APPLICATION OF LEAN TOOLS IN ROLLING STOCK PROCUREMENT SUPPLY CHAIN MANAGEMENT

by

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DECLARATION

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

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ABSTRACT

The main aim of this research study was an investigation of applicable lean tools in rolling stock procurement supply chain management (SCM). Lean principles resonate from the manufacturing environment while rolling stock procurement SCM is a typical example of the non-manufacturing environment. Hence a variance in applicable tools is apparent.

The case study of the research was studied and analysed. The procedure adopted for measurement and analysis of the case study (rolling stock procurement SCM) began with mapping the process areas. This was performed through a type of lean tool known as value stream mapping. After the SCM mapping, the lean waste in the SCM was identified through waste analysis.

During analysis, it was discovered that the bidding process holds the highest area of waste. Following this finding, the bidding process was evaluated, upon which lean tools for waste reduction are prescribed. From the findings obtained in the measurement and analysis step, mapping of the future state was carried out. Based on the mapping of the future state of the supply chain, relevant performance metrics are recommended for a periodic check. Limitations, as well as assumptions encountered during the research study, are also discussed.

The study conclusion is presented in the form of answers to the research questions. Some of the major waste discovered in the bidding process includes poor communication between bidding team and end user and difficulty in sourcing for potential suppliers.

The recommendations put forward in this research project are to strategically reform the bidding process by making required changes to tender documents, standardising the procurement SCM process and improving the communication culture between suppliers and SCM.

OPSOMMING

Die hoofdoel van hierdie navorsingstudie was ŉ ondersoek na toepaslike vaartbelynde instrumente in die voorsieningskettingbestuur (VKB) van die verkryging van rollende materiaal. Vaartbelynde beginsels is van toepassing in die vervaardigingsomgewing. Die VKB van die verkryging van rollende materiaal kom tipies in die nievervaardigingsomgewing voor. ŉ Verskil in toepaslike instrumente is dus voor die hand liggend.

Die gevallestudie van die navorsing is bestudeer en ontleed. Die prosedure wat gebruik is vir die meting en ontleding van die gevallestudie (VKB van die verkryging van rollende materiaal) het begin met kartering van die prosesomgewings. Dit is uitgevoer deur ŉ soort vaartbelynde instrument bekend as waardestroomkartering. Ná die VKB-kartering is vaartbelynde verspilling in die VKB deur verspillingsontleding geïdentifiseer.

Tydens ontleding is ontdek dat die bieproses die grootste verspilling inhou. Op grond hiervan is die bieproses geëvalueer, en vaartbelynde instrumente vir die vermindering van verspilling word voorgeskryf. Op grond van die bevindinge wat uit die meting-en-ontledingstap verkry is, is kartering van toekomstige toestande uitgevoer. Op grond van die kartering van die toekomstige toestand van die voorsieningsketting word toepaslike prestasiemetrieke vir periodieke kontrole aanbeveel. Beperkings asook aannames wat in die navorsingstudie aan bod kom, word ook bespreek.

Die gevolgtrekking van die studie word aangebied in die vorm van antwoorde op die navorsingsvrae. Voorbeelde van die meeste verspilling wat in die bieproses ontdek is, sluit in swak kommunikasie tussen die biespan en eindgebruiker en probleme om potensiële verskaffers te verkry.

Die aanbeveling wat deur hierdie navorsingstudie gemaak word, is strategiese hervorming van die bieproses deur nodige veranderinge aan tenderdokumente te maak, die verkrygings-VKB-proses te standaardiseer, en die kommunikasiekultuur tussen verskaffers en die VKB te verbeter.

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"I call to the Lord for help, and from his sacred hill he answers me"
(Psalm 3:4)

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

GLOSSARY

BET – Bid Evaluation Team

Bid – Request for Material or Service above R350 000

CRM – Customer Relationship Management

CSM – Customer Service Management

ERP – Enterprise Resource Planning

FMEA– Failure Mode and Effect Analysis

FMMS – Facility Maintenance Management System

IR – Indian Railway

ISO – International Standard Organisation

GEMBA – Collation of information on current Supply Chain management

JIT – Just-In-Time

KPI – Key Performance Indicator

MRO – Maintenance, Repair and Overhaul

NCR – Non-Conformance Report

PRASA – Passenger Rail Agency of South Africa

RFQ – Request for Quotation

RPN – Risk Priority Number

RS – Rolling Stock

SAP – Systems, Applications and Products

SC – Supply Chain

SCC – Supply Chain Council

SCM – Supply Chain Management

SCOR – Supply Chain Operations Reference Model

VaR – Value at Risk

VSM – Value Stream Map/Mapping

TQM – Total Quality Management

5S – Simplify, Straighten, Scrub, Stabilise and Sustain

CHAPTER 1: INTRODUCTION

1.1 Background

Supply Chain Management (SCM) is easy to discuss in theory; however, these theories pose a challenge when it comes to their application in a practical setting. In a real world situation, supply chain (SC) practices have undergone significant changes in terms of improvement. SC improvements have held a track record by means of better ideas and technology (Paul and Dan, 2004). Improvement methodologies such as Lean, Six Sigma, and Theory of Constraints are often used to make incremental or radical changes in a supply chain. This research will endeavour to apply the Lean methodology as a form of process improvement approach to improve a supply chain.

Lean thinking is an improvement methodology which has positively impacted various manufacturing and non-manufacturing industries. The implementation of Lean thinking and its concepts originated in the manufacturing environment. This concept gradually spread wide to the non-manufacturing environment. In recent times, many non-manufacturing or service industries have experienced lean as a form of process improvement tool and concept (Hu, Mason, Williams and Found, 2015).

This study will focus on the types of Lean tools that can be implemented in the non-manufacturing or service environment. And so, it will serve as an additional study to the previous studies performed in this background. The Rolling Stock Procurement SC of the Passenger Rail Agency of South Africa (PRASA), serves as a typical example of a non-manufacturing environment for the validation of the research study.

The investigation and application of Lean tools in the current SC activities is the key goal of this research. Furthermore, a secondary goal is to investigate the applicability of SCOR attributes for performance measurement which will assist the current SC improvement from current to best practices.

1.2 Research Problem

Non-manufacturing organisations' SC operations differ from those of the manufacturing environment. It, therefore, follows that the application of Lean improvement methodology in the non-manufacturing environment will also differ.

Due to the fact that tangible products can be traced through a SC in the manufacturing environment, there is sometimes the perception that the term 'supply chain' applies only to the manufacturing sector.

An example of the manufacturing SC contradiction can be found in the service sectors of the non-manufacturing environment. In service firms and organisations, SCM deals with the satisfaction of mission imperatives (delivery of medical advice, communications services, financial transactions, research and development, entertainment, etc.). Nearly every service involves the use of people, something physical (whether it be an asset or part of something performed), an action, and a time element.

There are common problems related to the non-manufacturing supply chain. These problems may be part of a group, ranging from supply side problems to internal operations problems to the problems encountered from the customer side of the chain.

Although much of the Lean SC research has already been performed, there are still gaps in practical applications, especially in the non-manufacturing environment. This might be as a result of uncertainty and the nature of the workspace. The main challenge faced with this research study is that there are fewer research applications of Lean in the non-manufacturing environment than in the manufacturing environment. The application of suitable Lean tools in this environment will be cumbersome and will require thorough investigation.

1.3 Research Questions

Question 1: What does the current SC look like?

Question 2: What concepts of Lean thinking are relevant to the current Supply Chain?

Question 3: What measures should be put in place for successful process change?

1.4 Research Objectives

In order to identify the objective of this research study, the researcher articulated the steps that will be followed in order to formulate the answer to the research questions (section 1.3). This study will, therefore, seek to meet the following research objectives:

- Identify the current SC structure.
- Investigate suitable Lean tools for the improvement process.
- Prescribe possible improvement measures.

1.5 Research Design and Methodology

This study employs a combination of empirical studies and non-empirical studies as its research design. The understanding of both studies is essential to aid the researcher as to which to apply first.

The empirical research method involves practical data that is collected to find solutions to research questions. Though there are more of its applications in academic research, they can also be valuable for producing answers to practical questions (Moody, 2002).

Below are two categories of empirical research:

1. Quantitative Research Methods: This method involves numerical data collection with the integration of statistical analysis for the data collected.

2. Qualitative Research Methods: This method involves the use of the qualitative data analysis method to analyse data that is collected through interviews, sounds, images, and videos as well as documentary evidence.

A research design is said to be non-empirical when it involves literature reviews, philosophical analysis, conceptual analysis or theory building. In this method, a researcher can draw up or construct an argument without validation data.

In this study, the research design that will be applied first is of the non-empirical type. This is due to the fact that certain literature sources will be consulted using concepts to bring together the keywords of the thesis for a clearer design. The researcher will employ empirical methods for the remainder of the study. This will involve the collection of quality data by means of carrying out periodic meetings and interviews with process team members of the supply chain. The data collected will then be analysed using the concepts developed.

1.6 Thesis Outline

The outline of the thesis as shown in Figure 1 encompasses five core stages. The first stage is the introductory section where the background, problem statement, research questions, the research objectives, the research design and methodology employed in the study are discussed. The second stage contains the literature review of SCM, Lean thinking and the Non-manufacturing Environment. Following the literature review, the definition of the case studies for the research is discussed. The fourth and fifth stages contain the application of the methodology and the conclusion for the research respectively.

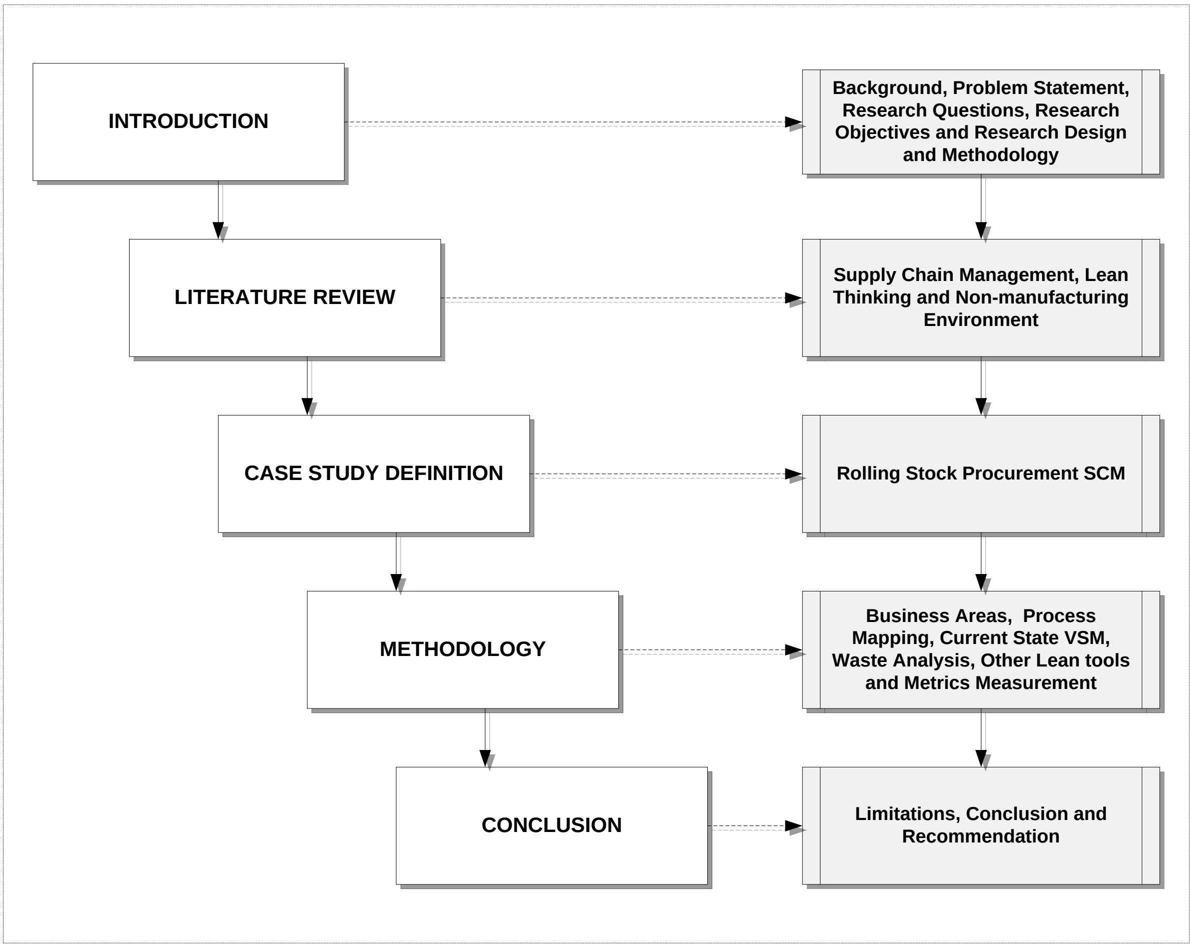

Figure 1: Outline of Thesis

CHAPTER 2: LITERATURE REVIEW

2.1 Literature Sourcing

Data gathered on the SC and Lean principles, theories and concepts used in this study originated from previous literature. The information acquired was found in textbooks, journal articles and white papers. At the beginning, scholarly databases such as Scopus, Web of Science and Business Premier were used to search for keywords like 'Supply Chain Management', 'Lean thinking' and 'Non-manufacturing Environment'. After the material was reviewed, it was discovered that there was still a lack of substantial information.

In the second stage, the Google Scholar database was utilised to search for these keywords both separately and combined. Google Scholar was used because its search is wide compared with other scholarly search engines as it includes book references, patents and cases. The second search outcome shows that there is more separate literature on the keywords than when they are combined.

A backward search for literature was carried out again by reviewing the references of already sourced journals and papers. The result of the combined literature for the three keywords was minimal and it barely covered the scope of the three combinations.

After the searches, the literature was sorted into the three parts of Supply Chain Management, Lean thinking and Non-manufacturing Environment as shown in figure 2.

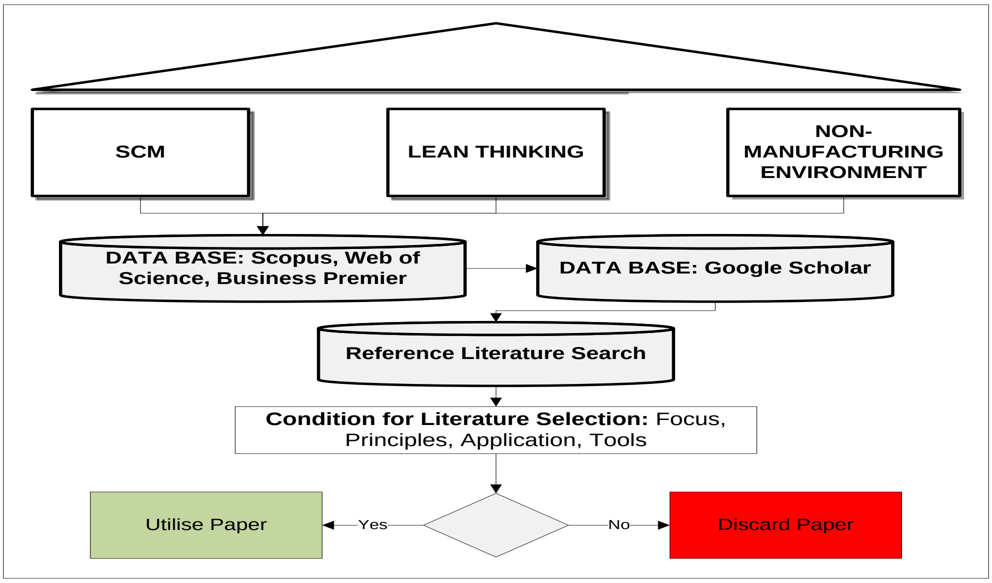

Figure 2: Literature Sourcing Structure

2.2 Supply Chain Management

The structure adopted for the SCM literature is shown below in Figure 3. Initially, SC and SCM were defined for clearer understanding. Following this, the supply chain relationship was explained, highlighting the supply chain processes. Lastly the supply chain KPI was discussed with a further discussion on the SCOR performance indicators.

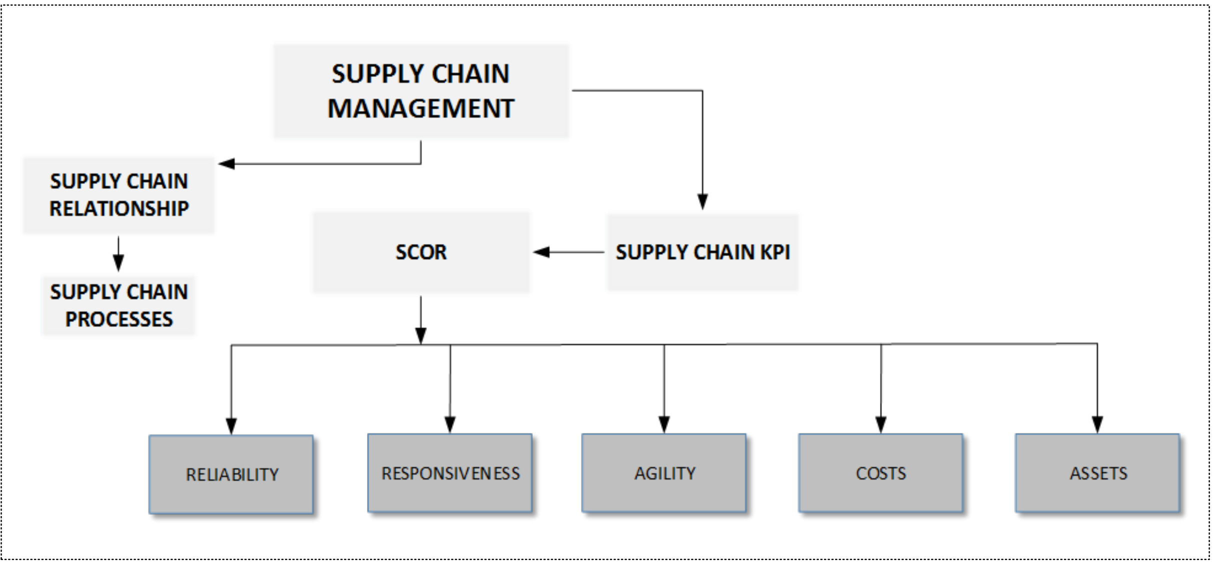

Figure 3: Structure of SCM Literature

2.2.1 Definitions

Daud (2010) briefly describes a SC as an association or network of distributors, transporters, retailers and storage facilities. The participating suppliers are linked to production, delivery and the sale to the end user. There are various numbers of business bodies where SC serves as an integrated process whose combined efforts achieve the following:

- Purchase of raw materials;
- Process the raw materials into required finished products; and
- Supply the finished product to the end user.

This kind of chain is traditionally characterised by the backward flow of information and forward flow of material. This network of organisations and interlinked activities is arranged sequentially to satisfy value production for the end user (Kumar, 2001). Most reputable organisations, through many years of experience, have observed that the SC spectrum is more than just a physical movement of materials or products from one location to the other. It also includes money movement, information and the creation and utilisation of knowledge (Kumar, 2001). Therefore SC can alternatively be described as Ayers (2006) states as the process of a product life cycle which comprises of financial, information and knowledge flows. Its sole aim is to satisfy the requirements of the customer with physical products and services processed by several linked suppliers (Ayers, 2006).

SCM involves the management of numerous companies who synchronise activities to differentiate themselves from other companies they compete with. Tan (2001) defines SCM as a process that comprises the entire value stream and addresses materials and supply management from the beginning of a process chain to its end. SCM can also be described as being a process integration of upstream and downstream activities. (Jonsson, 2009)

Accordingly, SCM covers supply and material management from the stage of raw material supply to end use and possibly recycling and reuse stage (Croom, Romano & Giannakis, 2000). In addition, it concentrates on monitoring an organisations' utilisation of their suppliers' technology, processes and capability to boost competitive advantage (Croom, *et al.*, 2000). It is furthermore a management philosophy that encompasses traditional sub-enterprise undertakings by bringing together partners of trade with the collective aim of process efficiency and optimisation (Croom, *et al.*, 2000).

The Council of Supply Chain Management Professionals (CSCMP) defines SCM as a process that covers planning and management tasks concerned with sourcing and procurement of raw material, conversion of raw material and management of logistical activities (Ayers, 2006). Principally, it also consists of coordination and collaboration with partners in the chain. The partners in the chain can be suppliers, liaisons, third-party service provider and end users. Essentially SCM is an integration of supply management and demand management within and across companies (Ayers, 2006).

2.2.2 Supply Chain Relationship

Amidst the positivity of SCM, there are obstacles surrounding the chain. One such obstacle is supplier relationship which can hinder process integration. The obstacle of the specification can be related to different priorities and goals. There is an absence of smooth communication structures between partners of the SC due to the lack of trust in the relationship (Jonsson, 2009). In many corporate organisations like 3M (formerly known as Minnesota Mining and Manufacturing), management has concluded that product flow optimisation cannot be reached without applying a process approach to the organisation (Lambert & Cooper, 2000).

Some of the identified key SC processes are stated and discussed below. Figure 4 shows the diagrammatic representation of how a supply chain processes are managed and integrated:

- Customer Relationship Management;
- Customer Service Management;
- Order Fulfilment;
- Demand Management;
- Manufacturing Flow Management;
- Procurement;
- Product development and commercialization; and
- Returns.

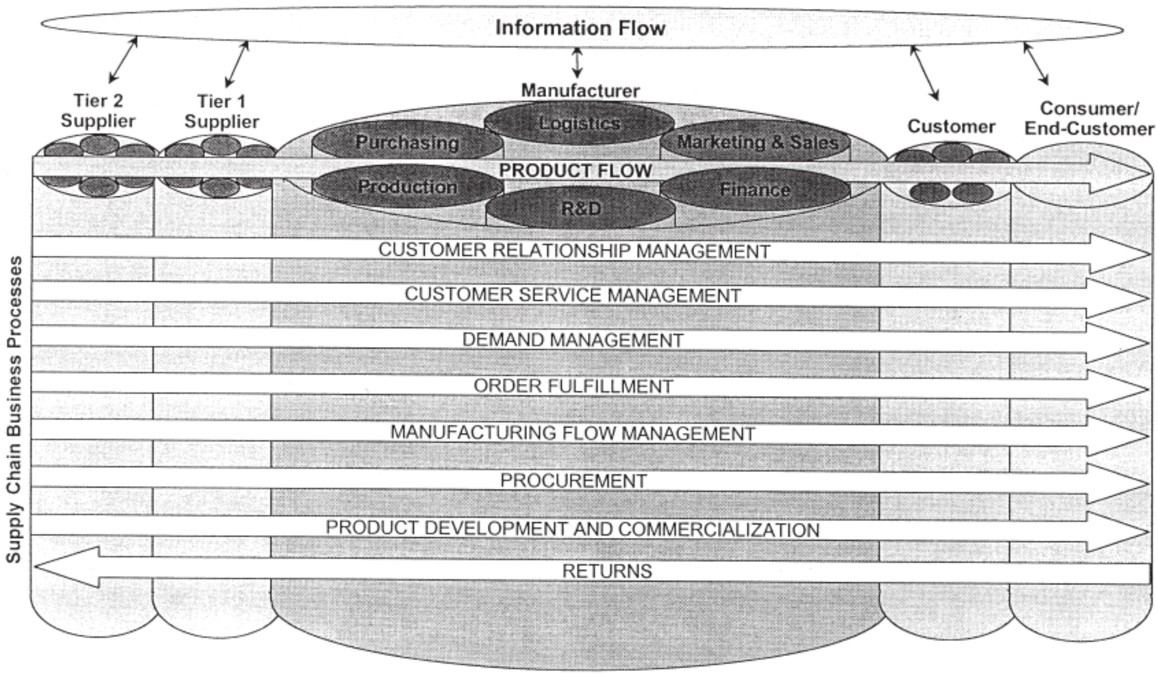

Figure 4: Integrating and Managing Business Processes across the Supply Chain

Source: (Lambert & Cooper, 2000).

