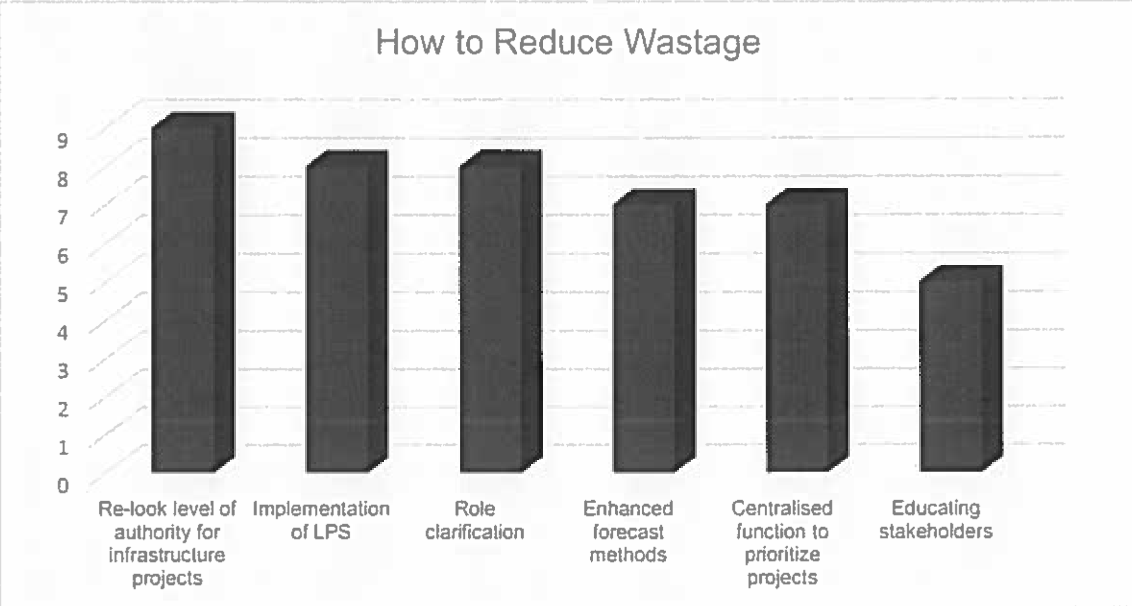


As seen in figure 15, the following ways were put forward to improve this waste:

- Re-look level of authority for infrastructure projects;
- Enhanced forecast methods;
- Implementation of LPS;
- Centralised function to prioritise projects;
- Educating stakeholders; and
- Role clarification.

Figure 15 also illustrates that 90% of the interviewees indicated that the North-West University should re-look their level of authority to accommodate infrastructure project approval and the approval of quotations. 50% of the participants are of the opinion that the education of all stakeholders, with regards to infrastructure projects, will reduce wastage.

Figure 15: How to reduce wastage



3.4 CHAPTER CONCLUSION

There is limited knowledge pertaining to *lean* principles in the Department in which the study was conducted. Wastage and causes of the wastage was determned. Re-work in terms of project design, along with time constraint in getting projects and tenders approved when the value is above R1 million, leads to the Planning Section struggling to maintain the prompt hand-over of the project to the Construction Section of the Department. This study indicated that the Department: Physical Infrastructure and Planning will benefit immensely by implementing *lean* principle tools such as The Last Planner System. Conducting these interviews in the participants' natural environment allowed for not only the above-mentioned conclusion, but alsoemphasised the importance of role clarification and the need for changes pertaining to current approval levels in order for the Department to cut down on wastage.

The literature review stressed the following problem areas, namely the:

- Re–work;
- Unreliable workflow;
- Lack of appropriate scheduling and production control;
- Ineffective and time consuming circle time;

- Insufficient focus control on the complete process;
- Lack of benchmarking;
- The unbalanced match of labour and related resources to the workflow;
- Lack of ability to identify necessatating joint operations involving multipletrades;
- The lack of visualising non-visible work; and finally
- The absence of Process Improvements Methodologies.

Issues arising from previous case studies:

- The use of design and construction project delivery does not ensure integrated product–process design;
- Traditional work breakdown structure (WBS) prevents project participants from seeing opportunities for systemic change;
- Frequent feedback is not provided to project planners in order to encourage modifications of the product design to better support process design;
- How well the project is supplying the basic elements of work such as information, materials, tools and equipment to the crews;
- The method used by the crew to perform the work; and
- How well the accomplishment of the work itself meets the needs of the workers.