Customer Relationship Management (CRM):

The first step toward an integrated SC process is to identify key customers or customer groups which the organisation targets as critical to its business mission. Product and service agreements specifying the levels of performance are established with these key customer groups. Customer service teams work with customers to further identify and eliminate sources of demand variability. Performance evaluations are undertaken to analyse the levels of service provided to customers as well as customer profitability (Lambert & Cooper, 2000). The meaning of CRM is can vary for different backgrounds. For certain environments, CRM might mean sending an electronic mail, while for the others, CRM might be the development of products that will fit individual customer needs (Winer, 2001).

Customer Service Management (CSM):

CSM is the SC process that represents the firm's appearance to the customer. This process is the key point of contact for administering product and service agreements (PSAs) which were developed by customer teams as part of the CRM process. The goal is to provide a single source of customer information, such as product availability, shipping dates and order status. CSM requires a real-time system to respond to customer inquiries and facilitate order placement (Bolumole, Knemeyer & Lambert, 2003.). Edwards (2000) identified that CSM can be classified into the following:

- Installed Base Management;
- Service Contract Management;
- Call Management;
- Service Order Management; and
- Knowledge Management.

Demand Management:

The demand management process must balance the customer's requirements with the firm's supply capabilities. Part of managing demand involves attempting to determine what and when customers will purchase. A good demand management system uses point-of-sale and 'key' customer data to reduce uncertainty and provide efficient flows throughout the SC (Lambert & Cooper, 2000). In the maintenance organisation, management of demand can be done by differentiating or grouping maintenance workshops according to work structure.

Order Fulfilment:

According to Fritz and Matthias (2004), to achieve order fulfilment satisfaction, the application of two generic approaches may be followed. One of the approaches is build-to-forecast and the other is build-to-customer-order. The build-to-forecast approach is dependent on the firm's sales forecast. Individual customer order initiates the production process in the build-to-order approach.

Manufacturing Flow Management:

Goldsby and García-Dastugue (2003) stated that manufacturing flow management is the SCM process that comprises all necessary activities required to move products through the plants and to obtain, implement, and manage the SC manufacturing flexibility. Manufacturing flexibility reflects the ability to make a variety of products in a timely manner at the lowest possible cost. To achieve the desired level of manufacturing flexibility, planning and execution must extend beyond the four walls of the manufacturer (Goldsby & García-Dastugue (2003). Since the maintenance environment does not deal with the production of materials, the term manufacturing flow management can be described as service flow management. The service flow management here will encompass the smooth flow and coordination of service activities carried out on scheduled maintenance jobs.

Procurement:

This can be defined as the act of purchasing products or services for an organisation in a broader perspective (Novack and Simco, 1991). Generally, there are six methods of procurement used by a procurement team in an organisation. The names of these methods can vary from one organisation to the other depending on the industry. The six types of procurement are:

- Open tendering;
- Restricted tendering;
- Request for Proposal;
- Two-stage tendering;
- Request for quotations;
- Single-source procurement.

Product Development and Commercialisation:

According to Rogers, Lambert & Knemeyer (2006) product development and commercialisation is the SCM process that provides structure for developing and bringing to market new products jointly with customers and suppliers. Effective implementation of the process not only enables management to coordinate the efficient flow of new products across the supply chain. It also assists SC members with the ramp-up of manufacturing, logistics, marketing and other related activities to support the commercialisation of the product. Lambert and Cooper (2000) suggest that product development and commercialisation managers must collaborate with customer relationship management to coordinate and identify the communicated and uncommunicated needs of customers.

Returns Management:

Mollenkopf, Russo & Frankel (2008) define returns management as activities associated with returns: avoidance, gatekeeping, reverse logistics and disposal. These strategies may be the most neglected part of many SC practices. The process of moving products from buyers back to sellers, if designed and managed well, can reduce costs and improve customer satisfaction. For this reason, returns management is important both from a cost perspective and a customer service perspective. That is why companies need to look at opportunities to replace their traditional, manual returns processes with new, streamlined, automated solutions (Norek, 2001).

2.2.3 Supply Chain Key Performance Indicators

Key Performance Indicators (KPIs) serve as a measurement of how an organisation's strategic vision is being accomplished. To better understand strategic vision in an organisation, the strategy for interaction is incorporated into an organisation's whole strategy. Furthermore, it is essential for each individual involved in the strategic improvement in an organisation to agree on what the formulated strategy signifies and the interpretations of its variations (Warren, 2011). KPIs help managers understand how their organisations are performing in relation to their strategic goals and objectives. When set and used properly, KPIs provide an indicator to senior managers and stakeholders as to how the organisation is performing and whether performance is on track with projections (Pacific Crest Group, 2014). Thus in order to establish appropriate KPIs, it is important to:

- set up goals;
- formulate metrics to accomplish these goals;
- execute plans according to the metrics formulated.

KPIs can be classified as either leading or lagging indicators depending on their values. The measurements of leading indicators are task specific. Based on progress towards achieving long-term objectives, they are quicker in response than result metrics. Leading indicators apply performance measurement and tracking before the surfacing of a problem (Smith, 2003).

Lagging indicators use historic data to build a performance trend line. The trend shows progress and can be projected forward a little to forecast likely progress (Sondalini, 2014).

The orientation of the applicable use of KPIs for a group of projects might differ from one another depending on the market, the nature of business, the expectation of customers, competitive activity, company's strategy and numerous other factors. The challenging part of KPIs orientation is proper blending and mixing of the various SC KPIs in order to correctly measure the things that are of core value to the organisation. A balanced approach must be applied in order to measure the underlying invisible root cause of arising problems (Bryne, 2012).

There are common methods of measuring SC performance which has been adopted over the years, but before deciding on the most suitable one to use, it is essential to understand the meaning of performance measurement. (Won Cho et al., 2012) define performance measurement as a procedure for efficiency and effectiveness quantification on past activities. Efficiency deals with the economical measurement of how an enterprise utilises their resources when providing pre-identified customer satisfaction, while effectiveness is the degree of meeting customer requirements. Further to this, it was emphasised that a performance measurement system should allow up-to-date decisions to be made and enable the taking of action because it measures the effectiveness and efficiency of past activities (Won Cho *et al.*, 2012).

Creation of suitable performance measures is a vital element in SC design and analysis. A set of performance measures or a performance measure is used for the determination of effectiveness and efficiency of a current system or for comparison of competing for alternative systems (Beamon, 1998). Furthermore, performance measures can be used to design recommended systems, by determining the values of decision variables that produce the utmost desirable performance level. There are a substantial number of performance measures that will be helpful and important for the effectiveness and efficiency of SC evaluation as identified in the literature.

In recent years, a number of industries have realised the potential of SCM, although there are often loopholes in the improvement of performance measures that are effective and also required to achieve a SC of complete integration. Furthermore, such metrics and measures are required for testing and revealing the sustainability of strategies where there is not a high level of difficulty on the route for development and realisation of goals (Gunasekaran, Patel &

Tirtiroglu, 2001). Chae (2009) emphasises that the success of SCM among other things rests on the closed loop of planning and execution regarding the process of reducing likely gaps between the two. It is not practically possible to completely eliminate such gaps from a firm's SC owing to the fact that future happenings are unknown and decision-makers often develop operational plans of various types under high levels of improbability.

Many measures used in the evaluation of SC performance are aimed at measuring the performance of the operation, inspecting strategic configuration of the entire SC and evaluating enhanced effectiveness (Cai, Liu, Xiao & Liu, 2009).

SC individual performance measures have normally been categorised into four groups: time, cost, flexibility and quality. The grouping is done by looking at quality and quantity; focus on strategy/operation/tactics, cost and non-cost, and SC practices. However, since strategy alignment is lacking in several measurement systems as well as systems thinking and a balanced approach, there is difficulty in methodically identifying the most suitable measurement approach.

Blanchard (2007) suggests that good and very detailed performance metrics are encompassed in the Supply Chain Operations Model (SCOR) which has been continually refined since it was created in 1995 by the Supply Chain Council (SCC).

In addition, measurement of strategies intended to improve the process in a company should be an important issue to bear in mind. According to Mentzer (2001), for the formation of a strategy, the environment is important. Many scholars, therefore, consider that strategies must react to and be constrained by the ever-changing environmental conditions. On the other hand, other scholars maintain that strategy represents the environment in a chain and the thoughtful selection of the existing choices.

2.2.4 Supply Chain Operations Reference Model

SCOR is a process reference model which has various definitions, process elements and metrics (Bauhof, 2004). According to the Supply Chain Council (2010), the SCOR Model is distinctive as it offers a framework that connects processes, performance metrics, and people into an integrated structure. The SCOR framework develops the effectiveness of SCM, information technology and associated SC improvement activities. This framework also supports communication between partners involved in the supply chain.

In SCOR, the performance or metrics section concentrates on understanding the outcomes of the SC and contains two elements, namely: performance attributes and metrics (Supply Chain Council, 2012:1).

SC performance attributes allow it to be analysed and evaluated alongside other SCs with competing strategies. There are five core performance attributes contained in SCOR, which are: Reliability, Responsiveness, Agility, Costs, and Asset Management. It is difficult to compare an organisation that aspires to be a low-cost providing organisation with an organisation that chooses to compete on reliability without these performance attributes (APICS, 2015).

According to the Supply Chain Council, a metric can be defined as a standard for measuring process performance. The metrics of SCOR are diagnostic and recognise three levels of predefined metrics as stated below:

Level 1 Metrics: This level of metrics is diagnostic for the general well-being of the supply Chain. Another term for this metric is a strategic metric and key performance indicators (KPIs). Level 1 metrics benchmarks assist in creating realistic targets that support strategic objectives.

Level 2 Metrics: This level of metrics functions as diagnostic for the metrics in Level 1. The performance gap, as well as the root cause for Level 1 metrics, can be identified through Level 2 diagnostic relationships.

Level 3 metrics: This level of metrics serves as a diagnostic metric for Level 2.

The performance metrics analysis from Level 1 through to Level 3 can be referred to as metrics decomposition, metrics root cause analysis and performance diagnosis. The first step in identifying the processes that need further investigation is called metrics decomposition. There are ten Level 1 metrics (strategic metrics) recognised by SCOR. Table 1 shows these metrics and their corresponding attributes (Supply Chain Council, 2012).

Table 1: SCOR Strategic Metrics

Attribute	**Level 1 Metric**
Reliability	Perfect Order Fulfilment
Responsiveness	Order Fulfilment Cycle Time
Agility	Upside Flexibility
	Upside Adaptability
	Downside Adaptability

	Overall Value-at-Risk
Cost	Total Cost to Serve
Asset Management Efficiency	Cash-to-Cash Cycle Time
	Return on Fixed Assets
	Return on Working Capital

According to the Supply Chain Council, it is recommended that an organisation SC scorecard contains at least one performance metric for each of the attributes so as to ensure balance in making decisions and performing governance.

2.2.4.1 Reliability

Reliability attributes deal with the capacity of carrying out duties as expected. The focus of the reliability attribute is on predicting the outcome of a process. Some usual reliability attributes are on-time delivery, right quantity, and the right quality. The reliability SCOR KPI (Strategic/Level 1) metric is Perfect Order Fulfilment.

Perfect Order Fulfilment:

Perfect Order Fulfilment is the percentage of orders meeting delivery performance with complete and accurate documentation and no delivery damage. Components include all items and quantities that are on time using the customer’s definition of on time, and documentation packing slips, bills of lading, invoices, etc.

- An order is considered perfect if the products ordered are the products provided and the quantities ordered match the quantities provided (% In Full).
- A delivery is considered perfect if the location, specified customer entity and delivery time ordered is met upon receipt (Delivery Performance to Customer Commit Date).
- Documentation supporting the order line is considered perfect if it is all accurate, complete, and on time (Accurate Documentation).
- The product condition is considered perfect if the product is delivered/faultlessly installed (as applicable) on specification, with the correct configuration, with no damage, customer ready, and is accepted by the customer (Perfect Condition).

2.2.4.2 Responsiveness

Responsiveness is a customer-based attribute that describes the speed at which performance of tasks is carried out. Cycle time metrics is an example of the responsiveness attribute. The strategic metric for this attribute is Order Fulfilment Cycle Time.

Order Fulfilment Cycle:

The order fulfilment cycle is determined by the average actual cycle time consistently achieved to fulfil customers' orders. For a specific order, the cycle commences from the order receipt and terminates when the customer accepts the order (Supply Chain Council, 2012). It is also classified as the time frame between product or service request from an internal customer and delivery of the requested product or service (Tomas, David, Ernest, 2002)

2.2.4.3 Agility

External influence response and ability to change serve as a description of the Agility attribute. Examples of external influences are Partners or suppliers moving out of business, non-forecasted increase or decrease in demand, cyber theft, labour issues, economy and natural disasters. Agility is a customer-based attribute. The Agility attribute performance metrics are Flexibility and Adaptability which can either be upside flexibility, upside adaptability, downside adaptability or overall value at risk. Depending on the organisation or industry, one or two of the KPIs can be applied for measurement of performance agility.

2.2.4.4 Costs

The process operating cost can be described as the Cost attribute. This cost comprises material cost, labour cost and transportation cost. The SCOR KPIs are SCM cost and cost of goods sold. Both of these indicators encompass all the cost in the supply chain. Cost is an internally focused attribute.

Total Cost to Serve:

Total cost to serve is the sum of all costs in the SC for the delivery of products or services to the customer. This includes SC planning cost; material/product sourcing cost; merchandising and services; production cost; manufacturing cost; maintenance, repair and overhaul (MRO) services and the cost to deliver products and services. Total cost to serve can be measured per event and at the aggregated SC level. This cost is usually measured in monetary units.

2.2.4.5 Asset Management

This attribute can also be referred to as 'Asset Management Efficiency' and can be described as the ability to efficiently utilise assets. Inventory reduction and insourcing vs outsourcing are asset management strategies. Asset Management metrics include supply inventory days and capacity utilisation. The SCOR KPIs are Cash-to-Cash Cycle Time and Return on Fixed Assets

The Asset Management Efficiency ('Assets') attribute describes the ability to efficiently utilise assets. Asset management strategies in a SC include inventory reduction and insourcing vs. outsourcing. Metrics include inventory days of supply and capacity utilisation. The SCOR KPIs include Cash-to-Cash Cycle Time, Return on Fixed Assets and Return on Working Capital. Asset Management Efficiency is an internally focused attribute.

Cash-to-Cash Cycle Time:

This is determined by calculating the time when cash is out of reach for business utilisation. The faster a cash-to-cash cycle is, the less the day's cash is not available for use in boosting the value stream. With this metric, an organisation can determine whether they are undergoing Lean operations with regards to cash. Furthermore, good performance on the cash-to-cash measurement has been associated with improved earnings per share.

Return on Fixed Assets:

Return on SC fixed assets measures the return an organisation receives on its invested capital in SC fixed assets. To calculate the return on fixed assets for a supply chain, specific data is required. According to (Supply Chain Council, 2012), unlike other SCOR metrics, where data requirements are specified, typically all of the required source data is already captured by business operating systems:

- General ledger system;
- Accounts receivable system;
- Accounts payable system;
- Purchasing system;
- Production reporting system; and
- Customer relationship management system.

Return on Working Capital:

Return on working capital is a measurement which assesses the magnitude of investment relative to a company's working capital position versus the revenue generated from a supply chain. Components include accounts receivable, accounts payable, inventory, SC revenue, cost of goods sold and SCM costs.

2.3 Lean Thinking

2.3.1 Introduction

Depending on the background and industry, organisations try to find the most suitable definition of Lean. According to Ren (2012), the use of Lean can be through principle, concept or a type of ideology that can be applied to the activities and management guideline of an organisation. Lean has the means of creating more value for customers using fewer resources i.e. the process of maximising customer value while minimising waste (Daud, 2010). The purpose of Lean application to all parts of an organisation's process is to enable a long-term development of the process.

In manufacturing and vehicle production, Lean was used to name the third form of the production system. This system has the capability to produce more and better vehicles in less time and space as well as making use of fewer labour hours as compared to the craft or mass production that preceded it. During this period, many concepts were discovered including; Just in Time (JIT) material deliveries, Pull and Push systems for advancement of work through a system of production, batch size economic reduction by reducing set-up time and increments of the production system transparency to enable process team members to manage the system (Ballard & Howell, 2003:2)

This section encompasses a brief review of some related Lean thinking literature. Figure 5 shows the areas that will be discussed under Lean thinking literature.

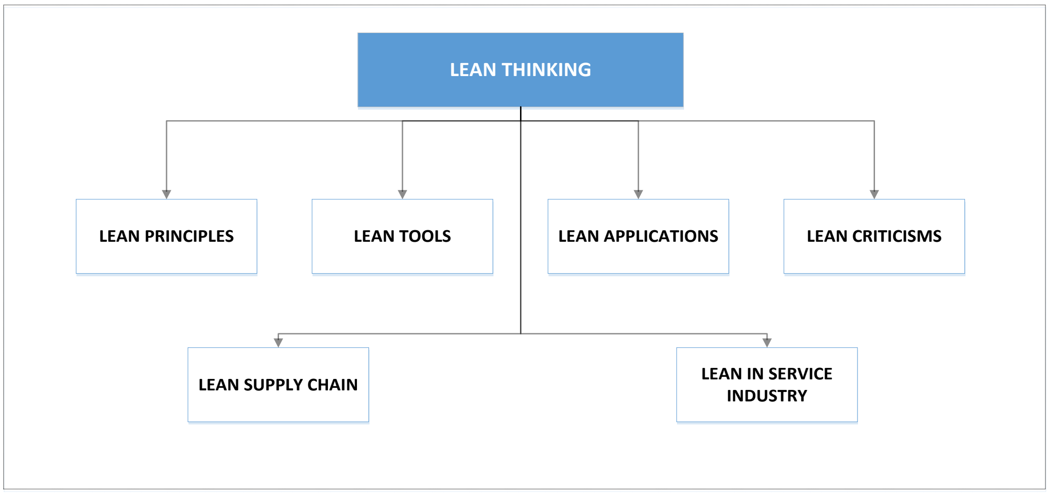

Figure 5: Structure of Lean Thinking Literature

2.3.2 Lean Principles

During this research, the paradigm that will be followed is to investigate the applicability of Lean in one core branch of the SC. Hence, the five principles of Lean thinking are essential in order to reach perfection. Once these principles are applied correctly in the system, then value perfection will be positive. In order to facilitate understanding as well as follow possible routes to the problem solution, the five principles will be discussed.

Identify Customer and Specify Value:

The first phase is the identification of value-added to the customer i.e. awareness that a minor fraction of the entire work and time in a company or organisation truly adds value to the customer. For a particular product and service quality to be seen from the customers' point of view, a clear definition of customers' value must be stated. This way, the waste and non-value-added activities in the process can be targeted for elimination.

Value Stream Identification and Mapping:

The value stream includes all of the steps and activities that take place to bring the process in an organisation into the completion phase. This serves as the end-to-end route for delivering value to the customer. As soon as a clear understanding of what the customer wants has been specified, the next step will be the identification of the process of how to deliver (or not deliver) these requirements to them.

Creation of Flow by Waste Elimination:

Only 5% of activities carried out along the Value Stream add value at the initial mapping of a Value Stream in a process. For service environments, this activity for value-added services can increase to 45% (Cardiff University, 2014). Elimination of waste increases the certainty of products or services reaching customers without interference, waiting or diversion (in the case of products).

Customer Pull Response:

In this phase, organisations should understand the demand of their customers and build a response plan to achieve this demand. By not doing this, an organisation will only base their production on the quality, quantity and duration of product delivery to their customer.

Perfection Pursuit:

Creation of flow and pull commences when separate process steps in an organisation are thoroughly restructured. This makes the return become really important because all the stages link together. When this occurs, unseen wastes are made visible and through constant elimination, the process will exponentially accelerate towards perfection.

2.3.3 Lean Tools

Numerous tools must be intertwined together for Lean practices in an organisation to work effectively and improve continuously. Bhasin & Burcher (2006) suggest that rather than practising one or two tools of Lean, it is appropriate for organisations to practise either most or all the tools. Below are some of the Lean tools that should be applied by organisations that intend to use Lean principles as a form of improvement:

- Value Stream Mapping (VSM);
- Continuous Improvement – kaizen;
- 5S and Visual Management;
- Eight waste elimination;
- Supplier development.

2.3.3.1 Value Stream Mapping

VSM is a way of organising the Lean project to incorporate the principles of a Lean value stream (Bill & Brian, 2011:230). Oftentimes, VSM is the Lean tool that is initially applied during the utilisation of a Lean improvement methodology. The reason for this is because it shows the door-to-door movement of activities in the SC.

Lian and Van Landeghem (2002) defines VSM as a tool for mapping processes which are used to describe SC networks. To understand the meaning of VSM, it is essential to have full knowledge of the word 'Value Stream'. Value stream is the sequence of value-adding activities that satisfy customers' specific needs. According to McDonald, Van Aken and Rentes (2010), value stream is defined as the entire valued-added and non-value-added activities necessary for a specific product or service to reach the customer effectively. The value stream includes both the overall SC as well as the internal operations.

A value stream map is a tool that is used for the improvement of a process through the identification of value-added services and waste elimination. McDonald *et al.* (2010) describe

VSM as an improvement technique in an organisation used for the visualisation of the complete production process, which represents both information and material flow for improvement of the production process through the identification of waste and its sources. In the value stream map, the process follows value creation with the addition of specific data that should work as an integral part of the process. These data contain processing, waiting and cycling times, quality of service or products (what the rate of rejection is), inventory and other necessary resources. Any other necessities needed to analyse the process must also be included. Earley (2014) suggests that in the stage of data collection, a little thinking and work should be carried out by getting the team players involved in the improvement process to collect data relating to the performance of the process. Some of the usual data that are collected are listed below:

- Cycle time;
- Inventory;
- Change over time;
- Up-time;
- Shifts worked;
- Number of operators;
- Scrap rate;
- Net available working time;
- Batch Size;
- Pack Size.

Most of the listed elements above are more applicable in the manufacturing environment. Depending on the nature of service, the VSM element will slightly differ. Some of the useful elements for service environment are:

- Customer;
- Supplier;
- Process/system control;
- Task administrator;
- Lead time;
- Processing time;
- Waiting time;
- Process Activities.

Hines, Rich and Esain (1999) presented a paper on the use of a new variant of a process point of reference known as value stream mapping. The goal was to develop a supplier network round a well-known distributor of mechanical, electronic and electrical components. The approach used was a mapping of activities in the process, identification of opportunities for improvement, and taking responsibility for the organisation's improvement programme. The result obtained after the implementation of these required steps was 50 new suppliers within eight product areas of category. The paper finally concluded that other companies can follow similar paths in solving related problems with the evidence that the outcomes obtained from early programmes and other essential learning points are valid.

Following the definition and explanation of a value stream map (VSM), the steps for the creation of a VSM is basically important especially for easier process sketching. McDonald *et al.* (2010) define VSM as an organised methodology for value stream improvement. The first step of value stream improvement is the identification of significant product groups and selection of one as the improvement target. The next step is the construction of a current state map for value stream products with the aid of information collected from the existing process. The third step in the value stream mapping process is to map the future state. McDonald *et al.* (2010) further outline eight questions that must be answered to construct the future state map as shown in Table 2. The first question speaks to the determination of takt time. According to Fekete and Hulvej (2013), takt time is the customer demand rate for a service or product. It synchronises the pace of sales with the pace of production. It shows how quickly every batch of service or production should be performed. Takt time's usual calculation period either is one day or one shift.

The calculation for takt time is shown below:

$$\boldsymbol{Takt\ time} = \frac{\boldsymbol{Available\ Production\ per\ day}}{\boldsymbol{Customer\ Demand\ per\ Day}}\,(\boldsymbol{hours/unit})$$

The fundamental problems connected to the construction of the future state map are covered in the first five questions. The sixth and seventh questions address details of technical implementation like the control system to define non-mapping details. The final question discusses the actions for the improvement needed for the current state’s transition to the future state. Then, a plan of implementation will be made to realise the future state.

Table 2: Future State implementation questions

Future-state questions	
Basic	1. What is the takt time? 2. Will production produce to a finished goods supermarket or directly to shipping? 3. Where can continuous flow processing be utilised? 4. Is there a need for supermarket pull system within the value stream? 5. What single point in the production chain will be used to schedule production?
Heijunka	6. How will the production mix be levelled at the pacemaker process? 7. What increment of work will be consistently released from the pacemaker process
Kaizen	8. What process improvements will be necessary?