Problem areas identified during the current case study:

- Re-work;
- Financial constraints;
- Tender approval for over R1 million;
- Identifying customers need;
- Project approval by council and DHET;
- Unscheduled work;
- Interference;
- Role clarification;
- Constant re-structuring changes;

- Insufficient planning tools; and
- Scope changes.

Techniques reviewed in the literature study:

- Last Planner System (LPS)
- Value Stream Mapping; and
- 5S process.

Techniques used during the previous case studies:

- Work structuring;
- Implementation of “5-Whys”;
- Increased production planning;
- Work method design;
- Decrease variability-increase reliability;
- Continuous improvement; and
- Increased project coordination.

Techniques used in the current case study:

- Last Planner System (LPS)
- Value Stream Mapping; and
- 5S process.

Introducing Last Planner System

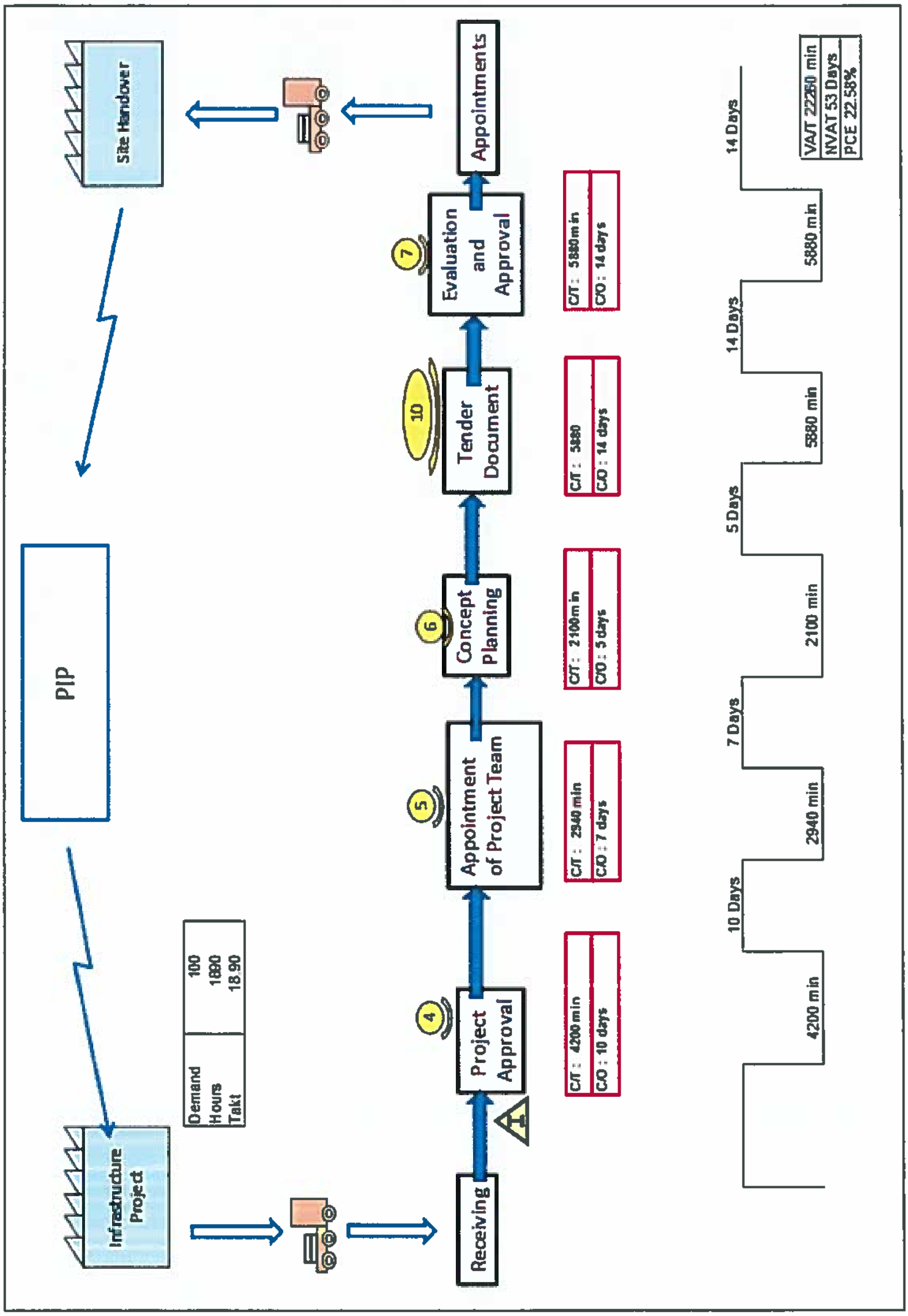
Several steps are vital to the introduction of the Last Planner System and are listed below:

- Make sure project management understands the production control system and its objectives;
- Provide additional training to participants;
- Include a ‘puller’ on action item log;

- Establish a look-ahead window with screening criteria for advancement;
- Track the status of assignments as they move through the look-ahead window;
- Adopt a sizing standard for assignments that consistently demands less output from production units than their estimated capacity in order to accommodate variability in capacity.