Source: *(McDonald et al., 2010)*

Rotherand & Shook (1998) indicated that the current state map and the future state icons in the value stream are categorised into three groups; material, information and general icons as seen in Appendix A**.** The current state map must be based on the set of data collected from the shop floor and should be constructed by applying the standard icon in Appendix A (Braglia, Carmignani & Zammori, 2006).

Application of VSM for process improvement has been practically successful for numerous organisations across the years and has also attracted several advantages. Some of the advantages identified by (Braglia *et al.*, 2006) are outlined below;

- VSM shows both the information flow and material flow.
- It connects the internal process of the facility to the entire Supply Chain.
- It appears as Lean Production application basis.
- It covers information concerned with both production time and inventory level.
- It serves as a link for the planning of product, forecasting demand and scheduling production for a smooth flow on the shop floor.

Unfortunately, VSM also has its disadvantages as pointed out by (Braglia *et al.*, 2006):

- Basically, it is a technique based on paper and pencil, therefore the level of accuracy is limited.

In practical settings, many organisations operate on high variety and low volume form of business i.e. numerous value streams contain a high amount of industrial part and product. Hence this complication cannot be handled through the application of a standard method.

2.3.3.2 Continuous Improvement - Kaizen

Bill and Brian (2011:230) claim that continuous improvement is an activity, usually in the form of kaizens, held on a regular basis, geared toward meeting goals of the Lean enterprise (increased productivity, higher quality, reduced inventory, reduced floor space, and reduction in lead time).

Kaizen is a Lean tool that deals with continuous improvement and lies in between the analysis and improvement step of the DMAIC (Define, Measure, Analyse, Improve and Control) methodology. Many authors have written about the importance of Kaizen as a key element in Japanese management, and the concept is often presented as one of the underlying principles of Lean production and total quality management (TQM). Yet there remains considerable ambiguity and inconsistency in the way the concept is described in the literature. For example, Kaizen is regularly misrepresented as either an endless 'free lunch' of improvements which emerge magically from the workers or as the mundane application of suggestion schemes and quality circles (Brunet & New, 2003). The improvement types for Kaizen, Kaizen events and traditional improvements are shown in Table 3.

Table 3: Kaizen, Kaizen events and Traditional Improvement

Improvement Type	**Kaizen**	**Kaizen events**	**Traditional improvements**
Large or small scale improvements	Small, steady improvements overtime	Big, fast, simple improvements in three to five days	Dramatic, one-time, complex, technologically based
Who is affected	Individuals or groups	Team based	Top-down approach
Costs	Low cost	Low cost	High cost usually
Buy-in potential	Good because employees came up with the ideas	Good because employees came up with the ideas	More difficult because users were not asked their opinion
Intended benefit	Can be used for any benefit, including quality of work life	Usually focused on reducing time or non-value added activities	Meant to revolutionise an organisation

Source: *(Manos, 2007)*

2.3.3.3 5S and Visual Management

5S is a very powerful Lean tool for organising and improving organisation processes. There are five basic steps for the 5S tool namely: Simplify, Straighten, Scrub, Stabilize and Sustain. According to Burke (2013:42), the idea of 5S is to use a 5-step process for waste reduction and productivity optimisation. This can be achieved by maintaining an orderly workplace and also making use of visual cues for the consistent achievement of operational results.

The 5S cover many visible or transparent increasing practices that focus on standardising the workplace components (machinery, space, tools and inventory) in terms of classification, type, quantity, location etcetera (Algan, Lauri & Patricia, 2010). With the use of visually attractive means like 5S boards, mascots, tablets and the like, 5S effort is displayed, underlined and reinforced in companies who intend to reduce waste with this technique (Algan, Lauri & Patricia, 2010).

The 5S technique offers measurable benefits. A very good way of identifying these benefits is to create and at the same time track some specific metrics. For instance, carry out measurement of the time required for item location in the workplace prior to 5S practice and then perform another measurement of the time required for item location after the workplace has been improved. For longer-term benefits, measurement can be carried out by monitoring the rate of injuries reported after 5S implementation. With 5S implementation, fewer injuries, as well as lower training costs, will be recorded. Training of employees is easier and faster in an environment that is orderly (Production Automation Control, 2009).

Another way of measuring the benefit of 5S around the workplace is through pictures. Pictures are effective for visually highlighting improvement appearance and order in the workplace.

2.3.3.4 Waste Elimination

It is also paramount to identify the waste of Lean so that a value stream can be defined in order to assist in the drawing up of a value stream map. Seven kinds of waste were originally identified in the value stream but a recently identified waste of employee underutilised skills was added to the list. One can easily use the term “DOWNTIME” to remember the eight Lean wastes as seen in the figure below.

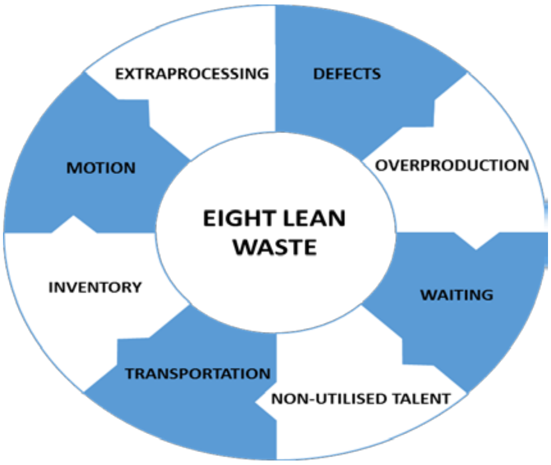

Figure 6: Eight Lean wastes

Defects: The waste of defect in a chain is often caused by unclear customer specifications at the beginning of the chain. These, in turn, result in a lack of process control, incapable processing in the distribution chain, unskilled personnel, restriction of quality to the only department, and incapable suppliers.

Overproduction: Overproduction is unnecessarily producing more than demanded, or producing it too early before it is needed.

Waiting: The waste of waiting is caused by unnecessary delays in the process. If operators of the process delay activities in any of the sub-processes, time is wasted and cost of production will increase, further impacting cumulatively on profitability.

Non-Utilised Talent: This includes underutilization of mental, creative, physical skills and abilities, whereas non-Lean environments only recognise underutilization of physical attributes. Some of the more common causes of this waste include poor workflow, organisational culture, inadequate hiring practices, poor or non-existent training, and high employee turnover.

Transportation: This type of waste arises as a result of redundant movement of things or moving things farther away than they ought to be. When supplies are stockpiled very far from the end point of use it creates lagging behind in the processing time.

Inventory: The majority of the reasons for having excess inventory could include production schedule not being levelled, inaccurate forecasting, downtime of machines, large set-up times, pushing materials through, batching of parts, and suppliers not delivering the required parts on time**.**

Motion: The waste of motion is any movement of people that does not add value to the product or service.

Extra-processing: Extra-processing or over processing is unintentionally doing more processing work than the customer requires in terms of product quality or features. Over-processing occurs in situations where overly complex solutions are applied to simple procedures.

2.3.3.5 Supplier development

A network of competent suppliers is needed in an organisation for it to have an effective scale of competition in the world market. A supplier development programme can be utilised to create and improve such a network. Furthermore, various supplier capabilities that are necessary for preparing an organisation to meet its competitive challenges are covered under supplier development programmes (Chan, Charles and Kee, 1990:2). Supplier development increases in importance in order to reach competitive advantages in today's global market. The industry is moving from an old way of treating suppliers where the low price was fundamental and suppliers with poor performance were left without business. Today companies understand the high cost of switching suppliers. The companies are dependent on their suppliers when downsizing their own organisations, which leads to supplier development instead of supplier switching (Rönnquist & Wenner, 2014:23).

The Supplier Development strategy is built with a customer-supplier Value Stream Analysis defining the process for the development of suppliers and their value creation process. It also sets the criteria against which suppliers will be assessed during procurement. It provides the concrete link between the aims and priorities of the client as a whole and their suppliers. It is, therefore, vital that the assessment and development strategy successfully allocates the two to three most important expected deliverables of the business transformation activity to the right suppliers, leading to them being chosen for long-term relationships.

2.3.4 Lean Applications

The implementation of Lean practices was based on numerous ideologies which were in existence before the appearance of Lean, such as Just-in-time (JIT) production and Total Quality Management (Taylor, 2010). Hines et al. (2004) point out that the concept of Lean has advanced over the years and this process of advancement will be constant. Hence, a major confusion has arisen as to what Lean is and what Lean is not; an observation drawn from academic research and practical application.

Toyota Motor Corporation implemented the early stages of Lean in their company, which was guided by Taiichi Ohno (Taylor, 2010). The initial implementation was carried out at the automotive engine manufacturing section by applying the technique of waste elimination on the flow of product. The technique was also applied to the assembly of the automobile and was later introduced to other sections of Toyota Motor Corporation SC (Taylor, 2010).

There are various case studies and industrial application of Lean ranging from manufacturing to service sectors. What follows is a brief discussion and results of Lean application in various sectors and industries. According to Salem and Zeimer (2005) the grouping of Lean Construction and Lean Manufacturing can be carried out by principles of customer focus, organisation and standardisation of the workplace, people and culture, elimination of waste in the process, and continuous improvement with quality assured programmes. Salem and Zeimer (2005) define Lean Construction as the continual elimination of waste by meeting every requirement of the customer while focusing entirely on the value stream and pursuing perfection in accomplishing a constructed project.

Middleton (2001) points out the vital concept of Lean principle for software developers. For example, he finds that as an alternative to the production of required documents of large sizes and then passing them over to the design unit for necessary verification, the verification should be done by the design unit as each page is finished. This way errors detected on each page by the design unit can be sent back to the analyst for correction. Hence, this practice will assist the analyst to receive an instant and ongoing response to their performance.

Through the implementation of Lean Practices, TRW Automotive Electronics Group reduced the time for raw material movement by 61 percent, minimized lost man days by 81 percent, slashed capital expenditures by 70 percent and increased turnovers in production inventory by 28 percent (Motwani, 2003). Outside the automotive industry, one of the most noticeable Lean manufacturing programmes is the Lean Aircraft Initiative that involves MIT, US Air Force and 25 defence contractors. There are reports on the application of Lean principles to the development and manufacturing of Low-volume-high-variety products like aircraft. Companies like McDonnell Douglas and Lockheed practised the application of the principles of Lean from the design to the manufacturing of their products (Jina, Bhattacharya & Walton, 1997).

2.3.5 Lean Criticisms

Though Lean thinking is a continuous improvement tool considered by various organisations for eliminating waste and adding value, numerous studies on this topic have reached the conclusion that it has its limitations. Hines *et al.,* (2004), point out that the ability of an organisation to cope with variability, the absence of contingency, narrow operational focus on the shop floor and negligence of the human aspect or resources are the major aspects of Lean criticism.

Taylor (2010) observes that besides the numerous benefits of Lean application, its concepts can bring about possible downsides. Such drawbacks can be identified when reduction of waste shifts the focus of a company to mostly short-term undertakings that add value to the system while disregarding the advantages of the long-term which can be attained through radical innovation. Though these innovative ideas can serve as a potential organisational contribution, they may be overlooked initially owing to the fact that they add little or no value to the current customer. According to Anvari, Ismail, & Hojjati (2011), at the time when there are unpredictability and instability of customers' demand, the principles of Lean do not apply. The following are the main components that contribute to the eradication of non-value-added activities in an organisation system: unnecessary transportation; excess inventory; needless motion; unnecessary waiting; overproduction; excess processing; defects; and untapped skills of organisation personnel.

A very good industrial example of Lean thinking limitation was found in Toyota, the inventor of Lean production. It was beginning to get clearer that Lean thinking had begun to display some limitations in Japan as well as in the West. Toyota achieved great success in the application of Lean principles into their manufacturing system in Japan but experienced Lean principle limitation via 'single project focus' that leads to overproduction of fat design product (Smart, Tranfield, Deasley, Levene, Rowe & Corley, 2003). Regarding automated processes, there are specific limitations of the applicability of Lean thinking. One of these is that Lean benefits can be realised for a process plant in the design and construction but has a minimal benefit on the unit of operations (Smart *et al.,* 2003). The underlying issue to this is possibly the human role connected to operations, where there may be no fitting individual available for the role of strategic change. Another related issue is the continuous process flow existence around the process change. Lean thinking reduces if humans do not need to cooperate in the change of system.

In an article published by (Koskela, 2004), he points out that the organisational process of production lacks adequate concepts of Lean thinking. This has resulted in a vague concept such as the term 'Value'. The five principles of Lean thinking do not fully cover value generation. Furthermore, the principles of Lean do not fully capture the core subjects in their respective areas. There is an occurrence of decreased explanation and justification opportunity as a result of poor tracing of Lean origins, principles and concepts.

The difference in the characteristic of Lean and traditional supply chain are listed in Table 4.

Table 4: Lean vs Traditional Supply Chain Characteristics (Myerson, 2012)

	Traditional Supply Chain	**Lean Supply Chain**
Suppliers	**Many**	**Few**
Relationship focus	Confrontational	Long-term
Primary selection criteria	Price	Performance
Length of contract	Short-term	Long-term
Future pricing	Increased	Decreased
Lead times	Long	Short
Order quantities	Large lots	Small lots
Quality	Extensive inspection	Quality at the source
Inventory (supplier and customer)	Large	Minimal
Information flow	One way	Two-way
Flexibility	Low	High
Product development role	Small	Large (collaborative)
Trust	Limited	Extensive

2.3.6 Lean Supply Chain

In the SCM model, suppliers are viewed as forming a chain of linked processes. The concept is derived from the need for each producer in the chain to have its lower-tier supplier provide process inputs at the right time, in the right quantity, and to the right quality. If this is not done throughout the chain, the supplier delivering to the last link (e.g., original customer) cannot meet the final producer requirement.

Pioneering lean manufacturers have demonstrated that the key to a competitive SC is to be found in the way shippers work in cooperation with their suppliers. Shifting the burden (and cost) of inventory down the SC has often been the driver behind sourcing of components with more frequent (JIT) deliveries. Suppliers are expected to maintain the capability to deliver, no matter how the schedule fluctuates. Inventory is used to buffer inaccurate schedules. However, shifting the burden (and cost) of inventory down the SC does nothing to improve the performance of the chain, and the lean enterprise is nothing more than a lean SC (Carrol, 2002:50).

The Lean supply chain is considered as an integrated whole for the entire flow of raw materials to the consumer. Interfaces between the stages from which product or service moves from companies to supplier or consumer are therefore seen as artificial. The processes in these stages do not transform naturally in the procedure to add value but as a result of assets that are economically arranged which are governed by numerous factors. Such factors include the geographical location of raw material, technology configuration convenience and labour skills (Lamming, 1996). All forms of waste in the value stream are identified by Lean Supply Chain. Furthermore, Lean SC eliminates every waste identified, which exhibits the principal strength of Lean Production System (Wu, 2009).

Liu *et al.*, (2013) observe that the integration of Lean thinking into SCM was applied to develop the concept of Lean SCM, which is a relatively new concept. Dynamics, complexity and improbability inherent to both SC networks and process waste category bring about a great challenge in decision-making in a Lean Supply Chain. One of the key requirements in integrating support to Lean SC decisions is efficiency in Knowledge Management.

The fundamental principle of Lean SC is that the cost effect that is related to poor execution of a sub process goes beyond the location of the execution. In other words, it is to the detriment of the customer as well as the supplier when a progress chaser that is present within the customers' organisation traditionally speeds up deliveries that arrive late from the suppliers. The suppliers here also include the suppliers whose delivery does not warrant a speed-up process. This point is fundamental, resulting from the fact that Lean SC does not traditionally recognise the positions of supplier and customers, which have a tendency to make the central pursuit for the removal of waste unclear.

There is a high degree of Lean Manufacturing acceptance in the business environment. Hence, for absolute effectiveness, extension into the SC will be required to avoid products or services that are at their best at the preliminary stage of the chain. Therefore, Lean in SC is about applying tools of Lean principle into the components of SC in every aspect of the business. Listed below are the components of Lean SC in an organisation or business environment.

- Lean Supplier;
- Lean Procurement;

- Lean Transportation;
- Lean Manufacturing;
- Lean Warehousing.

2.3.7 Lean in Service Industry

Throughout the years, Lean has contributed significantly to the service industry. It has steadily been recognised as a key improvement concept in enhancing operations for all types of organisations (Hu, et.al 2015:984). For Lean to be applicable to the service industry, a clear distinction must be understood between service and its inherent characteristics. Andrés-López, González-Requena & Sanz-Lobera (2015) define service to be a one-off set of benefits that are consumable and perishable which can be delivered by a service provider. The provider then tailors the service to the consumers' specifications, which are then utilised by the potential service consumer (Andrés-López *et al.*, 2015:24).

Previously the lean thinking philosophy and the application of Lean focused solely on manufacturing companies. However, that has shifted to new areas such as services (Dos Reis Leite & Vieira, 2012). The focus on manufacturing was due to the tangibility of products (Andrés-López *et al.,* 2015:26). Gupta, Sharma and Sunder M. mention that there have been some limitations with the transfer of Lean manufacturing principles in services due to the differences in characteristics (2016:1029). Due to the differences between the two industries, Andrés-López *et al.* recommend that the concepts and methods of Lean should be reassessed in order for the process of application to occur (2015:27).

In service, it is critical to the application of Lean for employment engagement and the respect for people (Gupta *et al.,* 2016:1025). Bonaccorsi, Carmignani and Zannori (2011) emphasise the importance of this application, as the marketplace evolves, the satisfaction of the customer poses a challenge. This is due to the difficulty of the service industry to reduce costs and provide better quality service to their consumers. Bonaccorsi, *et al,* (2011) believe that through the application of lean thinking, it could create a possible solution for the service industry in tackling both cost and quality concerns.

The service sector is responsible for the largest share of the world's GDP. It has facilitated job creation as well as increased wealth at higher rates than other sectors of the global economy (Dos Reis Leite & Vieira, 2012). Service industry contributes significantly to society as there are several types of service; such as public services, financial services, education, healthcare services, hospitality and many others (Gupta, *et al.*, 2016:1029). Within these services, there are factors which contribute to ensuring that services continue to elevate their significance in the world. According to Dos Reis Leite and Vieira (2012), the contributing factors are; 'urbanization, demographic changes, socioeconomic changes, increased sophistication and technological changes'.

The evolution of Lean services is displayed in Table 5 in relation to time during four eras: Pre-Lean era, Lean Awareness era, Lean Exploration era and Lean Implementation Era (Gupta et al., 2016:1030-1033).

Table 5: Categories of Lean Service Evolution

Lean Service Era	Description
Pre-Lean era	The initiation of an idea generation and the discussion to decide whether there can be a similar treatment for goods and services.
Lean Awareness era	During this period, services who fought external challenges of globalisation and struggled to improve customer satisfaction and quality improvement were known as the Lean awareness era.
Lean Exploration era	From 2004 to 2008, research was conducted on the application of a Lean tool box. However, the creation of a true learning culture and values were not established.
Lean Implementation era	The last era is the Lean implementation era, which shows the growth of Lean services application, with major work in the sectors of IT and healthcare along with work in the field of finance, public sector and education.

Following is a discussion on the Lean application in some of the various service sectors.

Lean in Public Services

According to (Radnor & Osborne, 2013:266) without an understanding of the principles and assumptions of Lean, the current implementation of Lean in public services focuses on the technical tools. Through the study conducted by Suarez Barraza, Smith and Dahlgaard-Park (2009) on Lean continuous improvement in the public sector, the Lean tools 5S, Process Mapping, and Kaizen workshops were analysed. The results of the study showed that the public services were able to reach significant improvement in their work processes through the use of technical tools (Suarez Barraza *et al.*, 2009:148).

There is the vast operational potential of the lean approach to improving productivity and customer satisfaction in local governments (Suarez Barraza *et al.*, 2009). In this process, significant numbers of documents related to public services were provided to citizens (Suarez Barraza *et al.*, 2009).

Lean in Health Care Services

There have been concerns of the applicability of Lean in healthcare although the improvement methods have delivered higher efficiency and better quality products (Young & McClean, 2009:309).

In past decades, the healthcare sector has made significant advancements in the adaptation of Lean principles in healthcare operations (Tay, 2016:1158). The implementation, however, differs across organisations (Tay, 2016:1158).

Kanakana (2013:574:5) believes that the application of Lean in the health sector is successful due to Lean's focus on customer satisfaction and employee involvement.

Lean in Financial Services

The implementation of Lean has also been successful in the financial sector, particularly in call centres (Kanakana, 2013:574-6). Financial sectors such as banks, insurance and revenue services can utilise Lean principles effectively and gain substantial benefits (Kanakana, 2013:574-6). These benefits improve efficiency, customer satisfaction as well as the reduction of costs (Kanakana, 2013:574-6).

Leyer and Moormann's (2014) study has observed and identified the ways lean thinking is conducted in the financial services. Through this observation, it has shown that in finance there are moderate levels of lean thinking (Leyer & Moormann, 2014: 1376). The reason stated was that the embodiment of lean thinking has to be embedded in the minds of the employee in order for the financial service provider to become a Lean company (Leyer & Moormann, 2014: 1380).

2.3.7.1 General Observation

According to Table 5, the Lean implementation era which is the present era of Lean in a service environment shows the growth of Lean service application. In the public services, an example of the type of service environment utilised in this study, significant improvement has been realised in this era. When applied to the health sector with a complete focus on customer satisfaction and employee involvement, it reaches a great level of success. The financial services can also implement Lean thinking to the culture of their establishment. However Lean success can only be realised with absolute team work of employees and individual Lean approach to process activities.

Many service sectors vary in terms of the services provided. Therefore, it is very important to have an absolute understanding of the type of service establishment and also understand their underlying issues. This will aid the process improvement specialist the knowledge of Lean tools suitable for improvement purpose.

In summary, it can be concluded that Lean thinking success in the service environment can be attained by properly understanding the service process.

2.4 Non-manufacturing Environment

Typically, non-manufacturing supply chains lie in the service sectors. Service industries can operate in various ways or dimensions. These dimensions can be translated to an interlinked network of the supply chain. Boon-itt and Pongpanarat (2011:217) define service SC as a network of suppliers, service providers, customers and other service partners that transfer resources into services delivered to and received by the customers. Service supply chains are different from manufacturing supply chains.

According to Yap and Tan (2012:226), service sectors have common SC operations like demand management, customer relationship management, supplier relationship management, capacity and resource management. In today's highly competitive environment, the challenge of cost reduction and operational efficiency without a lapse in customer service is dominant in the service industry. More and complex challenges of high customer expectation and change in technology frequently exist in the service sectors (Boon-itt & Pongpanarat, 2011:217)

There are many types of service industries, some of which are financial institutions, marketing services, health care, maintenance services and public services. The intent of this study is to look at one of these service industry types. Hence a case study that falls in one of these types will be used to validate the study.

Public services, as well as a Maintenance Repair and Overhauling (MRO) organisation, will be discussed from the listed types of service industries. This organisation will be implemented for the case study review.

2.4.1 Maintenance, Repair and Overhaul Organisation

McLaughlin and Durazo-Cardenas, (2013), describe Maintenance, Repair and Overhaul (MRO) as a comprehensive term that covers the necessary actions undertaken to ensure the smooth operation of equipment. According to the European Federation of National Maintenance Societies, maintenance is defined as a combination of administrative, technical and managerial tasks necessary to bring the lifecycle of an item to a required function. Haihua Zhu, James Gao, Dongbo Li and Dunbing Tang (2012) describe maintenance as a practice to ensure that systems frequently achieve the functions they are designed to reliably and safely carry out. The maintenance service has various goals, some of which are listed below:

- Reduce repair time;
- Advance reliability of product;
- Capture important information for further analysis.

It can, additionally, be divided into scheduled and unscheduled maintenance. Scheduled maintenance is a precautionary action that ensures the function of a product at fixed intervals while unscheduled maintenance is related to repair of a process in the system as it is a task that is neither planned nor programmed. In the aerospace industry scheduled maintenance consists of routine and detailed inspection. Unscheduled maintenance is required when an item in the system has broken down or failed. McLaughlin and Durazo-Cardenas, (2013), define the overhaul process as where equipment in a system is being checked for wear, tear and failure so as to return to a standard operation mode that might either be less than, equal to or greater than the built standard of the Original Equipment (OE).