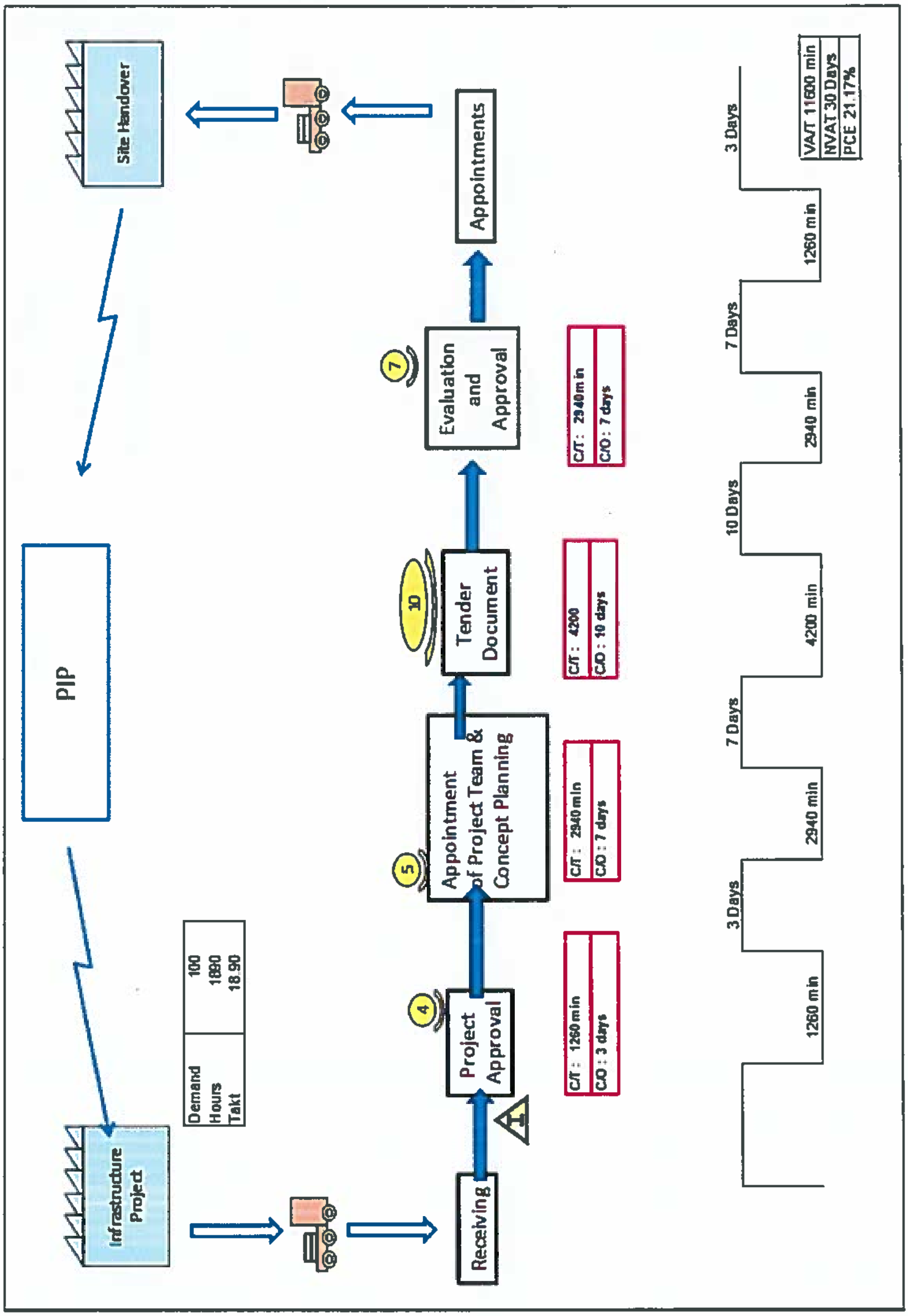
Current value stream mapping

Figure 16: Current value stream map



Future value stream mapping

Figure 17: Future value stream map



Differences between *lean* techniques and process improvement methodologies

In essence, *lean* techniques and process improvement methodologies have the same goal (Womack *et al.*, 2007:15). They both seek to eliminate waste and create the most efficient system possible, but make use of different approaches to achieve this goal (Womack *et al.*, 2007:15). The core difference between *lean* techniques and process improvement methodologies is that they identify the root cause of waste in different ways(Womack *et al.*, 2007:15).