Traditionally, in the MRO organisations, planning of resources has been accomplished as a product of availability of resources within a short-term duration of time, mainly two weeks. Usually, the precise action of maintenance duty is the result of emergency response and necessary matters to keep a specific end product or a part of equipment in service (Wetzer, 2008). The outcome of this is that the schedule of maintenance regularly functions as general guidelines with the poor allocation of critical resources. The poorly allocated resources normally need to be constantly changed and repositioned in an ad hoc way to reach the emergency maintenance needs. This lack of formality in the process results in excessive downtimes of equipment and excessive maintenance cost (Wetzer, 2008). The MRO type of service can be predominantly found in the aerospace, railway and rolling stock sectors.

2.4.1.1 Aerospace Industry

During product usage in the aerospace industry, a system of maintenance, repair and overhaul is exercised (Zhu, Gao, Li, & Tang, 2012). Lee, Ma, Thimm, and Verstraeten, (2008) point out that capital equipment and long service period, product life and the configuration of complex systems pose a great challenge in the aviation industry. The aviation industry does not gain profit from the sale of aircraft but by the appropriate maintenance of the aircraft over a lifespan of 30 years. Aerospace MRO firms, with properties or assets in service for a long period of time, must endeavour to place their focus on tireless product performance.

2.4.1.2 Rolling Stock Organisation

Resulting from the fact that rolling stock is one of the most important cost components of a railway system, an important consideration as to its cost implication is necessary prior to any procurement. The costs that are predominantly involved are the power supply, acquisition and rolling stock maintenance. For the provision of a quality service to railway passengers, careful decisions on the amount of rolling stock necessary are essential as the costs associated with rolling stock are usually extensive (Alfieri, Kroon, Groot & Schrijver, 2006).

There has been an advancement in the improvement of various parts of railway rolling stock, for example, lighter freight cars with larger capacities, kinetic energy regeneration, more powerful and less polluting locomotives and better braking systems for both locomotives and railcars.

It is vital that rolling stock operating companies meet every mandatory requirement for carrying out planned functions for rolling stock services and components. Doing this can be both challenging and time-consuming. There is also a very high risk of not fulfilling these specific requirements. Hence, to meet these specifications, suppliers have to verify that their requirements tally with those of the customer in order to avoid conflict between customer and approval body expectations. The design of the rolling stock vehicle should meet the required standards of the location (country) for easier access to railway networks.

Subsequent decisions that are to be made in rolling stock management are: choosing which type of rolling stock is to be utilised; procurement of new rolling stock; transient employing or leasing of rolling stock; enhancing existing rolling stock that has concluded its life process, and the maintenance policy to be applied (Caprara, Kroon, Monaci, Peeters & Toth, 2007). Apart from all categories of technical specifications, the suitable kinds of first and second class facilities per unit are significant issues in the acquisition of rolling stock. Characteristically, small units' rolling stocks may be comparatively highly expensive, while the operation of large rolling stock may be inflexible (Caprara *et al*, 2007).

Once the rolling stock has been manufactured, it is necessary for companies to perform installation and testing of the railway vehicles in order to validate system requirements. Abbink, van den Berg, Kroon & Salomon, (2004), find that much research that is carried out on railway rolling stock deals with routing and scheduling of freight trains and locomotives.

The rolling stock economic life span extends to several decades and is, therefore, an investment which cannot be changed on a regular basis. With this in mind, a clear decision needs to be made on how many carriages are required per scheduled train in order to reach a satisfactory level of passenger service (Peeters & Kroon, 2008).

The planning procedure of passenger railway operators in rolling stock is usually divided into numerous stages. There are mainly four stages of planning: strategic, tactical, operational and short-term planning. Following these stages, the concluding plans are carried out and adjusted if necessary in the actual operations (Budai, Maróti, Dekker, Huisman & Kroon, 2010).

In the strategic planning phase, long-term decisions are made regarding rolling stock procurement. The tactical level deals with assigning different types of rolling stock to their appropriate line of the network which can be done annually. The major aim of the operational planning is to discover a basic rolling stock circulation service of high quality and low operational cost. This circulation is ultimately carried out throughout the year. Nonetheless, minor changes are applied to daily timetables owing to railway infrastructure maintenance or extra trains. Modification of the rolling stock is required when changes to the timetable have been made and this process is carried out during the short-term planning stage. The time frame of this stage of planning spans from a couple of days to a couple of weeks prior to the operation (Budai *et al.*2010).

2.4.2 Public Sector Procurement

Arising from the fact that procurement does not deal with one single process or action, its definition often poses a high level of difficulty. Procurement contains a broad range of events from the stage of needs assessment for goods through to the goods disposal (CIPS 2013:3).

According to a white paper on public procurement (Gupta, Prakash and Jadeja 2015:296), an organisation, irrespective of whether it is public or private, requires external resources in pursuit of its objectives. This resource could be tangible or intangible. The importance of procurement as a business management function is crucial as it efficiently and effectively manages the entire process in the chain from needs assessment, product identification, forecasting, sourcing, logistics, value engineering, risk management, supplier relationship management and regulatory compliance. This whole function is answerable to the stakeholders which include shareholders, employees, clients, the whole society, government and in fact the entire environment. Procurement can further be explained as an act of supply management managed by capable, experienced practitioners and professionals.

The function of procurement has strategic importance as 60-70% of organisation expenditure is incurred in public procurement. It aids an organisation in the improvement of profitability, shares in the market, time reduction from concept to market and customer satisfaction. It also helps in other aspects such as research and development (R&D) for better quality and values, improvements in technology, innovation, better product and service delivery, and mass customisation (Gupta, Prakash and Jadeja, 2015:296).

For many reasons, public procurement serves as an important function in government. One reason is that the magnitude of outlays for procurement has a large impact on the economy and needs to be managed properly (Amemba, Nyaboke, Osoro, &Mburu, 2015:271). According to Bodhibrata (2012), the key watch words for public procurement are fairness, transparency, value for money, time and quality. The fundamental objectives of the processes of public procurement according to the World Bank are economy, efficiency, transparency and accountability.

In procurement, one simple rule is that, in the end, it is vital to channel thoughts in terms of total cost of ownership. This should not just include the price of purchase, but also the time and resources that were utilised in the pursuit of the ownership. The real cost involved with the acquisition of goods or services can be better understood by also understanding all of the steps involved in procurement (Amemba, C., Nyaboke, P., Osoro, A., Mburu, N. 2015:271).

2.4.2.1 Challenges of Public Procurement

Redges (2012:306) pointed out that in terms of changes, especially in underdeveloped nations, procurement in the public environment is one area that is lagging behind. The traditional form of procurement is still in use in underdeveloped nations and is based on adversarial relationships with numerous suppliers. In the tendering process, the bid and bash approach is used which is hugely focused on bid and arm's length relationships with a lot of suppliers. Short relationships with suppliers are the norm because the contracts awarded to suppliers have an expiry date. This means that the relationship between the material requester and the supplier ends automatically on the expiry date and after that, a new tendering process will commence where potential suppliers are again prompted to compete for bidding. Until the present time, no attempts have been made to go into long-term mutual agreements with a selected number of suppliers. This traditional mode of procurement has the following pitfalls;

- Increase in procurement cost;
- Monitoring performance of numerous suppliers;
- Continuous education of suppliers on institution processes and requirements.

Additional time is spent in continual soliciting of prospective suppliers each time the same requirement arises. Furthermore, there is a limitation on the utilisation of suppliers' total resources because they are kept at arm's length. The public sector simply sees the suppliers as vendors and not as external resources they can benefit from as they limit their benefit to the procured goods and services (Redges 2012:306).

Each year, procurement is performed for each material individually or independently on a lump sum basis. The outcome of this is an elongated cycle time due to the repetition of efforts in finalising the annual contract. There are certain disadvantages to using the system of lump sum procurement for purchasing all items on a year-to-year basis. These include high inventory, high stock, high cycle time, poor responsiveness, duplication of efforts in contracting, the high cost of procurement as a result of the uncertainty of future business, the poor incentive for innovation and arm's length supplier relationship management.

More challenges arise as vendor approval from a centralised agency becomes a continual process. There are issues of lack of transparency in product development and source approval. Quality assurance of incoming raw material primarily depends on pre-dispatch inspection of all items. This results in higher inventory in the system, higher cycle time, poor responsiveness and additional cost.

2.4.2.2 Benefits of Public Procurement

Benefits that can be realised in public procurement are: quality product assured; goods delivered at the right time; right quantity delivered; right price given; right place of delivery assured; transparency assured; corruption reduced and value for money spent (Richmond, K., Owosu-Bempah, G., Amoako, D., Osei-Tutu, S. 2013:65).

Procurement possesses the potential of creating synergies between innovation, environmental protection and market growth. In particular, spending strategically by the government can stimulate market demand for sustainable production of goods and services e.g. by shifting more rapidly to cleaner technology. In contrast to the common perception, financial savings over a whole lifetime can be achieved by sustainable procurement e.g. procuring LED bulbs might be more expensive in the short term but it eventually contributes to cost savings in the long term (OECD, 2012).

CHAPTER 3: CASE STUDY DEFINITION

3.1 Introduction

The purpose of this chapter is to discuss the SCM functions of the case study chosen for the research. As highlighted in the introductory section on Non-manufacturing Environment literature, one type of non-manufacturing organisation will be utilised for the research case study. It was ensured that the case study chosen for the research study fell into this environment. More discussion on the case study is carried out in subsequent sections.

3.2 Rolling Stock Procurement SCM

A good example of non-traditional Lean environment can be found in the MRO organisations. The Rolling Stock Procurement SCM of the Passenger Rail Agency of South Africa (PRASA) is the case study chosen for this research study. This chapter aims to broadly discuss the PRASA RS Procurement SCM functions. The components of PRASA RS Procurement SCM are divided into three stages. Similar to the components of Lean SC in sub-section 2.3.6 these SCM stages fall into the following categories:

Demand Management (Lean Customer), Acquisition Management (Lean Supplier, Lean Procurement and Lean Transportation,) and Materials Management (Lean Warehousing and Lean Customer).

The organisation currently uses a combination of SAP® enterprise software and Facility Maintenance Management System (FMMS) for the management of its operations. SAP® is utilised for purpose of procurement and inventory management while FMMS is used for providing and capturing maintenance work orders (Tendayi, 2013).

Most of the information in this section was obtained by a thorough GEMBA walk (interviewing of Managers and Supervisors, and the collection of raw information in form of documents) on the current process.

The organisation’s SC denotes the set of functions involved in the planning, design, development, production and delivery of a product or service which forms basic inputs or raw material through to final user and disposal. SCM, therefore, specifies the management of the interdependent activities within the organisation SC, with the goal of increasing effectiveness and efficiency in order to reduce redundancy and streamline the process. The SCM department in this environment is responsible and accountable for the activities outlined below:

- The compilation of bid documents.
- Ensuring the completeness of bid documents.
- Ensuring that all potential suppliers are compliant with relevant legislation through ensuring the completion of background checks on these potential suppliers.
- Ensuring that the bid process complies with policies, procedures and regulations.
- Performing all monitoring activities.
- The recommendations of company procurement policy.
- The initiation and preparation of requests for proposals/bid/quote to and from potential suppliers.
- The initiation and management of Bid Evaluation Teams.
- The management of contracts for products and services.

For needed material to be purchased, delivered and managed it has to pass through three phases: Demand Management, Acquisition Management and Materials Management. However, there are different procurement strategies for the two categories of materials in this organisation which will be discussed in section 3.2.2

3.2.2 Overview of Procurement Procedure

The two categories of materials or service procurement in this organisation are procurement below and above R350 000. An illustrative flow diagram of these procedures is shown in Appendix A and B respectively. Since PRASA is a Public Limited Enterprise, its procurement procedures are greatly subject to regulatory frameworks that control the practice of the purchases. One of the regulatory frameworks used is the Preferential Procurement Framework drafted by Republic of South Africa National Treasury (Gordhan, 2011). This framework is based on the aims of the Broad Based Black Empowerment Act and its codes of Good Practice:

A request for quotation (RFQ) is allowed for procurement not exceeding R350 000. In respect of a quotation not exceeding this amount the following will apply:

- A minimum of three (3) written quotes should be obtained from suppliers on the database. In the event that potential suppliers are not available on the approved Supplier Database, quotations can be obtained from any other suppliers provided the authorisation has been granted.

- Requests for quotations must be in writing by means of a letter, facsimile or electronically (email), with precise and detailed specifications from the onset as contained in the authorized Purchase Requisition.
- If it is not possible to obtain at least three (3) written price quotations, the reasons for that should be recorded and approved by the Chief Procurement Officer or their delegate.

For procurement exceeding R350 000, a competitive bidding process is applied where steps different from that of RFQ will be followed during the acquisition stage. In view of this, it is very important to have full knowledge of the process of acquiring a material from demand to its final receipt. The bidding process will be discussed in details in section 3.4 under the acquisition management stage of the SCM.

As previously stated, there are three basic processes in the value stream that can bring a material or service from request to receipt. These processes are stated below and discussed in subsequent sub-sections:

- Demand Management;
- Acquisition Management;
- Materials Management.

3.2.3 Demand Management

The Demand Management process starts from the performing of a needs assessment for every product that is to be procured at the beginning of each fiscal year. For an effective needs assessment to take place, there are various elements which ought to be considered, namely:

- Future and current need requirements;
- Identification of critical delivery dates;
- The frequency of need;
- Budget availability;
- Expenditure analysis (based on past expenditures);
- Specifications;
- Commodity analysis (checking for alternatives);
- Company strategic plan;
- Industry analysis.

Following the needs assessment by the line department requesting the material or service, the SCM department will develop a procurement strategy based on the nature of material or service required, delivery condition and the prospective suppliers. Procurement strategies might include, among others:

- Utilizing term contracts;
- Local versus international buying;
- Utilizing local black business;
- Utilising a paper-based bidding system.

3.2.4 Acquisition Management

The processes in acquisition management are numerous. Critical attention and observation are therefore required to successfully bring the acquisition of a material or service into timely completion. Below is the discussion on each step in the acquisition management process.

3.2.4.1 Supplier Database Management

The initial step in this phase is database management, where the SCM will build and maintain an approved supplier database. There would be categorisation of suppliers in the database according to the goods and services they provide, locality, and a record of past performance indicating whether the supplier has been restricted or not. The SCM must ensure that the supplier database is kept up to date to avoid unnecessary complications.

3.2.4.2 Bidding Method

The decision on the best possible bidding method depends on the assessment result in the demand management phase. As initially stated, RFQ is applied for purchases or services less than R350 000 while the competitive bidding process is applicable for purchases or services above R350 000. Apart from the usual competitive bidding for procuring material or services, there are other methods of bidding. The optional methods are applicable in the instance where the competitive bidding process and RFQ are not applicable. Some of these methods are listed below.

- Unsolicited Bids;
- Emergency Purchases;
- Sole Source;
- Confinement.

3.2.4.3 Bid Administration

Bid documentation should be based on conditions of the contract and should at least include contents like data sheet/drawing, pricing schedules, and a specific contract agreement stipulating delivery standards and requirements. Also in administering a bid, special conditions as drafted by Legal services and approved by Chief Procurement Officer must form a part of the bid.

Another important part of bid administration is performance security. This is required to serve as a penalty for loss resulting from the bidder's failure to complete the obligations under the contract. Often a bank guarantee is required as performance security.

The assessment of evaluation criteria and weightings are vital because they are those aspects of a bid that will be measured, quantitatively and qualitatively, to arrive at an integrated assessment as to which bid is likely to best meet the needs as described in the bid document. To compensate for important differences in evaluation criteria, weights are allocated to the criteria.

3.2.4.4 Bid Evaluation

Bid evaluations must be done in two phases by the Bid Evaluation Team (BET). The first phase is to ensure that all the bids are evaluated for compliance with critical criteria as stated in the bid documents. Critical criteria or prerequisites are those aspects of the bid that, if not met in full, will automatically disqualify the bid from further evaluation. The second phase is to evaluate each bid based on the response received in relation to the criteria and conditions stipulated in the bid document. Qualifying bids are evaluated and scored against the criteria that were stipulated in the bid document.

3.2.4.5 Bidding Adjudication

After the BET has evaluated the bid against the predetermined criteria, it will make a recommendation to the adjudication committee as to the preferred bidder. The final approval body for bids depends on the Delegation of Authority. The contract will be awarded to the bidder who provides the best overall value to the company. All bidders will be notified of the outcome of the evaluation process once the bid has been awarded to a successful bidder or the bid has been withdrawn by the company.

After the bid award and notification process, company representatives will conduct a debriefing session. The debriefing session will be structured in a manner which will allow the supplier to gain an appreciation of the reasons for non-selection of their bid. This may include technical, operational or commercial detail but must not include disclosure of any commercially sensitive or proprietary information.

3.2.4.6 Appointment of Consultant

Generally, the rolling stock procurement unit follows the approach of Quality and Cost-based Selection (QCBS) for the appointment of a consultant. The approach addresses competition among firms in which the selection is based both on the quality of the services to be rendered and on the cost of the services to be provided. The company will in most instances make use of this approach. Besides QCBS, there are other approaches of appointing consultants as listed below.

- Quality based selection (QBS);
- Selection under fixed budget;
- Least-cost selection;
- Section based on consultant's qualifications;
- Single source selection;
- Single or individual consultants.

3.2.4.7 Contract Preparation

Depending on the nature of the transaction the purchase or service delivery contract may vary. With this in mind, it is the role of the SCM to ensure that every requirement is included in the contract for the specific requisition. Some of the common types of contracts are:

- Lump sum Contract;
- Time-based Contract;
- Percentage Contract;
- Commitment Contract;
- Non-commitment Contract;
- Purchase Orders;
- Service Orders.

3.2.4.8 Procurement

The procurement process in the acquisition management of the PRASA RS SCM must abide by the regulatory framework drafted by Republic of South Africa National Treasury (Gordhan, 2011). The company also follows a specific management discretion and verification strategy.

3.2.4.9 Contract Administration

In the context of this organisation, contract administration is the process of handling and maintaining elements of a contractual agreement between the department and the contract or service provider. One such element for contract management is ensuring control over change, i.e. managing changes to any part of the original agreement. Another one is to measure performance against contract requirements and service level agreement.

3.2.5 Material Management

The management of supplied material runs through three phases, namely: inventory management, warehouse management and vendor performance. For the case of this research study and subsequently for mapping purposes, only inventory management will be used as it covers the receipt stage for the requested material or service.

Material planning and management lie within the boundaries of various roles in PRASA Material Management Services. The roles of personnel are shown in Appendix B. The responsibility for planning the budget for material consumption of scheduled maintenance and unscheduled maintenance lies solely on the shoulders of the MRP Technical Planner which makes this role a very crucial one in material planning. Appendix C shows the step-by-step procedure for material planning and budgeting of scheduled and unscheduled activities. When purchased rolling stock material does not conform to the required quality, it is segregated and corrected to avoid the unintentional use or release of such material. Appendix D shows the process flow to control non-conforming procured materials. The form attached as Appendix E is the Non-conformance Report (NCR) used to collate information on the material or services which do not conform to quality.

3.2.5.1 Inventory Management

The management of inventory defines the stock/stores management including item codification management and setting of inventory levels; and the purchasing, receiving and issuing of goods. As listed here, the first activity to carry out is the identification of every item by the use of a codification technique, where a unique code is given to every item. After codification, records will be created for the codified materials by preparing record cards. When the codified materials have been recorded, the inventory stock levels will be monitored to keep levels of specific items in stock. An order should be placed either when a request is received from an end user for material which is not held in stock or when a predetermined stock level is reached.

3.2.5.2 Warehouse Management

The company's Warehouse Management follows the process of expediting of orders, receiving of items, storage, issuing of items, stocktaking and identification of obsolete stock to record efficiency. In expediting of orders, if the delivery conditions provided in the order form are not complied with, there will be a follow-up by contacting the supplier immediately. When receiving an item, it should be accompanied by an invoice or delivery note to indicate evidence of valid purchase. For storage of materials, the necessary legal stipulations and safety regulations should be complied with. At the time when items are issued, the issue number will be generated and the record of consumable items should reflect the cost centre and site of the project. All items must be subjected to a stocktaking process at least twice per financial year to determine surplus stock, redundant items, losses, obsolete items, stock on hand and unserviceable items.

3.2.5.3 Vendor Performance

The performance of suppliers is measured by determining their reliability. The reliability of the supplier should be monitored in terms of delivery periods, quality and quantity. Any aspects that cause a low score on these metrics will be followed up by contacting the supplier. If the defect is as a result of a contract item, it should be reported to the contract management.

CHAPTER 4: MEASUREMENT AND ANALYSIS

The measurement and analysis for this study will be in stages to enable understanding of problems and their root cause as well as recommending a solution or remedy for the purpose of continuous improvement. The listed procedures below are steps that will be followed to move the process from a Non-Lean to a Lean system.

- Identify the process areas contained in the Supply Chain.
- Map these identified process areas.
- Identify the waste contained in the process areas.
- Prescribe a solution for elimination of these wastes identified through the introduction of specific Lean tools.

It is very important to note that the researcher will improve a part of the SC (not necessarily the whole chain) to see how Lean usefulness tallies into it. The reason for this is that a complete SC is too large and would, therefore, require a lot of time for absolute improvement. The technique or procedure for the improved part of the SC can later be applied to other parts of the chain to realise complete streamlining.

As stated above, the first activity to be carried out in the methodology is to identify the process areas contained in the supply chain. An overview of the process areas will provide a better understanding of the SC. Before overviewing the process area, the SC relationship as correlated to the case study is briefly discussed below.

4.1 Company Supply Chain Relationship

In the SC relationship section of the literature study (section 2.2.2), various key SC processes were highlighted. Alignment of these SC processes in the RS Procurement SCM is important in order to identify what works and what does not. The researcher observed during the process assessment that one key lapse of the SC relationship is poor communication. This lapse exists from the management level down to the supervisory level in the SC. Following is a discussion on the working status of the key SC processes in terms of their relationship.

4.1.1 Customer Relationship Management

The customer in this environment is totally different from that in the manufacturing environment. In this particular SC, the customers are internal maintenance units who require products or service for maintenance of RS. Though the CRM in this SC is basically performed by the materials manager with the assistance of maintenance supervisors, insufficient communication still exists regarding the products or service needed. This minimal communication, in turn, prevents periodic performance evaluation on service provided.

4.1.2 Customer Service Management

The CSM is a key process that operates in association with the CRM. CRM in the SC is very poor because maintenance units do not have a direct flow of communication with the team in charge of providing services needed. The downside of this is that vague or wrong specifications of the required product or service are only detected at a later stage when the material has already been supplied to the warehouse for use.

4.1.3 Demand Management

The current RS-SC process commences with demand management as stated in section 3.2.3. In the maintenance environment, the demand management process can be accomplished through recording scheduled and unscheduled activities in the process to determine which equipment will be purchased for maintenance. This can assist management to conceptualise procurement strategy.

4.1.4 Procurement

Procurement lies under acquisition management in this RS-SC. There are two frequent methods of procurement observed in this SC. These are competitive bidding and request for quotation. An overview of the procurement process in the current RS-SC is contained in section 3.2.2 and an explanation of SC acquisition management as a whole is covered in section 3.2.4.

4.1.5 Order Fulfilment

In order to fulfil a service order, the RS-SC follows similar approaches to that of the manufacturing environment. These approaches are build-to-forecast and build-to-order. There the terms of these approaches will change to scheduled maintenance and unscheduled maintenance simply because the RS services is a non-manufacturing environment. Scheduled maintenance is performed on RS that have a recorded service duration. This can occur within a stipulated amount of time. Unscheduled maintenance refers to the maintenance of RS that breaks down during its operation.

Challenges are often encountered in balancing scheduled and unscheduled maintenance due to uncertainty in the failure of some rolling stock equipment.

4.1.6 Manufacturing Flow Management

As outlined in the literature study, because the environment under study is a non-manufacturing environment, the term can be changed to service flow management. The RS-SC have different workshops for maintenance and maintenance scheduling because these workshops vary. Also, many activities occur in just one particular maintenance workshop. For instance, there is a carriage and waggon workshop as well as a lifting workshop. In the carriage and waggon workshop activities like testing vacuum cylinders and hanging vacuum cylinders are performed. In the lifting workshop, some of the activities performed are lifting coaches, operating bogie drop, and removal and replacement of rolling stock components. All these activities have variable timing and can be coordinated by using the FMMS database for the service flow.