The principle of *lean* assumes that waste comes from unnecessary steps in the production process that do not add value to the finished product, while process improvement methodologies believe that waste results from variation within the process (Koskela & Ballard, 2006:163).

There is truth in both of these assessments, which is why both *lean* and process improvement methodologies have been so successful in improving overall business performance in a variety of fields. In fact, these two disciplines have proven to be especially successful when working in tandem (Koskela & Ballard, 2006:163).

Solutions with regards to previous case studies

- Distinguish between the needed items and the unneeded items;
- Correct items were to be designed, sourced and or stored in the correct place for easy access;
- Frequent feedback is needed;
- In order to accomplish their desired result, sustainable procedures were needed to be established;
- Make sure project management understands the production control system and its objectives;
- Provide additional training to participants;
- Include a 'puller' on action item log;
- Establish a look-ahead window with screening criteria for advancement;
- Track the status of assignments as they move through the look-ahead window;

- Adopt a sizing standard for assignments that consistently demands less output from production units than their estimated capacity in order to accommodate variability incapacity.

Solutions pertaining to current case study

- Re-look the level of authority pertaining to infrastructure projects;
- Enhanced forecast methods;
- Implementation of LPS;
- Centralised function to prioritise projects;
- Educating stakeholders; and
- Role clarification.

3.6 SUMMARY

This chapter presented the research process adopted and the rationale for using qualitative methodologies. Choosing to use the qualitative methodology was justified by the nature of the study examination and the method was deemed appropriate for the research questions. Qualitative research methodology mostly describes phenomena using words while the quantitative research methodology measures them and numerically describes the results. This is because quantitative methods tend to be broader and more easily generalisable while qualitative methods can provide a much deeper, richer set of data.

Chapter 4

4.1 INTRODUCTION

This chapter presents the research summary in relation to the aim and objectives of the dissertation, which is to implement selected *lean* management tools to achieve effective planning within a construction environment at a Tertiary Institution. This chapter will also propose which *lean* tools should be introduced at the selected organisation, and will present the conclusions and recommendations arising from the research findings.

4.2 RESEARCH SUMMARY

The concept *lean* has revolutionised the manufacturing industry and assisted numerous companies to reduce waste and ultimately improve their output. The application of *lean* principles has been extensively researched, but little attention has been given to applying this concept in a construction environment.

The aforementioned paved the way to explore the main aim of the dissertation, which is to implement selected *lean* management tools to achieve effective planning within a construction environment at a Tertiary Institution. The specific objectives set in achieving this aim are given below:

- To conduct a literature study to gain insight into those *lean* operations and *lean* construction principles that are applicable to a construction environment in a tertiary institution;
- To identify what kind of activities cause construction process delay;
- To identify and describe the elements required for effective implementation of selected *lean* management tools;
- To incorporate those *lean* tools and techniques found in the literature study into the planning process;
- To propose which *lean* tools should be introduced at the selected organisation.

The research for this dissertation was carried out as set out in Chapter 3 in order to achieve the aforementioned aim and objectives. The degree to which these research objectives have been realised, began in Chapter 2 of this study in which a literature study was conducted relating to the area of *lean* manufacturing and *lean* construction principles (Objective 1). This stage reviewed the concept of *lean* operations and its application to a construction environment. It provided insight into the selected supplementary process improvements methodologies named Six Sigma and Total Quality Management (Objective 3).

CChapter 3, the second stage of this study, focused on two previous case studies and a qualitative study approach involving ten semi-structured interviews with key participants within the Department (Objective 2).This stage also identified and described the elements required for effective implementation of selected lean management tools, namely the Last Planner System, Value Stream Mapping, and the 5S process (Objective 4).It further identified what kind of activities cause construction process delays and aimed to incorporate those *lean* tools and techniques found in the literature study into the planning process (Objective 5).