4.1.7 Product Development and Commercialisation

Ineffective information flow in the SC prevents strong collaboration between teams in the CRM. This, in turn, prevents opportunities for innovation in service or product delivery. The lack of metrics for measuring effective delivery also serves as a hindrance for updating delivery quality. Hence in the present case study, the opportunity for product/service development and commercialisation barely exist.

4.1.8 Returns Management

In the RS-SC customer satisfaction is not reached and platforms for communicating this dissatisfaction are not appropriately executed. Also, suppliers who do not meet with expectations in service are often not disqualified to avoid similar future errors in the SC. This stage of the SC process is neglected as in other environments, which need to be looked into deeply.

4.2 Process Areas

Process Area is a cluster of related practices in an area that, when implemented collectively, satisfy a set of goals considered important for making a significant improvement in that area. Once the process areas have been selected, selection of how much the processes will be improved in association with the process areas also needs to be clarified. For this study, the processes will be improved by the incorporation of Lean tools into them.

According to the case study definition in Chapter 3 (PRASA Rolling Stock Procurement SCM), the process areas (Figure 7) in the Procurement SCM are as follows;

- Demand Management;
- Acquisition Management;
- Materials Management.

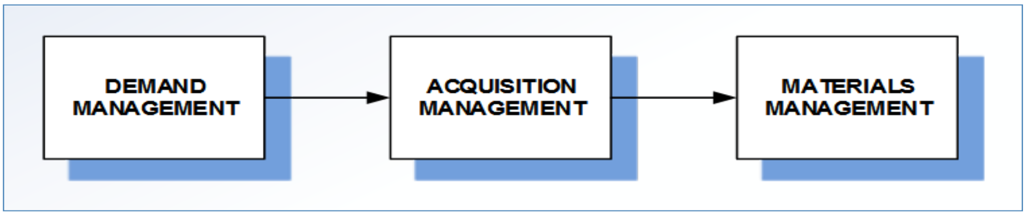

Figure 7: Procurement SCM process areas

4.3 Process Mapping

The goal of process mapping is to provide a detailed view of various levels in the process. The objective of the process mapping procedure is to identify the isolated steps that lie between stages in the process and to understand material and information flow in the process. The actions that are applicable for carrying out process mapping for the chosen case study are listed below:

- Identification and documentation of different stages in the process.
- Definition activities in each stage.
- Identification of the boundaries in the process.
- Detection of major activities in the process.
- Organisation of every activity in each stage in a preceding order.
- Validation of process through review and meeting with process experts (This is more of Practical application).

Tables 6 and 7 show the summary of the process mapping for rolling stock material purchase following the first five actions listed above. To better understand the organisation of activities in the process in a preceding order, the flow chart required to bring the Procurement SCM to completion is shown in Figure 8 and Figure 9.

Table 6: Process mapping for material above R350 000

Stage Name	Stage Number	Activity	Boundaries	Major Activities
Demand Management	1	Needs Assessment		Needs Assessment
			1	
Acquisition Management	2	Supplier Database Management		
		Bidding Process		Bid process
		Appointment of Consultants		
		Contract Preparation		
		Procurement		Procurement
		Contract Administration		
			2	
Materials Management	3	Inventory Management		Inventory Management
		Vendor Performance		

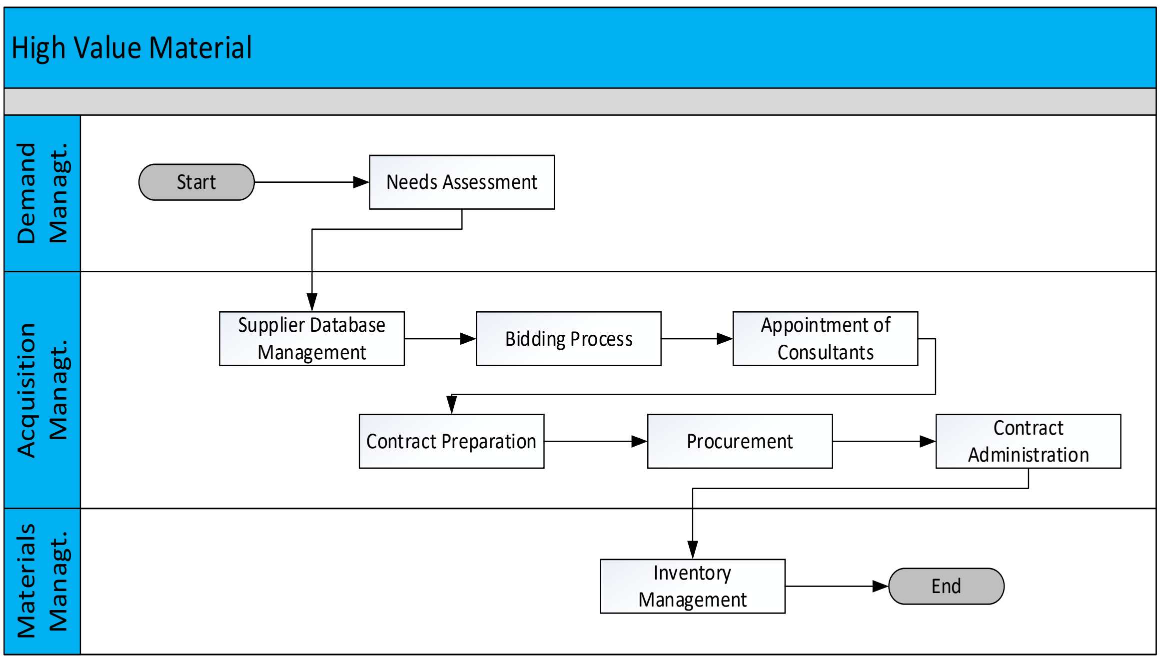

Figure 8: Flow Chart of Procurement above R350 000

Table 7: Process mapping for material below R350 000

Stage Name	Stage Number	Activity	Boundaries	Major Activities
Demand Management	1	Needs Assessment		Needs Assessment
			1	
Acquisition Management	2	Supplier Database Management		Supplier Database Approval
		RFQ Process		RFQ process
		Supplier recommendation		
		Supplier Approval		
		Purchase Order		
			2	
Materials Management	3	Inventory Management		Inventory Management

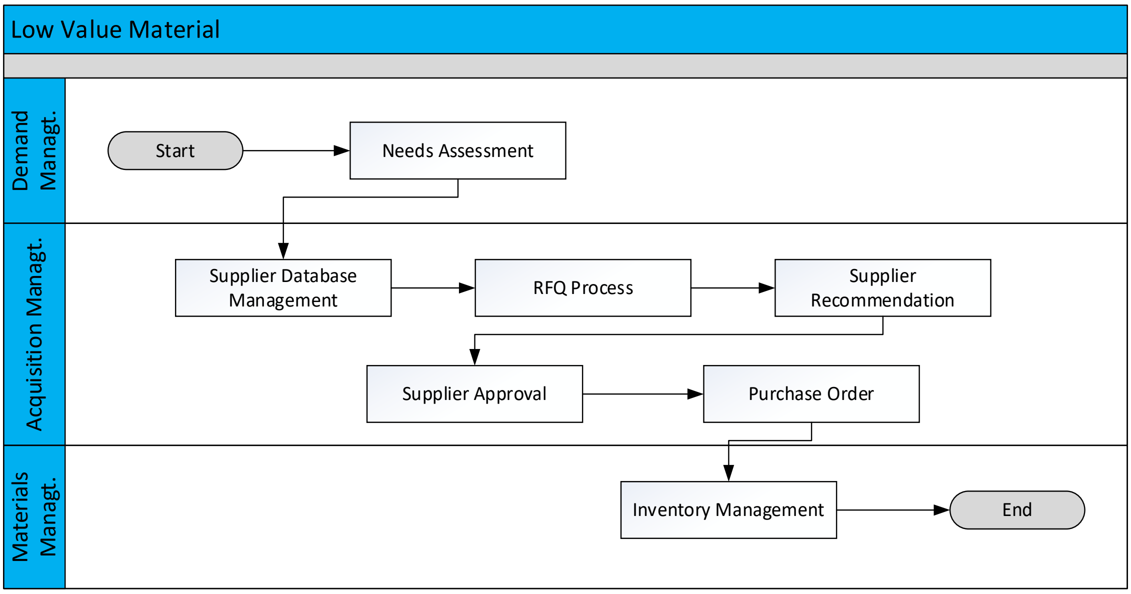

Figure 9: Flow Chart of Procurement below R350 000

4.4 Current State Value Stream Mapping

As initially pointed out in the value stream mapping section (2.3.3) of the literature study, the use of Lean improvement methodology commences with the application of VSM. This will be the first Lean tool that will be applied to the case study. The current state VSM will be determined to show the present situation in the SC so that further Lean tools can be recommended to reach the SC future state. The idea of firstly applying this tool is to basically identify the key activities existing within each process families. The current state maps of both material requests below and above R350 000 are shown in Figures 10 and 11 respectively.

Material or service acquisition and receipt begin with a formal electronic requisition from the line department requesting the goods or services from PRASA internal SCM. The line department is required to perform proper demand management on the material or service required. This covers a needs assessment and suitable compliance to procurement strategy.

After the demand management has been carried out by the line department, the request for this material or service will pass through some processes in the acquisition stage. The acquisition management stage consumes a higher time frame than the demand and materials management stages. The activities listed in the first part of the process mapping shown in Table 6 of section 4.3 are the competitive bidding process and can only be applied when the needed material is above R350 000 in value. The activity on the second part of the process mapping in Table 7 is the RFQ process. This applies for materials below the value of R350 000. The process in this stage ranges from creating and selection of a database for suppliers to evaluating the supplier before procuring materials or services.

After the acquisition management, the materials are properly managed through Inventory management discussed in the case study definition (Chapter 3). In this stage, materials are required to be coded for identification during the stock count and issuing of goods.

Aside from the flow charts of the procurement SCM, the value stream mapping Lean tool shows more visual representation on how door-to-door activity is performed in the process. Details like Enterprise Resource Planning (ERP) software which is SAP in this case used for process control activities are included in the VSM. Other necessary details contained in the VSM are:

- Requisition department;
- Organisation internal SCM;
- Activity roles;
- Lead time;
- Processing time;
- Waiting time.

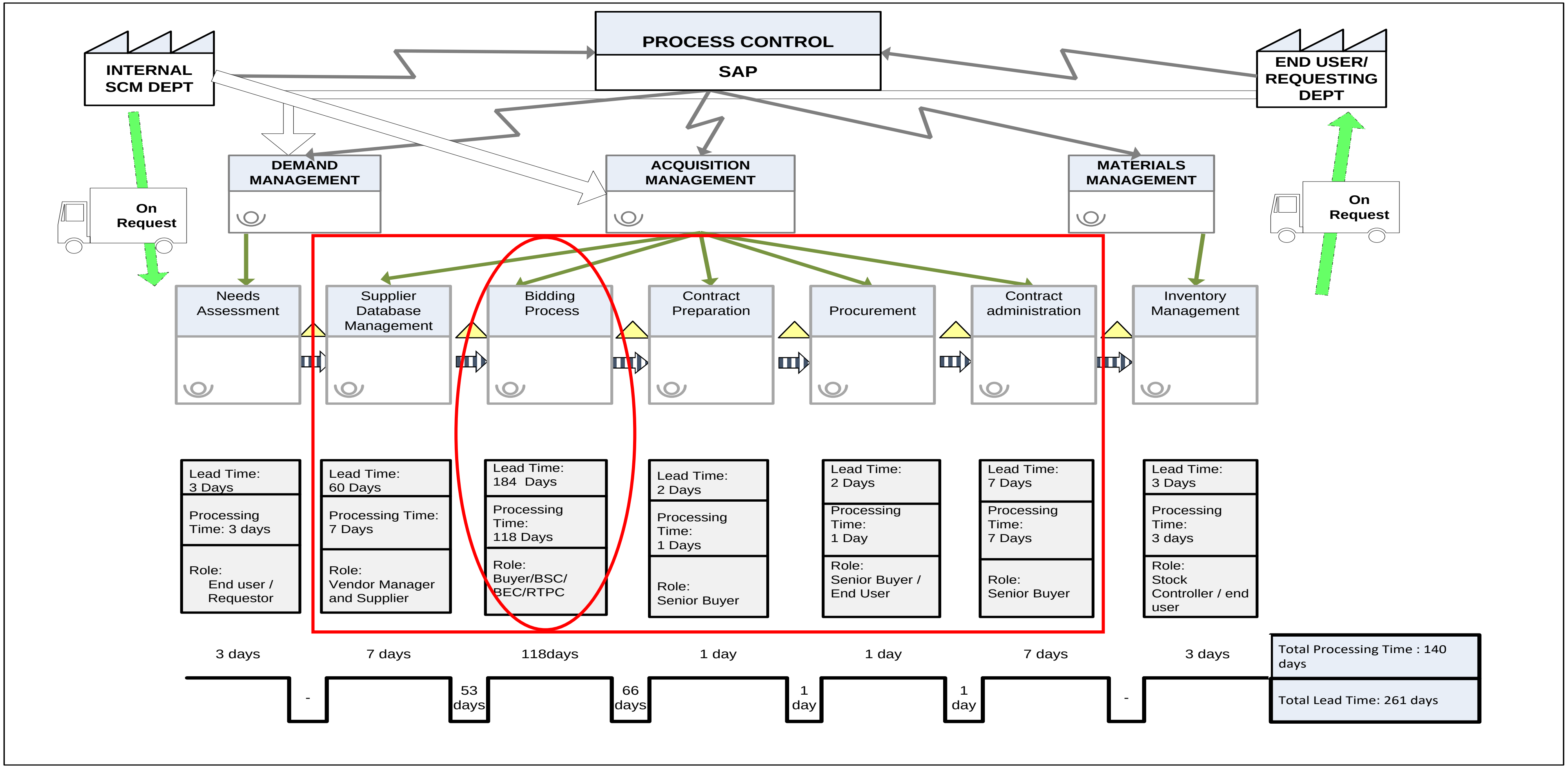

Figure 10: Current State Map for Material above R350 000

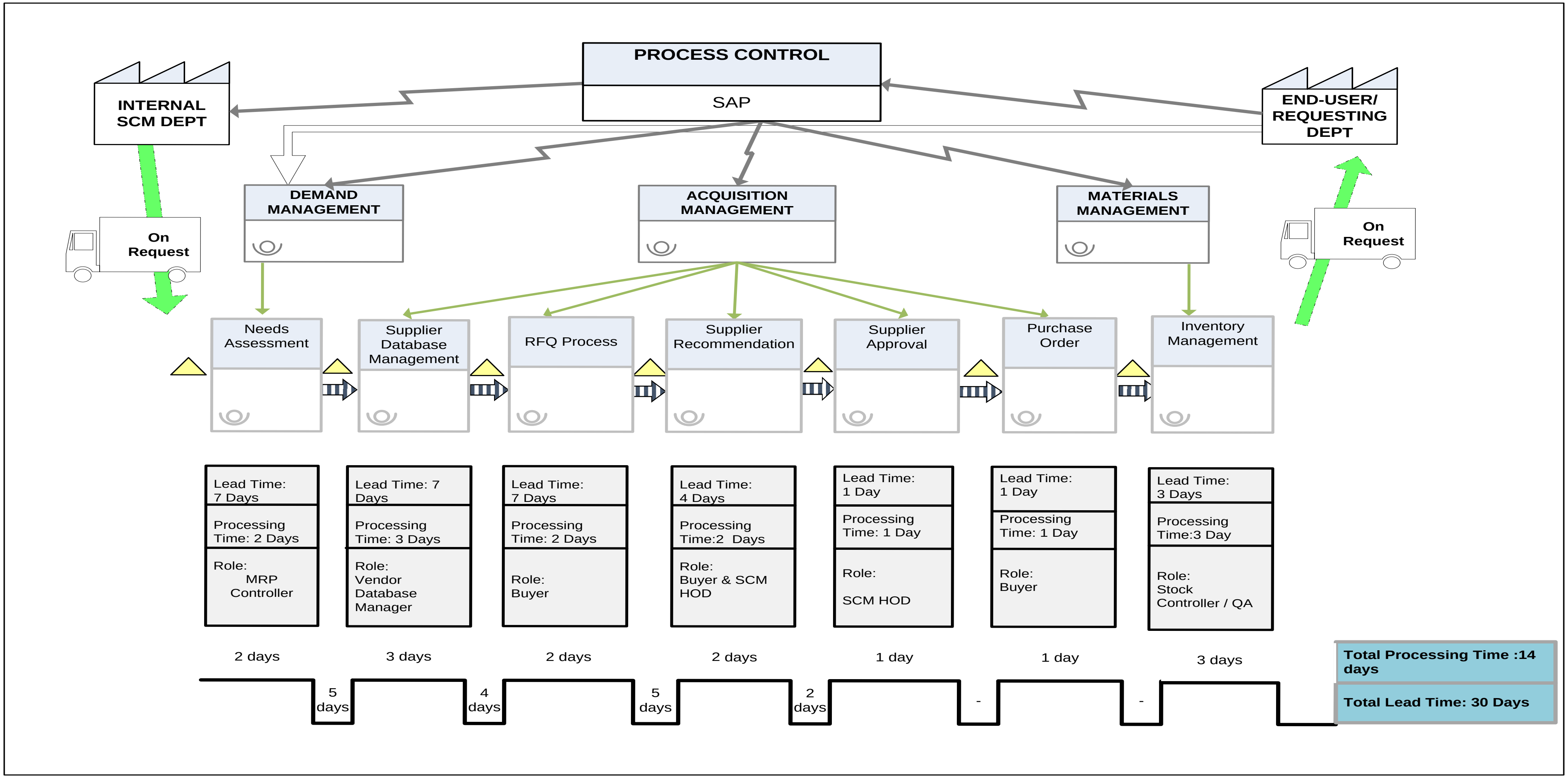

Figure 11: Current State Map for Material below R350 000

4.4.1 Current State VSM Observations

Basically, the information contained in the current state value stream map begins with the requisitioning unit requesting the material. This request flows through an Enterprise Resource Planning (ERP) software, and then through to the internal supply chain department that is required to process this request. After the request which is performed through a needs assessment in the demand management stage, the internal SCM department completes the acquisition management activities for acquiring the needed material. After the material is acquired the inventory is properly managed in the materials management stage.

Timing Information and process owners

The information of timing and process owners on each of the activities carried out in every stage of the supply chain management is provided in the data box. There are more activities in the acquisition management stage of the SCM than in the other two parts of the chain. And these activities in the acquisition stage require more time to accomplish. 255 days out of the total 261 days in the whole chain Lead time is spent in acquisition management. The processing time in this stage of the chain is 134 days while the waiting time is 121 days. In this case, the waiting time in the supply chain is seen as a waste because it can result from unnecessary delay activities that contribute less value to the process. Table 8 shows the acquisition management time share.

Table 8: Acquisition management time share

	Acquisition Management
Processing Time (days)	134
Waiting Time (days)	121
Lead Time (days)	255

The percentage of waste share in terms of time for every specific activity in the acquisition management is shown in this waste indicator figure (Figure 12). The Bidding process holds the highest percentage of waste among the activities in the acquisition management as more time is consumed in the bidding process as highlighted in red in the current state value stream map figure (Figure 10). Also from Figure 12, it shows that 72% of acquisition management time is spent on the bidding process.

The Bidding process will be the area to be concentrated on for appropriate streamlining. The reason for this is because supply chain management is normally so large that it is impossible to improve all of the parts at once. The appropriate procedure is to look through the whole SCM and choose an area for improvement. In this case, the concentration pyramid (Figure 13) falls on the Bidding process.

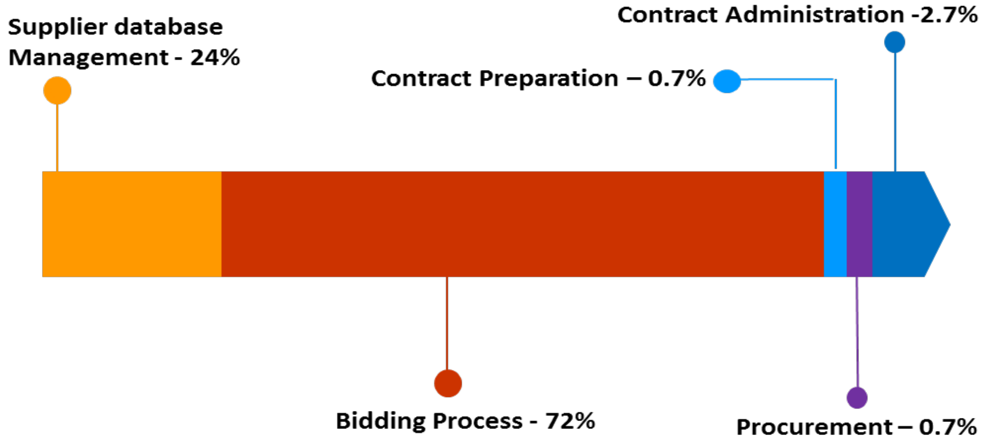

Figure 12: Percentage Waste share

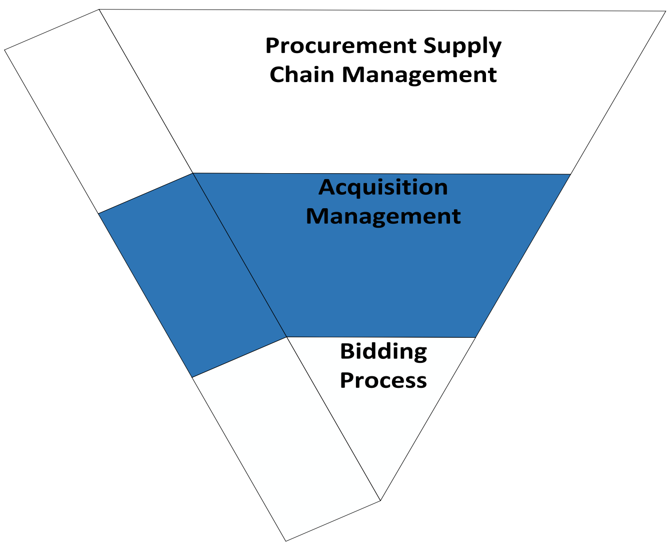

Figure 13: Concentration Pyramid

4.5 Failure Mode and Effect Analysis

For further analysis of the process, a failure mode and effect analysis (FMEA) of the procurement SCM was performed. The FMEA goal is to organise systemised groups of activities in order to identify and evaluate the potential failure of a process. Furthermore, this type of analysis can identify actions that could possibly reduce or eradicate the likelihood of problems within the process (Cudney, Furterer & Dietrich, 2014).

The FMEA analysis of both the bidding and RFQ process will be carried out just like the current state VSM for the two processes. Though the process team members in the SCM perceive the bidding process to be more problematical than the RFQ, it is still necessary to carry out analysis for the two processes then concentrate on the bidding process for later analysis and recommendation.

The FMEA for the current SC process will contain the following steps:

- Process step definition;
- Identification of potential failure;
- Identification of failure effects;
- Identification of failure cause;
- Estimation of potential failure severity, occurrence and detection;
- Calculation of risk priority number (RPN);
- Recommendation plan.

The Process steps were extracted from the process mapping in section 4.3. Identification of potential failure, failure effects and failure cause were obtained through the information provided by the SCM team.

Estimation of failure severity will be done by a numerical rating scale of 1 (low severity) to 10 (high severity). Similarly, the occurrence of failure was estimated by a numerical rating scale of 1 (low probability of occurrence) to 10 (high probability of occurrence). Estimation of problem detection follows the same mode of a numerical rating of 1 (easy detection of failure) to 10 (difficult detection of failure). The RPN can be calculated by multiplying the severity time, occurrence time, and detection. Based on the RPN values, a histogram was plotted to determine the potential failure with the highest RPN value. This highest RPN value will be the centre of improvement in the improvement phase. The recommendation plan for the identified problems is stated on the FMEA form.

$$RPN = Sev.rate \times Occ.rate \times Det.rate$$

The sample FMEA form used for the collation of information for FMEA analysis can be found in **Appendix G**. Tables 9 and 10 show the responses received for the FMEA analysis followed by their respective histograms (Figures 14 and 15).