4.3 CONCLUSION AND RECOMMENDATIONS

4.3.1 Conclusion of study

The following core conclusions were drawn from the research study:

The previous case studies reveal a trend in the construction industry pertaining to how *lean* concepts have been applied and the difficulties relating to their implementation. These case studies indicated that there is a general perception of the understanding of the concept *lean* among construction professionals. However, the current case study revealed that this is not necessarily the case, assuggested by the analysis of the semi-structured interviews which formed part of the research. The participants at the Department: Physical Infrastructure and Planning at the North-West University do not have knowledge of the necessary *lean* tools or process improvement techniques that could be implemented to establish more effective planning.

4.3.1.1 General conclusions

Wastage was identified in the following areas:

- Communication gaps between the planning division and the end user with regards to the scope and concept plan of the project;
- Processing the scope and concept plan into accurate Bills of Quantities;
- Lack of focus from Executive Management with regards to infrastructure;
- Riots that prevented much needed infrastructure investigations aimed at finalising the scope of projects;
- Strikes in the construction manufacturing sector prevented ideal materials from being available. Essential changes to the Bill of Quantities must take place in order for contractors to price;
- Costing of projects takes longer since being outsourced;
- Travel time between campuses.

The current case study reveals that in order to implement *lean* tools and process improvement techniques, the department have to overcome the following barriers:

- Time-consuming approval periods;
- Lack of sufficient skills and knowledge;
- Environment of bureaucracy;
- Lack of appropriate training;
- Lack of trust;
- Little control of the entire value stream; and
- Interference in planning and design process.

Methods concerning the improvement of wastage, can be summarised as follows:

- Re-look the level of authority for infrastructure projects;
- Enhanced forecast methods;
- Implementation of LPS;
- Centralised function to prioritise projects;

- Educating stakeholders;
- Role clarification;
- Implementing the future value stream map

4.3.2 Recommendations

After reviewing previous case studies and evaluating the current construction environment at the North West University, the following solution is recommended in order to establish effective planning through implementing selected *lean* principles:

- The department must look beyond traditional processes and future processes mainly related to the supply chain must be redesigned.

    - Map the current supply chain on a time line that indicates wastes and inefficiencies. Negotiate with supply chain partners ways to address these inefficiencies.
    - Ensure that supply chain partners and subcontractors are part of the *lean* Six Sigma project to ensure better flow through the system.

- It is required that some form of standardisation of business processes be applied so that the institution can more effectively measure performance and progress towards a more effective planning approach through the adoption of *lean* principles.

    - Revisit the business process manual for the department, including methods to reduce *lean* wastes.
    - Deliberately engineer out any non-standard processes from the present business process manual.

- The employees should be required to have suitable levels of commitment, knowledge and skills that include understanding the underlying concepts for successful implementation of *lean* principles within the institution.

    - Present a *lean* workshop to teach employees the core principles of *lean*.

- Introduce some kind of reward or recognition system for employees pertaining to reducing *lean* waste.

- The development of a strategic plan for a more sustainable long- term focus is of crucial importance since it enables the evaluation of the threats and opportunities for integrating *lean* principles.

  - Have a champion on strategic level to drive the *lean* process.
  - Have a *lean* policy and strategy that dovetails with the strategic plan of the department.

- *Lean* concept and principles may be difficult to comprehend, but training can be provided on how to implement these principles rather than providing training that focuses only on *lean* theories.

  - Redesign present training processes to include *lean* concepts.
  - Introduce a strong on-the-job training programme to enhance *lean* and total quality management savings.

- Resources should be kept flexible, mostly because of the volatile environment of the tertiary sector within South Africa.

  - The redesign and renegotiation of the approval system to be more deft and flexible.
  - Consistently revisit the value stream map.

- Maintaining constant flow, by reorganising time and resources.

  - Visibly display the latest value stream map in the office.
  - Introduce visual management.

With the main focus of this study being the implementation of *lean* principles, the volatility of the tertiary sector of South Africa and the bureaucracy of a university institututions should be taken into account. It is important to note that construction in South Africa, and particularly at tertiary institutions, has a considerable number of different design and planning processes and each construction environment is unique. As a result, further studies can be conducted develop a framework for implementing selected *lean* principles to achieve effective planning within a tertiary institution.

Recommendations for future research include that this study be undertaken every two years in order to implement new objectives. It is also recommended that other *lean* principles such as the "5 why" questions, work method design, decrease variability-increase reliability, and continuous improvement be researched within the current environment. New research should be done regularly in order to establish and implement customised total quality management and six sigma programs for the department.

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