The three activities in the FMEA form below marked in red are the initial activities that need utmost attention.

Table 9: Process FMEA Form (above R350 000)

Process Step/Input	Potential Failure Mode	Potential Failure Effect	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Actions Recommended
Need Assessment	No Demand Plan , Obsolete material and lack of funding	Delay in procurement and obtaining material. Affects train schedule	7	Poor Planning and Poor decision making	7	MRP Controller reviews demand plan using the system history	5	245	Control material usage with Facility Maintenance Management System (FMMS) to map demand plan
Supplier Database Management	Failure of suppliers to submit required documents	Delay in procurement and obtaining material. Affects train schedule	7	Suppliers not interested in the process or do not wish to repeat sending document to meet compliancy.	8	There are no current controls. Insufficient supplier documentation in turn causes no registration on the database	5	280	Compliance to Vendor management as stipulated in SCM Policy
Bidding Process	Lack of proper specifications / lack of supplier base	Delay in procurement and obtaining material. Affects train schedule	9	Vague specification submissions/ incorrect submissions	9	BSC Committee in place to prevent poor specifications	5	405	Workshop for End-user required for ideal documentation submissions
Contract Preparation	Vendor not loaded in the database.	Delay in procurement and obtaining material.	6	Suppliers not interested in the process or do not wish to repeat sending document to meet compliancy. Process delays within SCM	6	Policy Dictates Controls	3	108	Compliance to Policy and compliance to timelines
Procurement	Delay in PR creation	Delay in procurement and obtaining material.	5	End user not complying to timelines within their project plan/demand plan	6	No current control. Only detected during weekly contract administration	5	150	Daily checks on demand/project timelines
Inventory Management	Incorrect material delivered	Poor Specification on RFQ and failure of suppliers to submit their specification changes.	7	Delay in procurement and obtaining material.	6	NCR Process	3	126	Timelines to be set into the processes
Vendor Performance	Not Currently happening	Poor Suppliers in system	5	Delay in procurement and obtaining material. Repeating of Non-conformance report	6	None	7	210	Formulation of Performance Metrics. Compliance to Policy on poor vendors

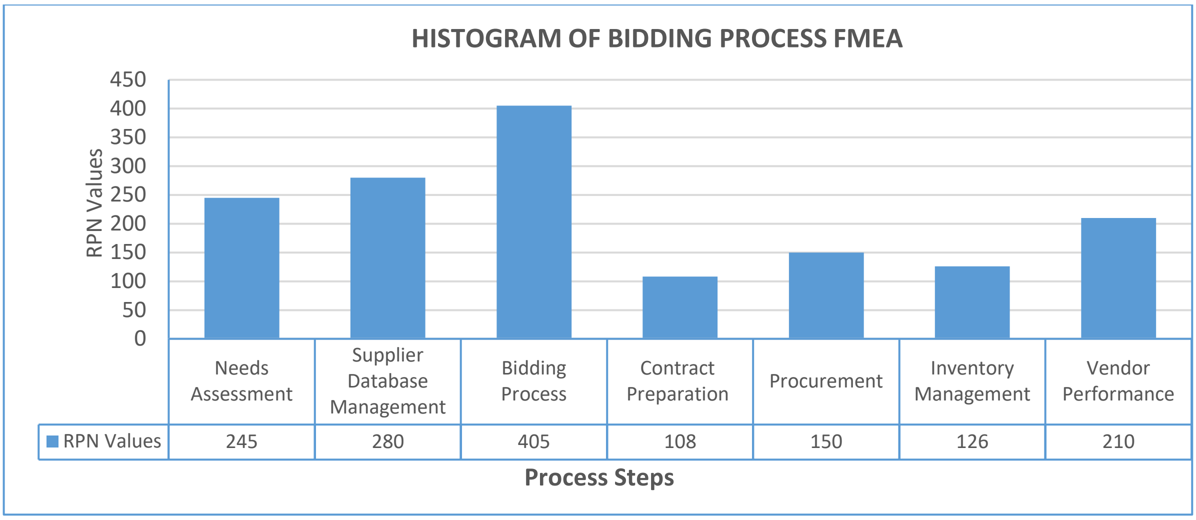

Figure 14: Histogram for Material cost below R350 000

Table 10: Process FMEA Form (Below R350 000)

Process Step/Input	Potential Failure Mode	Potential Failure Effect	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Actions Recommended
Need Assessment	No Demand Plan , Obsolete material and lack of funding	Delay in procurement and obtaining material. Affects train schedule	7	Poor Planning and Poor decision making	7	MRP Controller reviews demand plan using the system history	5	245	Control material usage with Facility Maintenance Management System (FMMS) to map demand plan
Supplier Database Approval	Suppliers fail to submit required documentation	Delay in procurement and obtaining material. Trains schedule affected	6	Suppliers not interested or do not wish to repeat or send required documentation. Also Process delays within SCM	7	There are no current controls. Insufficient supplier documentation in turn causes no registration on the database	4	168	Compliance to Vendor management as stipulated in SCM Policy
Request for Quotation	Poor Supplier database	RFQ process extended, delays in procurement and delays in obtaining material for train maintenance	8	Suppliers not interested or do not wish to repeat or send RFQs as they do not get orders.	8	Policy Dictates Controls	5	320	Contracts to be entered based on pricing and frequency of procured items
Supplier Recommendation	Missed the compliance as stipulated in policy	Loss of potential supplier	6	Failure of suppliers to check advertising mediums	8	Policy Dictates Controls	3	144	Compliance to Vendor management as stipulated in SCM Policy
Supplier Approval	Longer processing time	Loss of potential supplier	5	No clearly defined process with timelines and accountability	8	Policy Dictates Controls	3	120	Timelines to be set into the policy for this process
Purchase Order	Delays in processing	Delay in procurement and obtaining material which in turn affects rolling stock operation	5	No clearly defined process with timelines and accountability	8	None	4	160	Timelines to be set into the processes
Inventory Management	Incorrect material delivered	Poor Specification on RFQ and failure of suppliers to submit their specification changes.	7	Delay in procurement and obtaining material which affects the scheduling of trains	6	NCR Process	3	126	Timelines to be set into the processes
Vendor Performance	Not Currently happening	Having Poor Suppliers in system	5	Delay in procurement and obtaining material. Repetition of Non-Conformance Reports	6	None	7	210	A process to be put in place. Compliance to Policy on poor vendors

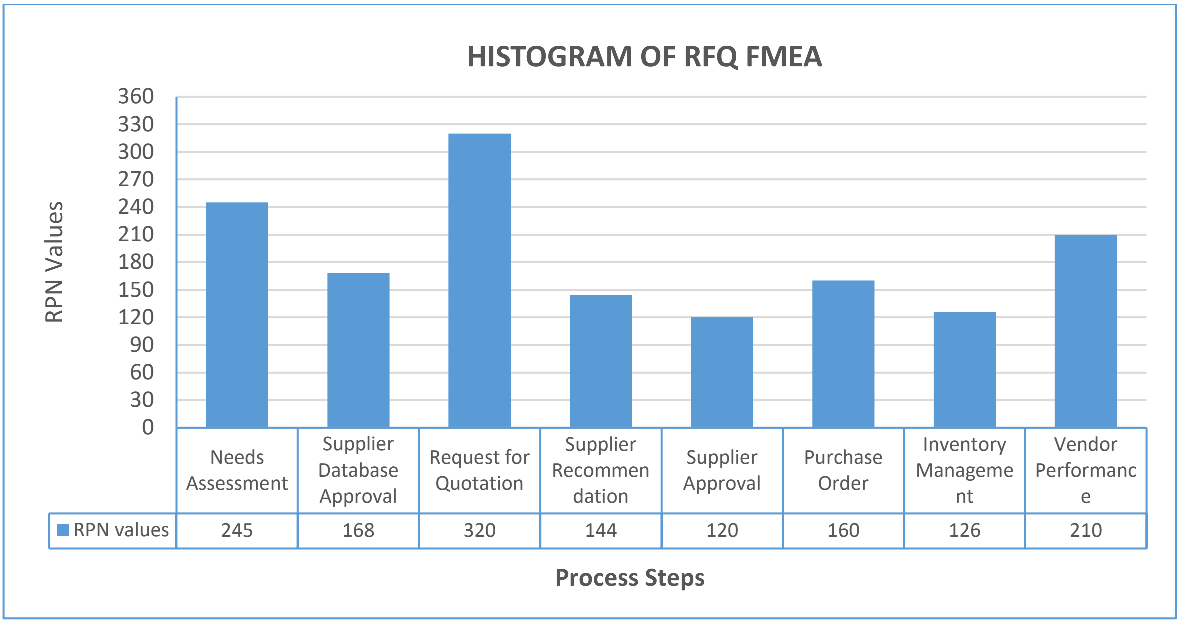

Figure 15: Histogram for Material cost below R350 000

The histograms above were drawn by plotting the RPN Values against the process steps in the SC. The process step with the highest RPN values will be the centre of improvement as initially stated. For the current process, the activities that require improvement for both categories of purchases are listed below in their order of priority.

- Category above R350 000
  - Needs Assessment
  - Supplier database Management
  - Bidding Process
- Category below R350 000
  - Request for Quotation
  - Needs Assessment
  - Vendor Performance

The information provided in the FMEA forms was collated and merged from the information received in the particular field of study which was provided by the respondents as shown in Table 11 below.

Table 11: FMEA Respondents

Unit/Entity	Respondents
Demand Management	2 Managers
Acquisition Management	2 Managers
Materials Management	2 Managers and 1 Supervisor
Research and Development	1 Research Engineer

4.6 Waste Analysis

The objectives of an organisation cannot be achieved if the waste is dominant in the organisational chain. The reason for this is that it uses limited resources in ways that do not contribute to the organisation's overall goals. Lean is an organisational performance management system characterised by a collaborative approach between employees and managers to identify and minimise or eliminate activities that do not create value for the customers or stakeholders of a business process. One way Lean organisations strive toward their goal of perfection is by remaining constantly aware of waste so it can be avoided or eliminated. The Lean philosophy identifies eight sources of waste that detract from the value a customer receives from a business process.

4.6.1 Rolling Stock Procurement SCM wastes

Specific Lean wastes have been identified during the GEMBA walk (interview of process team members) on the current SCM activities. These wastes have been detected in each stage of the SCM. Generally, as explained in Chapter 2 there are eight different kinds of wastes in a manufacturing value stream. Since the current process of analysis is different from the traditional Lean manufacturing background, there might be slight variations in the observed wastes.

From the current state VSM diagram (Figure 10), acquisition management contains the major waste of time in the procurement SCM. Under acquisition management the bidding process stage holds the highest lead time of all the activities contained in this chain. Hence, focus will be placed on reducing this lead time in order to increase operational efficiency and reliability. Some general waste in the SC will be outlined, which will be followed by responses from the practical experience of support managers on the bidding process from an interview conducted by the researcher.

In demand management poor forecasting/detailed planning and inaccurate specification of desired material or services needed may bring about the wastes of defect, over processing, waiting and underutilised staff skills. In the case of material request, it may result in a waste of inventory and transportation.

The waste of over processing, waiting and the defect is very predominant in the acquisition stage. As earlier discussed (see section 3.2.2), the acquisition process can be either of two categories depending on the monetary value of the rolling stock material to be procured. For the RFQ process (material or services below R350 000), the major challenge identified during the GEMBA walk on the process is difficulty in sourcing a suitable supplier. This may result from having fewer or no responses to the RFQ which leads to either repeating the RFQ procedure or dealing with the available supplier. An effect of these failures in response is over processing or receipt of non-conforming materials. In the case of the competitive bidding process, the main challenge is the longer lead time in treating of bid deliverables. The wastes identified in materials management include minimal management support for specific sign-off, maintenance of reordering level, and incomplete processing of a blacklisting supplier.

Also, if procured materials are not properly codified it affects the issuing of goods which in turn causes unnecessary waste of motion and inventory. Table 12 shows the identified waste in the current SC value stream.

Table 12: Current Supply Chain Lean Wastes

Supply Chain	Problem/Waste	Type of Waste	Applicable Lean Tool
Demand Management	Monthly Poor forecasting/Detail plan and inaccurate specification of goods or services	Defect, Overprocessing, waiting, underutilised staff skills	Poke-yoke, Standardisation, Kaizen
Acquisition Management	Difficulty in sourcing for suitable supplier	Overprocessing and underutilised staff skills	Standardisation, Visual Boards, Poke-yoke, Supplier Development
	Low Supplier response to RFQ	Waiting	
	Procurement of non-conforming material	Defect	
Materials Management	Minimal Management Support on necessary sign-off relating to non-conforming materials	Waiting and Defects, underutilised staff skills	Just-In-Time, Kanban and Poke-yoke
	Maintaining reorder level and stock at hand	Inventory	
	Incomplete processing of Blacklisting supplier	Waiting	

As previously highlighted, the bidding process in acquisition management causes the highest waste in the value stream as it records the longest lead time. With this in mind, the elimination of waste will be concentrated more in this area of the chain. The reason for this is that the whole chain cannot be improved due to time constraint for this study, but the improved part will serve as an improvement strategy/model for other parts of the chain. Thus, this study will endeavour to apply Lean tools for harnessing challenges within this time-consuming activity (bidding process). Figure 16 illustrates the procurement SCM process family which holds the highest lead time, and in turn Figure 17 highlights the activity in this process family which contains this time. Figure 18 shows a close look at the activities required for the bidding process and the time consumption they entail.

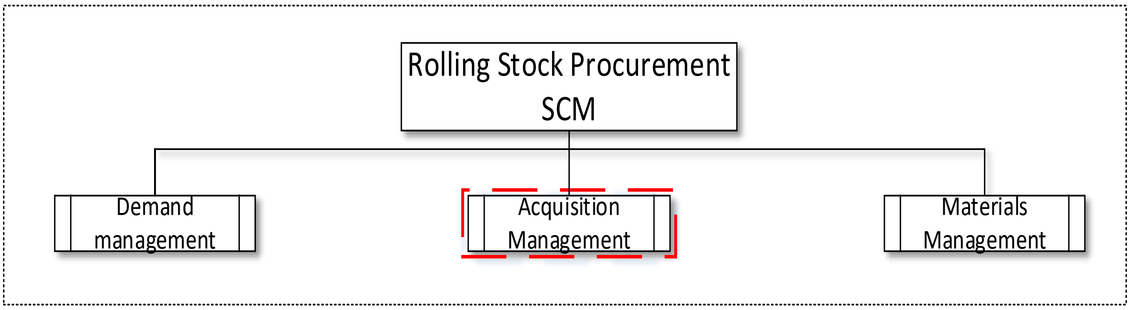

Figure 16: Process family with highest lead time

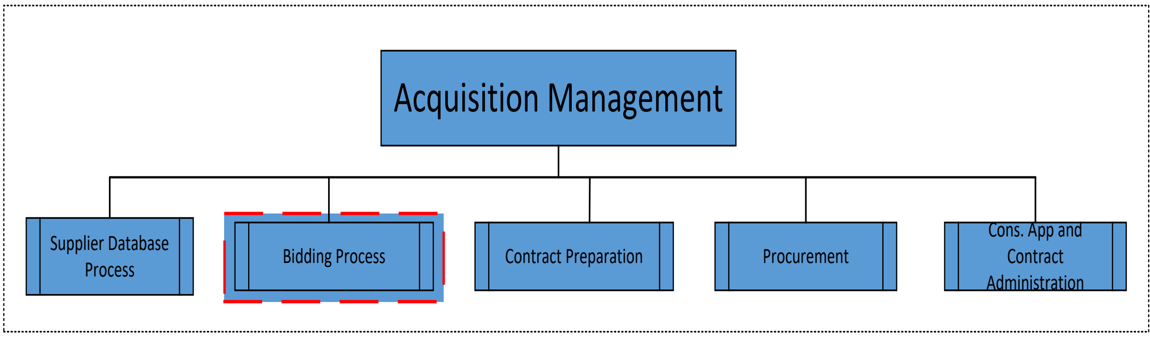

Figure 17: Acquisition activity with highest lead time

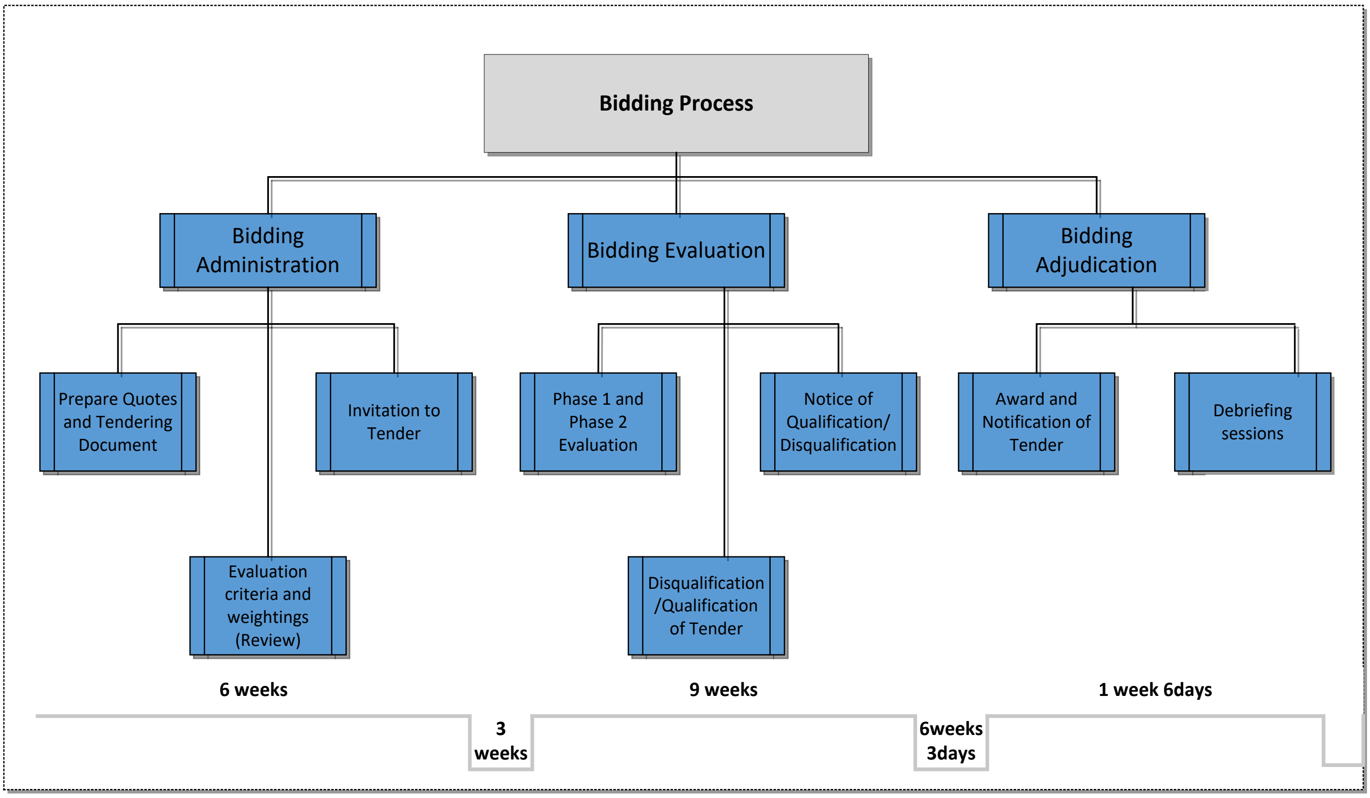

Figure 18: Bidding process activities

4.6.2 Evaluation of Bidding Process

According to real-time industry experience, some support managers that liaise with the company SC department on the acquisition activity were interviewed. Questions in the interview sections were largely directed at challenges that are encountered in the bidding process. The inputs from this personnel were very important to understanding the underlying problems in this activity. What follows is a practical case of a typical bidding process.

A bidding request was submitted in July 2015 to purchase special tools at a value of R1 million. Initially, a bid request document and a bid evaluation document were submitted. At this stage, the Bid Specification Committee (BSC) document was not yet required. Twenty-one days passed by without feedback. The reason for this is simply because the Bid Evaluation Committee (BEC) needs to meet to discuss the requests submitted and these meetings are only held on Mondays. On the Monday of the fourth week, the BSC meeting was held and the requester of the tool was required to make specific changes to the initial documents. The requester also utilised the opportunity to submit a further bidding request for tools valued at R1.5 million. (This request was submitted in August 2015.) The tender request for this second request required specific brand names and numbers which contradicted ISO standards.

On the following Monday, necessary changes were made to the submitted bidding document, but the BSC meeting was not held. In the seventh week after the first submission, the meeting was cancelled due to absenteeism of some members of the committee. The Monday of the eighth week after the tender request i.e. two months later, another BSC meeting was held, and the committee resolved that the ISO 9000 requirements for the technical evaluations be removed.

The tender briefing on both tender requests was carried out on 6 November 2015 which is four months after the first submission. Tenders closed a week later on 13 November 2015. No tender was offered for the R1 million request but two tenders were offered for the R1.5 million request. The R1 million request had other obstacles like provision of local approval letters. The downside of the unapproved tender is that the equipment needed was not available for the unit despite waiting so long.

4.7 Waste Reduction

In the introductory part of the methodology, the next step after the identification of waste is prescribing a solution for the identification of these wastes through the application of suitable Lean tools. Hence, what follows in the next sub-section is the reduction measures specifically in the Bidding process under the Acquisition management process family.

This section contains three core contents, which include; problem/waste in the bidding process, type of waste and applicable Lean tools to reduce these wastes (Figure 19).

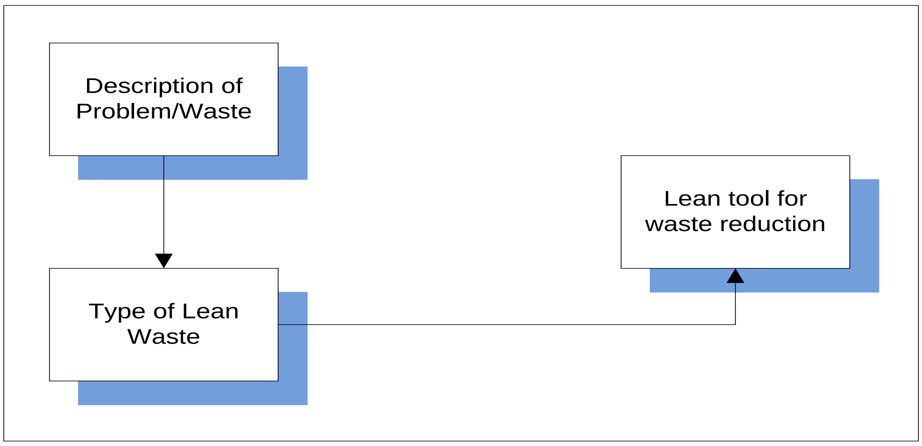

Figure 19: Process waste reduction flow

4.7.1 Description of Problem/Waste

Poor communication between bidding team and end user:

There is unclear communication between the bidding team who are in charge of processing the bid and the end user who uses the requested material or service. The downfall of this can be distortion in this particular activity (Bidding process) because there is no mutuality in tackling arising challenges.

Lack of understanding of updated requirement for tender request:

Most of the process team members in the chain do not really understand the updated requirements for tender requests. This misunderstanding exists especially within the end user phase of the bidding process as the updating of the tender request normally requires approval from top management to be valid.

Non-conformance with ISO-standards on product purchase:

This problem arises when the intended purchase passes through a middleman before supply. The effect of this is a lack of product warranty as the product does not come from the original supplier. Furthermore, defects in the purchased material will take a longer time to be sorted out thereby causing numerous cycle delays in the process.

Frequent cancellation of meetings:

Meetings regarding the bidding process can be for various reasons. Whatever the reason for the meeting may be, it is vital for every team member involved in the bidding to attend so that challenges encountered can be discussed in one sitting. This will enable the group to set metrics for measurement of prescribed solutions.

Poor training of end user contributes towards non-value-adding:

The end user, who is normally the line department that requests the material or service should receive proper training to understand the activities as well as the challenges in the bidding process. The individual training these personnel needs to fully understand the process as well as any likely changes so that the training can take place effectively and the relevant knowledge conveyed.

Difficulty in sourcing for Supplier:

This particular waste has continually posed a big challenge to the process. This waste is as a result of inadequate blacklisting of previous suppliers who did not conform to the bidding standard requirements. Hence, there is a high possibility of choosing from these suppliers during a new bidding process due to unavailability of suppliers that meet the requirements for a specific material or service. This also causes an extra processing for required material or service. Table 13 below shows the waste identified in the bidding process.

Table 13: Identified wastes in the bidding process

Waste	**Type of Lean waste**
Poor communication between bidding team and end-user	Underutilised staff skills, Waiting
Lack of understanding of updated requirement for tender request	Underutilised staff skills
Non-conformance with ISO-standard on product purchase	Defects
Frequent cancellation of meetings	Waiting, Over-processing
Poor training of end user contributes towards non-value adding	Underutilised staff skills
Difficulty in sourcing for Supplier	Over processing and underutilised staff skills

4.7.2 Applicable Lean Tools

Poor communication between bidding team and end user:

Two types of Lean waste exist within this particular waste in the bidding process. A Lean tool that will to a large extent reduce these wastes is necessary for the route to continuous improvement. The first Lean waste identified within this activity is the waste of underutilised staff skills. The existence of this category of waste is clear due to the imbalance of skills distribution within teams and individuals involved in the process. The reason for this is that there is a lack of information for a particular part of the chain which in turn underutilises their skill in this area. Some of the means to reduce this waste of underutilised staff skills are:

- teamwork;
- training of employees;
- encouragement of people to take ownership of their areas;

- measures and compensation packages.

All these means can typically keep the employees in the chain involved and drive towards perfection for continuous improvement of communication between bidding team and end users. Employees in an organisation are the biggest asset. Hence, respecting them, nurturing them and involving them in the business's activities will automatically reap a reward for the organisation. The applicable Lean tool to reduce the waste of underutilised staff skills in this environment is Standardisation of work.

Standardisation of the bidding process will aid in creating some benefits which will constantly organise the process and in turn maintain quality, productivity and eradication of unsafe practices. The following are benefits that can be realised as a result of standardising the bidding process:

- Stability of the bidding process;
- Training of team members;
- Creation of baseline for continuous improvement;
- Maintenance of organisational knowledge.

The waste of waiting is also present in the poor communication between bidding team and end users. The end users who are responsible for requesting materials wait for a long period of time due to poor communication in the chain. The remedy for the waste of waiting can be applied for reduction of this specific problem. As for the waste of underutilised staff skills discussed above, one good Lean tool for reducing the waste of waiting is Standardisation of work. Another Lean tool that can be applied for incremental improvement for this particular waste is the use of Visual management by the application of visual boards to check update on lead time, processing time, and waiting time. This will assist process owners to apply correctional measures on encountered problems and precautionary measures on potential problems. Table 14 below shows the applicable Lean tools for the waste encountered.

Table 14: Poor Communication Lean waste and reduction

Waste	Type of Lean waste	Applicable Lean tool
Poor communication between bidding team and end user	Underutilised staff skills, Waiting	Standard Work and Visual Boards

Lack of understanding of updated requirements for tender request:

The first problem of poor communication between bidding team and end user largely contributes to this second problem of lack of understanding of updated requirements for the tender request. When team members are not communicated regularly by the personnel responsible for the change in the documentation, waste of staff skills as well as over processing exist within the chain.

The waste of staff skills can be reduced by standardising work activity as initially discussed while the waste of over processing for this particular activity can be reduced by applying the Lean tool of 5S and yet again standardisation. The use of Standard Operating Procedures (SOP) will serve as written instructions for all employees and will aid in the reduction and elimination of over processing in the process.

5S is a very powerful Lean tool for organising and improving organisation processes. There are five basic steps for the 5S tool, namely: Simplify, Straighten, Scrub, Stabilize and Sustain. The 5S evaluation sheet in Appendix H was used to analyse the SC activities in the research project. From the process team members' responses received in the 5S evaluation sheet, it was found that higher percentage of the responses in the first three stages were negative. This shows that the implementation of radical improvement strategies is very vital.

Table 15: Misunderstanding of tender request Lean waste and reduction

Waste	Type of Lean waste	Lean tools
Lack of understanding of updated requirement for tender request	Underutilised staff skills, Over-processing	5S, Standardisation

Non-conformance with ISO-standard on product purchase:

Quality is one very important aspect in a working environment. To ensure the material which is being bid for meets quality requirements and has an after-sales service life, it needs to be of certified standard. Most large institutions use the ISO standards in terms of quality conformance. A section for ISO standards needs to be included in the tender/form request so that the benefits reaped from the use of ISO certified materials can be gained by the Procurement SCM.

A predominant waste that can arise for nonconformance of the product is the Lean waste of defect. There are many ways to eliminate the waste of defect. In Lean manufacturing, the waste of defect is best eliminated by preventing it through the use of Poke-yoke devices that detect if a product is defective, either preventing the process from running or highlighting the defect for action. But since the particular process exists within the non-manufacturing environment, the adoption of ISO conforming materials serve as a Poke-yoke and will assist in the elimination of this specific waste. Therefore the use of ISO conforming purchase request forms will serve as a Poke-yoke in this environment.

Table 16: Non-conformance with ISO-Standards Lean waste and reduction

Waste	Type of Lean waste	Lean tool
Non-conformance with ISO-standard on product purchase	Defects	Poke-yoke

Frequent cancellation of meetings:

During the Gemba walk on the SCM process, this challenge was found to be one of the greatest wastes that is present in the system. The percentage of time consumed during the bidding process largely exists to cover the period when a meeting is held to administer, evaluate and adjudicate the bid. The main reasons for this meeting are either to make changes on already submitted documents or the introduction of new content in the process. This can last for a period of four months or more and the activity adds no value to the end user. The predominant kind of Lean wastes that can be found on frequent cancellation of meetings is waiting, over processing and defects.

Waste of waiting happens when end users wait for the outcome of these meetings and for the requested material. The waste of over processing occurs as most of the meetings continue for a long period with less value to the end result.

To be clear on what is required of the process and to eliminate the waste of waiting, the use of visual boards can be adopted. This will ensure that the activities are better matched with the processing time stipulated in the visual boards. Similarly, standardisation of work can reduce the waste of over processing of the bid request and focus on meeting standards for continuous improvement.

Table 17: Frequent cancellation of meeting Lean waste and reduction

Waste	Type of Lean waste	Lean tools
Frequent cancellation of meetings	Waiting, Over-processing	Visual Management, Standardisation

Poor training of end user contribution to Non-Value-Add:

As outlined in the waste description, the end user in the procurement SC is the line department that requests the product or services. As a result of the challenge of the lack of understanding of updated requirements for bid requests, poor training of end users in these updated requirements brings the waste of underutilised staff skills. Also this challenge cause non-value-add in the supply chain. When the personnel responsible for utilizing a product or service do not fully understand the procedure involved for the product to achieve receipt of it, then the personnel's skill is underused. Training of end users on the bidding process requirement by a knowledgeable trainer will bring the time frame of activity into their awareness and allow them to set a baseline for product receipt.

The Lean tool that can aid in the reduction of this waste is Standardisation and Kaizen (Continuous Improvement). Standardisation is required for the training to be performed as planned at the beginning of every fiscal year. Kaizen is required for end user's knowledge of the process to reach a near perfect stage.

Table 18: Poor training of end-user Lean waste and reduction

Waste	Type of Lean waste	Lean tools
Poor Training of End-user contribution to Non-Value-Add	Underutilised staff skills	Standardisation, Kaizen (Continuous Improvement)

Difficulty in sourcing for Supplier:

The reason for the difficulty in sourcing for a supplier is incomplete blacklisting of suppliers that do not initially conform to a product request. This brings about a clear waste of over processing because the suppliers on the system will end up not conforming to the required material standard which will cause the process to be protracted. Another Lean waste that is present in this problem is the waste of waiting and underutilised staff skill. The waste of waiting occurs because end users who require the material wait for a longer time than required. Less utility of staff capability both in the end user and purchasing team also occurs as a result of this particular problem. The main Lean tool that can reduce or eliminate this waste of supplier sourcing difficulty is Supplier development and Standardisation of the operating process which is the fourth step in the 5S improvement methodology.

Supplier development is a process of working with suppliers on a one-on-one basis to discuss and further improve their performance and capabilities. Therefore, in this case, supplier improvement will be the process of improving the supplier database. In a clear sense instead of eliminating existing suppliers in the system, challenges and discrepancies can be mutually identified so that a means to their elimination can be worked out.

Table 19: Supplier sourcing Lean waste and reduction

Waste	Type of Lean waste	Lean tools
Difficulty in sourcing for Supplier	Over processing and underutilised staff skills	Supplier Development, Standardisation

4.7.3 Future State Value Stream Map

Whilst drawing the Current State VSM enables a pictorial understanding of the operations in the Supply Chain, the real utility of this Lean tool is the ability to develop a vision of how good the value stream for the process could be (Brunt, 2000).

Similar to the manufacturing background, the current SCM in this research study follows specific guidelines in order to develop the future state value stream map for the process. The guidelines that were applied during this research are presented in the form of questions which will be answered to formulate the future state process. These questions encompass where Lean tools can be applied in the current state of the process to support flow. The creation of a future state map also covers the second and third principles of Lean (Value Stream Identification and Mapping, Creation of Flow by Waste Elimination). The questions below covers the entire SCM as seen in the current state map in section 4.4. Figures 20 and 22 show the future state VSM for both the Bidding and RFQ SCM. Following the future state VSM for the bidding process, the improvement tools required to reduce waste in the bidding process are shown in Figure 21.

- Where can the SCM practice continuous flow?
- What activities need to undergo 5S?

- At what stage is Kanban required?
- Where in the SCM is Poke-yoke required?
- Where can pull systems be used?
- What is the Total Processing time?
- What activities in the system should involve Kaizen?
- What other supporting processes are important for the SCM success?

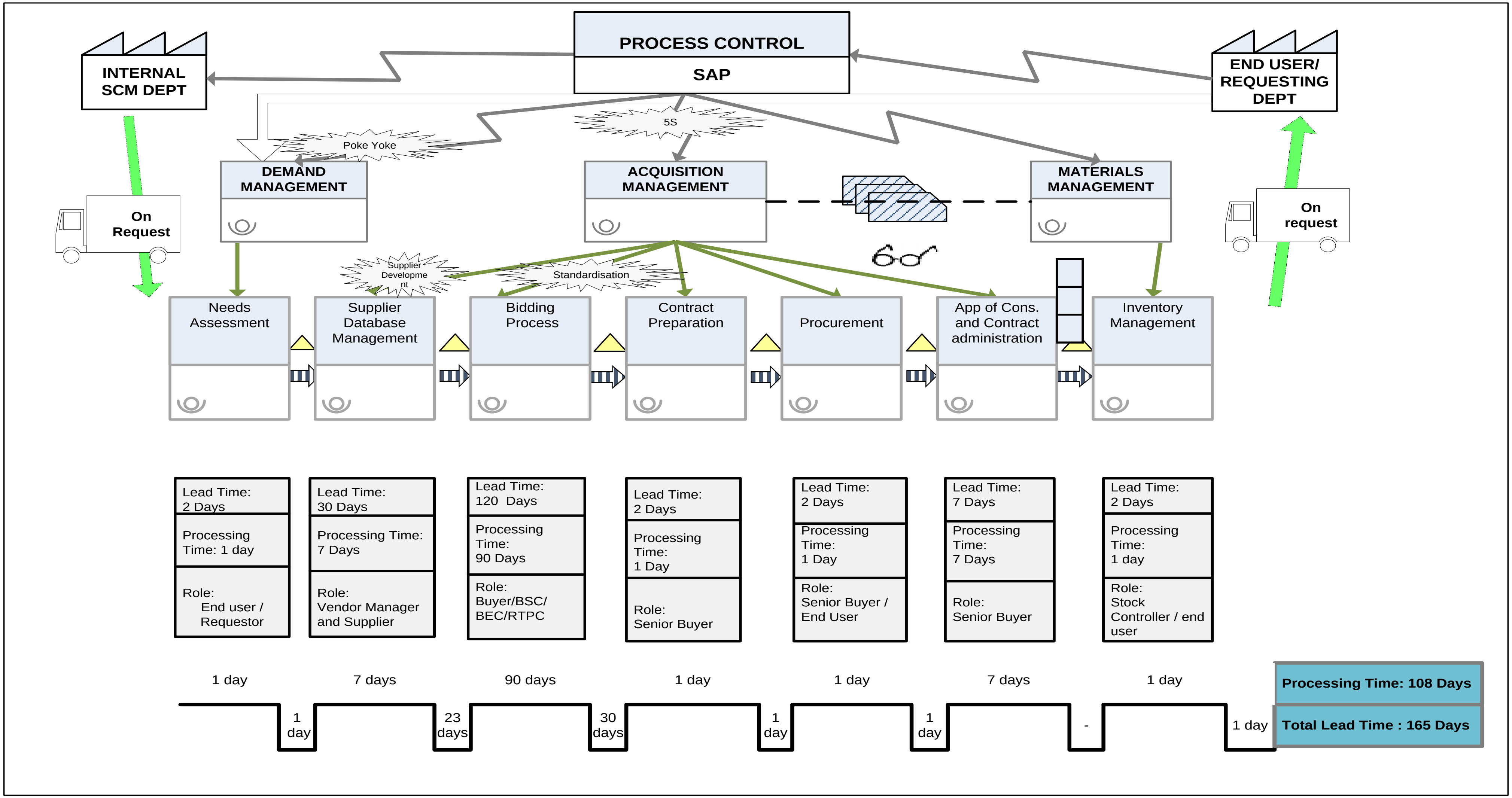

Figure 20: Future State Map for Procurement above R350 000

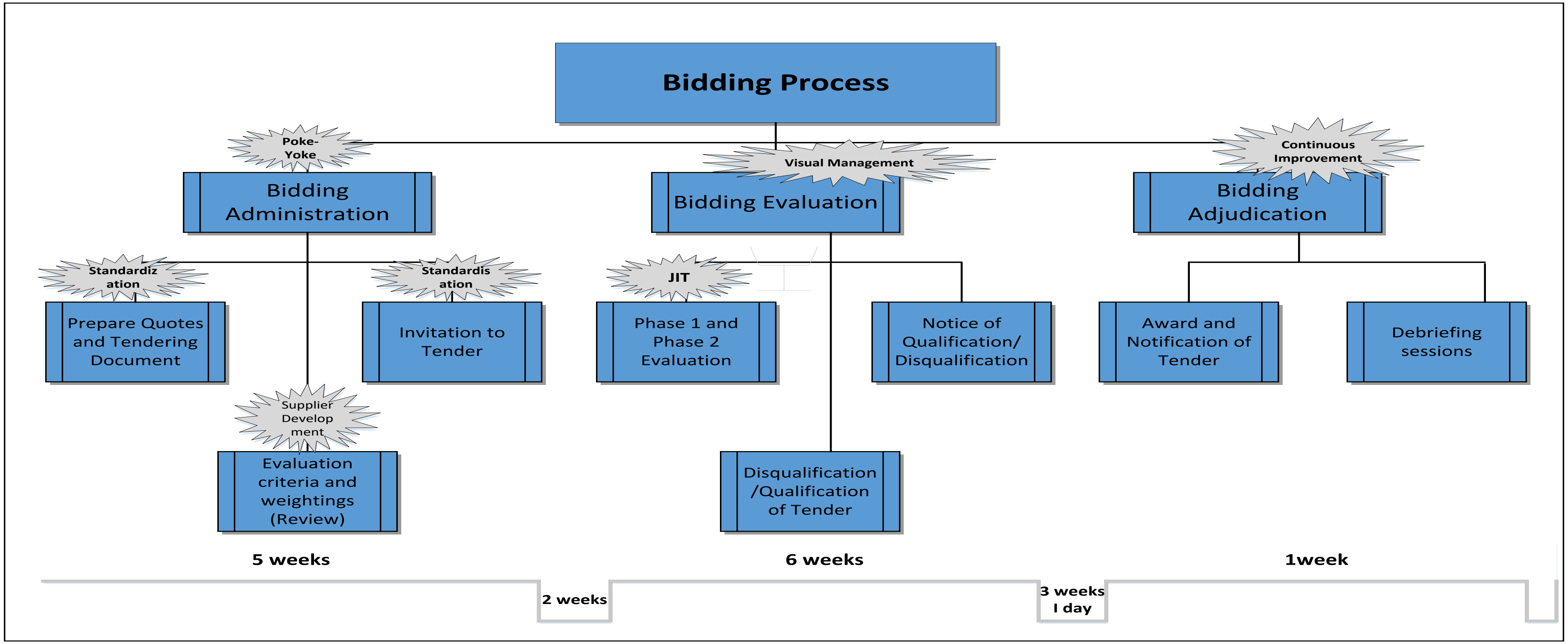

Figure 21: Bidding Process Improvement Areas

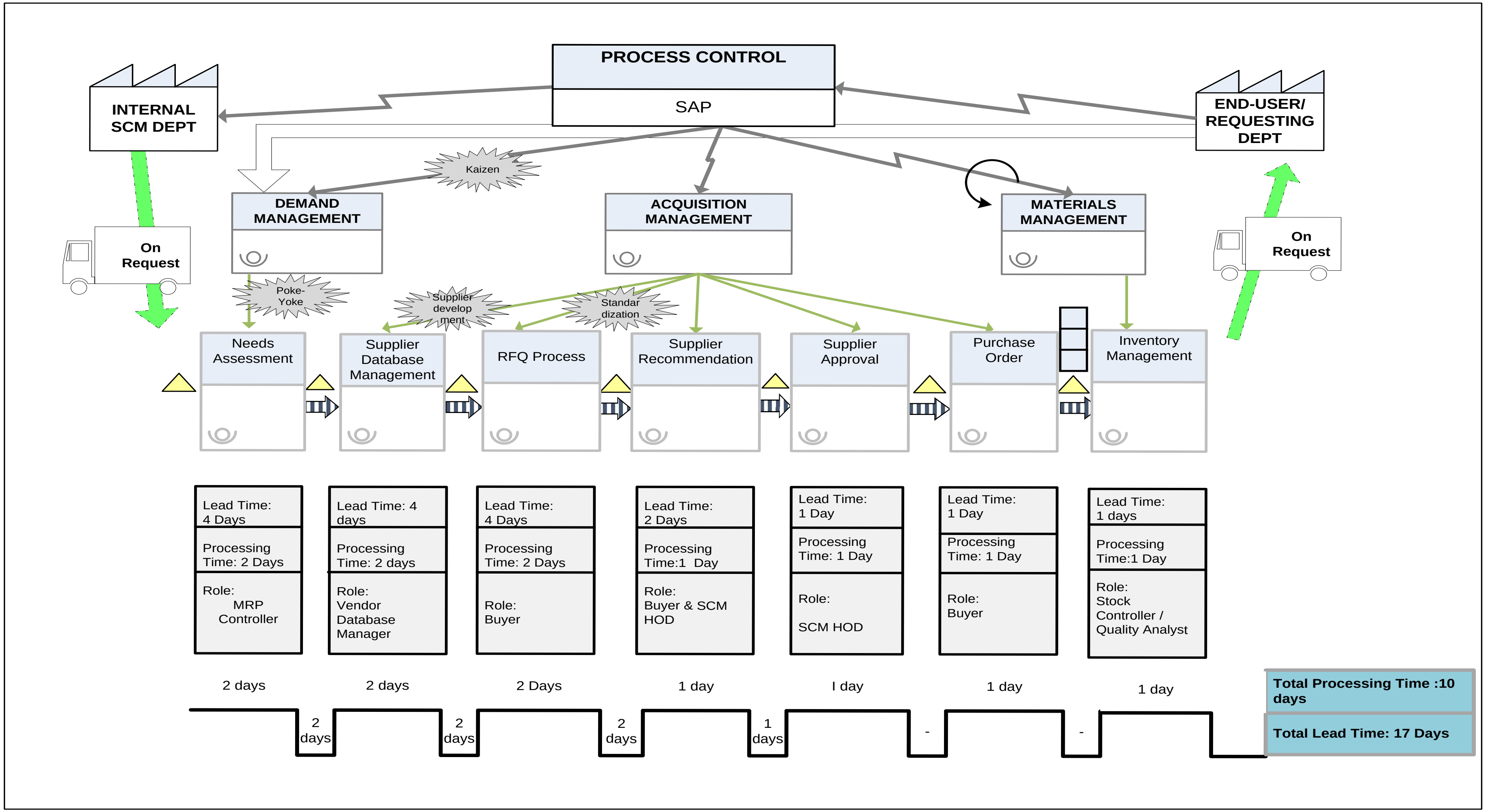

Figure 22: Future State Map for Procurement below R350 000

4.7.3.1 Responses to FSM Guideline Questions

The questions in section 4.7.3 aided the researcher in drawing the future state value stream map. This section contains responses to the questions that were asked in section 4.7.3. It also provides a clearer understanding of the future state value stream map figures (Figures 20 and 22). What follows is a discussion on the guiding questions and their responses.

How can the SCM practice continuous Flow?

Continuous flow as a requirement of Lean principles can be applied for the improvement of the SCM by applying Lean tools where appropriate and necessary. In the future state maps application of numerous Lean tools will aid the company to experience continuous flow of activities in the SCM.

What activities need to undergo 5S?

The acquisition management of both the Bidding and RFQ procurement require the application of 5S. The use of Standardisation (Fourth step of 5S methodology) in the bidding process of acquisition management will reduce the waste of unnecessary hidden activities and in turn reduce its long lead time to a reasonable one.

At what stage must Kanban be applied?

In the case of this SCM, Kanban cards can be very useful in-between Acquisition management and Materials management. This can perhaps be in the form of visual boards to flag negativities and downtime resulting from a completed acquisition activity. This is very important in order to eliminate repetition of long lead time activity as well as provide a better understanding of the completed process to the team.

Where does the company need to apply Poke-yoke?

As highlighted in section 4.7.2 the waste of defect in Lean manufacturing is best eliminated by preventing it through the use of Poke-yoke devices that detect if a product is defective, either preventing the process from running or highlighting the defect for action. Similar to the manufacturing environment this SCM can eliminate the waste of defect by carrying out a proper needs assessment in the demand management stage of the SCM. This can be achieved by providing the right specification of material that is required for maintenance.

Where can Pull systems be used?

Pull systems are useful in the materials management stage of the SCM for assessment of reordering level which poses a challenge in materials management. There is a high percentage of stock-out situations which can severely slow down maintenance success. Hence pull systems are very essential.

What is the Total Processing time?

For material or services above R350 000 in value, the total processing time is 108 days. The time was reduced from 140 days to 108 days after specific Lean tools were applied into the current SCM. Similarly, for material or service below R350 000, the processing time was reduced from 14 days in the current state map to 10 days in the future state map with the application of related Lean tools into the process. The processing time values for the two SC processes were obtained by the summation of processing time for each process step or activity and can be denoted as$\sum[Activity\ Processing\ time]$.

What is the Total Lead time?

Lead time in the SCM is one element that is very important. The reason for this is that it indicates the true time each activity reaches its completion state. With the application of lean tools in the present SCM, the lead time for the bidding procurement reduced drastically from 261 days to 165 days. The lead time for the RFQ type of procurement also reduced from 30 days to 17 days. The Value-added times in the future state VSM are 96 days and 13 days for the bidding and RFQ procurement respectively.

What are other supporting actions important for SCM success?

Kaizen or continuous improvement is a Lean tool which deals with either incremental or radical development. Hence, it is recommended that most important parts in the process activities implement this tool. For materials or services above R350 000, the activities which require continuous improvement are:

- Supplier database management by the application of supplier development;
- Kaizen improvement training required for personnel involved in bidding process and contract administration;
- Formulation of KPIs for the Procurement strategy in Acquisition Management;
- To keep the level of inventory at the desired level, the “Go see” icon was applied between the Acquisition and Materials Management.

CHAPTER 5: MEASUREMENT METRICS

5.1 Introduction

Performance measurement is the practice of measuring system or process effectiveness, efficiency and capability given a benchmark or target. Effectiveness is the measure of doing the right job where the stakeholders' requirements are fulfilled. Effectiveness can be explained as doing the job right with better economic value, utilising resources to meet stakeholder level of satisfaction. Capability in a broader sense is the merging of effectiveness and efficiency in both short term and long term i.e. the ability to perform the right job in a right manner. This can be tangible like technology, resources or intangible such as corporate culture (Deborah, N. 2005:4).

5.2 Relevant SCOR Metrics

The researcher discovered during the current SC process GEMBA walk that crucial performance metrics are absent. The downside effects of this can be numerous, from slowing down the progress of the process to preventing opportunities for incremental innovation. The success of Lean implementation can only be realised in the long term. With this being essential criteria for Lean methodology and application, specific performance metrics are important in the case of monitoring the progress of the process. In the Literature review of this thesis, the Supply Chain Operations Reference Model (SCOR) metrics was discussed briefly. The SCOR metrics will be adopted to understand how it tallies into the current process for continuous improvement

As discussed in section 2.2.4, five performance attributes are contained in SCOR. There are specific metrics outlined by SCOR that can be used to measure these attributes. Some of the applicable SCOR attributes will aid in the continuous measurement of a process performance in order to realise an ideal state. The attributes mentioned in the literature review are Reliability, Responsiveness, Agility, Cost and Assets.

Strategic (Level 1) metrics of KPI will be applied for attribute measures in this study. The reason for this is because the bidding process (highest area of waste in the supply chain) does not have any existing metrics to measure procedures in the organisation.

5.2.1 Reliability

In the reliability attributes, perfect order fulfilment serves as the metrics used for measuring performance. As in the literature review, perfect order fulfilment deals with the percentage of orders meeting delivery performance with complete and accurate documentation and no delivery damage. Therefore, in the case of the tendering process, perfect order fulfilment will be translated as the number of tenders approved within a stipulated amount of time. The calculation for this is:

$$\boldsymbol{Perfect\ Order\ Fulfilment} = \frac{\boldsymbol{Total\ Number\ of\ Completed\ Tenders}}{\boldsymbol{Total\ Number\ of\ Submitted\ Tenders}} \times \frac{\mathbf{100}}{\mathbf{1}}$$

Total number of submitted tenders refers to the tender requests that were successfully submitted for material purchase, while total completed tenders are those tender requests which were successfully offered at the end of the bidding process.

Using a period of one year, the requisitioning unit was requested to provide details of tenders submitted versus tenders processed and completed. It was confirmed that 6 tenders out of 10 submitted were processed and completed.

Following the above the data for Perfect Order fulfilment is calculated thus:

- Total number of completed tenders = 6
- Total number of submitted tenders = 10

Hence;

$$\mathbf{Perfect\ order\ fulfilment} = \frac{\mathbf{6}}{\mathbf{10}} \times \frac{\mathbf{100}}{\mathbf{1}} = \mathbf{60\%}$$

At strategic level (Level 1 metrics), the reliability percentage for the tender request is 60%. The score is unsatisfactory in terms of reliable performance. Therefore, management should create strategic measures for request process accuracy.

5.2.2 Responsiveness

For planning, it is important to know the amount of expected lead time required to develop purchase orders (POs). Long lead times will extend the procurement cycle and will delay the time in issuing a PO with the supplier or manufacturer. This, delay in time will potentially lead to shortages and stock-outs.

This indicator measures the efficiency with which requests are processed and POs prepared. Improving the contract lead time will improve response times to internal facilities that need the products.

The responsiveness of an SCM is the cumulative cycle time for the fulfilment of a requested order. To determine the responsiveness of the bidding process the order fulfilment time will be defined. The order fulfilment time for the bidding process can be determined by measuring the time frame from the commencement of the bidding administration to the end of bidding adjudication. This time is inclusive of the value and non-value-added time between the two process steps. From the information provided in Figure 18 (Bidding process activities) the following information was used for the calculation of the order fulfilment cycle.

$$\boldsymbol{Order\ Fulfillment\ Cycle\ Time} \\ = \boldsymbol{Bidding\ Adm}(\boldsymbol{PT} + \boldsymbol{WT}) + \boldsymbol{Bidding\ Ev}(\boldsymbol{PT} + \boldsymbol{WT}) + \boldsymbol{Bidding\ Adj}(\boldsymbol{PT})$$

$$= [\![(\mathbf{6} + \mathbf{3}) + (\mathbf{9} + \mathbf{6.43}) + (\mathbf{1.86})]\!]\boldsymbol{weeks}$$

$$= \mathbf{26.29}\boldsymbol{weeks}$$

$$= (\mathbf{26.29} \times \mathbf{7})\boldsymbol{days}$$

$$\mathbf{184.03} \approx \mathbf{184}\ \boldsymbol{days}$$

Table 20: Bidding Process calculation elements

LEGEND	
PT	Processing Time
WT	Waiting time
Adm	Administration
Ev	Evaluation
Adj	Adjudication

5.2.3 Agility

The SCOR KPIs for the Agility attribute include; flexibility, adaptability and Value-at-Risk (VaR). The information required for the Flexibility and Adaptability KPI calculation is not readily available. To monetize the SC risk as a form of determining the bidding process agility, the VaR must be established. Value-at-Risk is a popular risk metric widely used by the finance sector to understand the risk exposure of a trading portfolio based on historic volatility.

Any event with a potential to disrupt linkages across the entire SC is considered as a Risk Event. SC VaR is the product of the probability of risk event and the monetary impact of the events which can impact any core SC functions.

The risk identified in the bidding process is a lack of specification of needed material. The downside of this can be revenue loss, an extension of contracts and loss of transportation for the public. For analysis, a period of one year was used to analyse the submitted bids that were successfully processed to completion. The Process team members confirmed that 10 tenders were issued within the above stated period. Of these, 6 bids out of the submitted 10 successfully reached completion. This leaves a number of 4 bids unprocessed. The team members further confirmed that at least one of the bids with the lack of specification of required material are sometimes processed where the material is being purchased. This challenge occurs four times on average creating the risk of capital loss of the bid itself. The range of value for the bids is between R1 million – R1.5 million. And so, on average, the value of the bid will be estimated to be R1.25 million.

For the purpose of calculating the VaR, the variables must be identified. The simple VaR calculation for the bidding process will be:

$$\boldsymbol{VaR = Probability\ of\ Bid\ Process\ Risk \\ \times\ Monetized\ Impact\ of\ Bid\ Process\ Risk}$$

- Probability of bidding risk: 4
- Monetized impact of bid process risk: R1.25 million + Total Cost of servicing the Bid

The value for the total cost of servicing the bid was taken from the cost metric section (5.24 - Table 21) and it's estimated at a value of R36 800.

$$\boldsymbol{VaR = 4\ \times (1\,250\,000 + 36\,800\,) = R5\,147\,200}$$

5.2.4 Costs

The SCOR KPI for the cost attribute is determined by measuring the total cost to serve a supply chain. For the current situation, the one that will be considered is the cost attached to servicing the bid. In the bidding process, some activities which are cost-related are few and might necessarily not bear a high cost compared to the cost of tender value. The Cost related activities in the bidding process, as well as their monetary values, are listed in Table 21.

Table 21: Cost of servicing the Bid

Service	Cost	
Cost of Tender Advert and Publishing	R15 000 (1)	R15 000
Attendance of Tender Briefing		
Flight	R3 500 (4)	R14 000
Accommodation	R1 250 (4)	R5 000
Car Hire	R700 (4)	R2 800
Total Service Cost		**R36 800**

The cost of tender advert and publishing is estimated to be R15 100 per material order. Other servicing costs required to service the bid lie in the miscellaneous expenses during the tender briefing such as air fares for outside region tender briefing members, accommodation for these members and car hire. For a usual bid, four participants attend briefings from an outside region. Hence, in turn, the cost elements for tender briefing attendance are multiplied by 4.

5.2.5 Asset Management

There are three types of KPIs for the asset management performance attribute as discussed in the literature study. These three main assets are cash-to-cash cycle time, return on fixed assets and return on working capital. For the purpose of this research study, one of these KPIs would be used to determine the asset management efficiency. The cash-to-cash cycle time will be utilised for achieving this goal. To calculate the value of cash-to-cash cycle, certain variables are required. Before explaining these variables, it is important to understand the formulae for the calculation of the cash-to-cash cycle.

$$\begin{aligned} \boldsymbol{Cash - to - Cash\ Cycle\ time} \\ &= (\boldsymbol{Days\ Sales\ \ Oustanding}) + (\boldsymbol{Inventory\ days\ of\ Supply}) \\ &- (\boldsymbol{Days\ paybale\ Oustanding}) \end{aligned}$$

$$\boldsymbol{Days\ Sales\ Outstanding} = \frac{\boldsymbol{Average\ Receivables}}{\boldsymbol{Net\ revenues - Earned}} \times \boldsymbol{Number\ of\ days}$$

$$\boldsymbol{Inventory\ days\ of\ Supply} = \frac{\boldsymbol{Average\ Total\ Inventory}}{\boldsymbol{Cost\ of\ Goods\ Sold - Earned}}$$

$$\boldsymbol{Days\ Payable\ Outstanding} = \frac{\boldsymbol{Average\ Liabilities}}{\boldsymbol{Cost\ of\ Goods\ Sold - Earned}}$$

Average Receivables

This is the money or funds payable to PRASA rolling stock entity. According to (PRASA, 2015), a government subsidy for service delivery to the public can determine by taking an average of the government subsidy for a period of two years as calculated below.

$$(\boldsymbol{4,328,003,000 + 3,887,342,000}) \div \boldsymbol{2} = \boldsymbol{4,107,672,500}$$

Net Revenue

This value covers the operating lease income, fare revenue and government subsidies. The average net income for a financial two-year period is stated below.

$$(\mathbf{6,998,515,000} + \mathbf{6,594,230}) \div \mathbf{2} = \mathbf{6,796,372,000}$$

Earned

The fare revenue is the earned value because it is the return of procured materials. The fare revenue in this particular situation is the fund generated from sales of transportation tickets. From (PRASA, 2015), the fare revenue income value is R2, 262,275,000 on average for an annual fiscal calendar.

Average Total Inventory

The average total value of inventory for a duration of two years is R233, 664,000

Number of days

365 days of a calendar year

Cost of Goods Sold

To determine this variable, three elements must be identified. These are: the beginning inventory value, the value of purchased rolling stock for the financial year, and ending inventory value. The beginning inventory value will be added to the value of material purchased and then subtracted from the ending inventory as seen in the formulae below.

$$(\boldsymbol{Beginning\ Inventory} + \boldsymbol{Purchased\ material\ value}) - \boldsymbol{Ending\ Inventory}$$

The values for these three elements are listed below followed by the calculation of Cost of Goods Sold.

- Beginning Inventory Value: R225 100 000
- Purchased Material (rolling stock) Value: R5 700 000 000
- Ending Inventory: R242 228 000

$$\boldsymbol{Cost\ of\ Goods\ Sold} = (\mathbf{225,100,000} + \mathbf{5,700,000,000}) - \mathbf{242,228,000}$$
$$= \mathbf{5,682,872,000}$$

Average Liabilities

The average liabilities is the sum of the current liabilities at the beginning and the end of a fiscal period divided by 2.

$$(\boldsymbol{Current\ liabilitites}\ (\boldsymbol{Beginning}) + \boldsymbol{Current\ Liabilitites}(\boldsymbol{End})) \div \mathbf{2}$$

$$(6,432,246,000 + 6,439,600,000) \div 2 = 6,435,923,000$$

Following the identification of the variable values, the cash to cash cycle calculation will be worked out further.

$$\textit{Days Sales Outstanding} = \frac{\textit{Average Receivables}}{\textit{Net revenues} - \textit{Earned}} \times \textit{Number of days}$$

$$\frac{4,107,672,500}{6,796,372,000 - 2,262,275,00} \times 365 = 330.6 \approx 331$$

$$\textit{Inventory days of Supply} = \frac{\textit{Average Total Inventory}}{\textit{Cost of Goods Sold} - \textit{Earned}}$$

$$\frac{233,664,000}{5,682,872,000 - 2,262,275,000} = 0.068 \approx 0.07$$

$$\textit{Days Payable Outstanding} = \frac{\textit{Average Liabilities}}{\textit{Cost of Goods Sold} - \textit{Earned}}$$

$$= \frac{6,435,923,000}{5,682,872,000 - 2,262,275,000} = 1.88 \approx 1.9$$

$$\textit{Cash to Cash Cycle time} = (\textit{Days Sales Oustanding}) + (\textit{Inventory days of Supply}) - (\textit{Days paybale Oustanding})$$

$$(331 + 0.07) - 1.9 = 329.17 \approx 329$$

The cash-to-cash cycle time for a measurement of 365 days period is 329 days.

Figure 23 shows the relevant SCOR KPIs applicable for the measurement of the present performance of the process.

Attribute	Level- 1 Metric
Reliability	Perfect Order Fulfilment
Responsiveness	Order Fulfilment Time
Agility	Value at Risk
Cost	Total Service Cost
Asset Management Effeciency	Cash-to-Cash Cycle

Figure 23: Relevant KPIs

For clarity on the type of performance metrics to adopt for the process, consideration of the background is required. The current SC falls under the procurement background and it is therefore required that the indicators that will be appropriate for measurement of this SC fall under the same procurement scope. In the literature review, procurement, as well as public procurement, was discussed.

In lieu of a realistic benchmark for PRASA RS Procurement SCM, the Indian Railway (IR) Procurement SCM (a world-class leading railway industry) was used for determination of the appropriate performance indicators. For effective comparison, the procurement SC of IR was studied. Section 5.3 covers a brief overview of IR procurement SC as a comparison benchmark. Information on three strategic metrics out of the five proposed in this section was not applicable in the Indian railway. However, for benchmarking purpose the reliability and responsiveness KPIs were utilised for comparison.

5.3 Introduction to Benchmarking Metrics

Indian Railway (IR) Procurement SCM

According to Gupta *et.al.* (2015) in the Indian Railway, the Material Management Department ensures uninterrupted material supplies and storage of the material if necessary. The assets include 262 warehouses and a large storage area for material components.

The items are codified based on main equipment, assembly and subassembly e.g. diesel loco spares will have item codes that start from 10 to 19, while electric loco spares will have an item code that starts from 20 to 29. Also, there are purchase groups as well as subgroups which are organised on the basis of the user group. For example, there is a separate purchase group for electric loco spares, diesel loco spares etc. The system in place is an annual procurement of items of different categories through the invitation of tenders for lump sum quantities for years. For tenders that are of high value, decisions are taken by tender evaluation committees which consist of the officers of the following departments:

- User department;
- Materials management;
- Finance department.

From a four-year observation, it was discovered that most materials (90-95%) in value terms are acquired through approved suppliers or sources. Sources approval is carried out by a centralised agency such as Chittaranjan Loco Works (CLW), Diesel Locomotive Works (DLW), or Research Design and Standard Organisation (RDSO).

Suppliers are required to arrange an inspection of all consignments from third party inspection agencies like CLW and RDSO prior to dispatch of material. Sources approving agency, procuring agency and inspection agencies are independent of each other. The material is finally received and accepted by a consignee who is in charge of the warehouse and then stocked and issued as per requirement. Suppliers are required to submit bills, in the prescribed format along with necessary documents, such as inspection certificates and dispatch details for purposes of claiming payment.

Figure 24 illustrates IR procurement process flow which typically consists of seven stages. The process initiation commences with the estimation of material needed by the user department. This is backed up by approval from the required authority. After approval, the tenders for these needs are issued for notification requiring submission of bids from approved vendors. Following submission by vendors, the bids are evaluated and a contract is issued for the successful candidate. The contract is then executed in line with inspection performed by a third party. The vendor provides the service following the inspection and IR material management endorses the receipt.

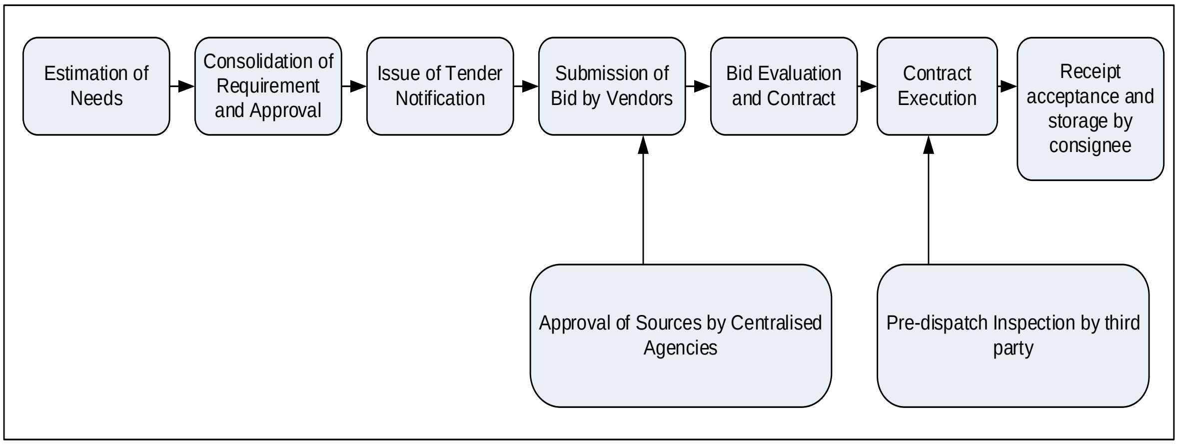

Figure 24: Flow Chart of IR Procurement Process

(Source: Gupta, Prakash and Jadeja, 2015)

5.3.1 Applicable Benchmark KPIs

For comparison and appropriate measurement, some similar KPIs for the IR procurement SCM were compared against those of the PRASA RS procurement SCM. To ensure accurate information for comparison, the IR procurement system was studied to extract applicable parts of this system to those of the PRASA procurement SCM. As initially pointed out, only two out of the SCOR proposed KPIs are applicable in the Indian Railway Procurement for comparison. Nevertheless, an extra two KPIs outside SCOR KPIs were found relevant for comparison and so these were included. Table 22 shows a comparison of the current state of PRASA Procurement KPIs and Indian Railway Procurement KPIs. Furthermore, the PRASA future situation in terms of metrics standpoint was included in the table.

Table 22: PRASA Procurement KPIs vs IR Procurement KPI

Performance Indicators	PRASA Current	Indian Railway Current	PRASA Future
Lead Time (Order Fulfilment Time) Bidding Administration to Adjudication	184 days	163 days	165 days
Number of Active Suppliers	Uncertain	3000	2600
Reliability of vendors(Perfect Oder Fulfilment)			To be measured
Cases of Supply success (%)	60%	90%	
Cases of delivery failure (%)	40%	8%	
Stock Situation			To be measured
Availability of stock items	40%	95.6%	
Unavailability of stock items	60%	4.4%	

According to the bidding procurement current state VSM, the lead time from bidding administration to adjudication for PRASA Procurement SCM is 184 days. The reason for this is mainly because of waste as explained in section 4.6. The maximum duration of time for bidding administration to adjudication in IR procurement SCM is far less than that of PRASA procurement SCM. One positive strategy used to achieve less lead time is the ability to have long-term contracts with suppliers. While IR procurement SCM-active suppliers total 3 000, the number of active suppliers in the system for PRASA procurement SCM is uncertain, the primary reason being a delay in payment of suppliers. Non-payment also hugely affects the reliability of suppliers. When suppliers do not receive payment regularly for their services, they tend to withdraw from providing these services. The stock situation in IR procurement SCM is acceptable and far better than the stock level in PRASA Procurement SCM. Stocks in IR are being managed to always service needed requests. Unavailability of stock items in PRASA is more than 50% which causes a downtime in daily maintenance.

5.4 Lean Procurement Framework

The framework for lean procurement SCM presented in this part of the research study reports the implementation of lean thinking in procurement SCM. Figure 25 shows the framework for procurement SCM and consists of various variables that make up the framework. These variables are combined to reach an outcome of waste minimisation and value creation.

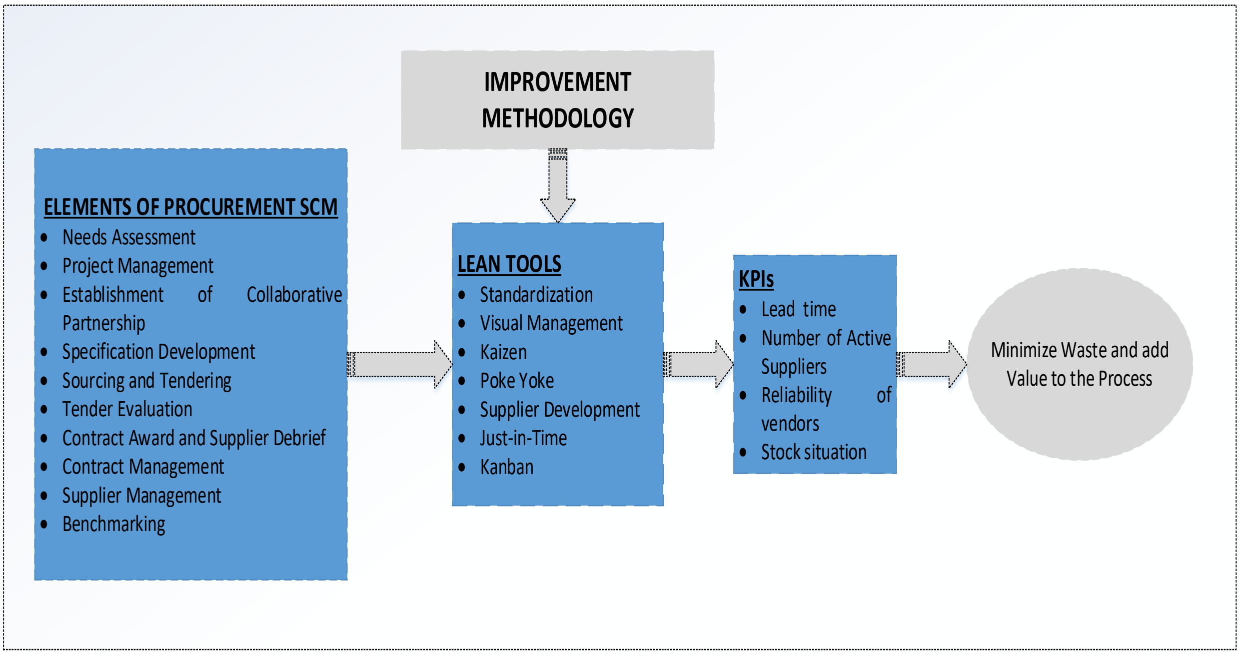

Figure 25: Framework for Lean Procurement

5.4.1 Framework Variables

All the variables used for the framework shown in Figure 25 are listed below. The list of these variables is followed by their explanation.

- Elements of Procurement SCM
- Lean Tools
- KPIs

Elements of Procurement SCM:

The elements of procurement SCM in the framework were chosen from the case study definition in Chapter 3 and were utilised through the use of current state VSM. The current state VSM aided prioritising the areas with the most waste. These elements stand as a reference line for continual improvement methodology.

Lean Tools:

As outlined in the introductory section of this thesis, the improvement methodology that was applied for the research study is lean thinking. Some lean tools were discussed in the literature review section. These tools serve as an improvement technique for solution challenges encountered around the process.

KPIs:

The KPIs utilised for measurement in this research are mostly related to the area in the SCM that holds the most challenges. These KPIs in conjunction with the lean tools need to constantly be in check for the extreme realisation of desired improvement state.

CHAPTER SIX: STUDY LIMITATIONS AND ASSUMPTIONS

6.1 Study Limitations

This research study was conducted using a unique SC case study of the railway industry. In this environment of study, some of the information needed for analysis was not readily available which presents data availability as the major limitation encountered during the course of the research study. Another limitation was the unavailability of team members in the SCM for scheduled periodic meetings and the process walk (GEMBA) as well as data collection. However, the information collected was utilised for the process analysis and recommendation.

6.1.1 Lean Tools Limitations

During the data collection process of the research, some of the lean tools like the VSM and waste analysis were limited only to the responses received from the available team members. Thus, all the wastes in the whole level of the SC, as well as the bidding process, were barely covered. It may be noted that a suggestion on the possible improvement of the bidding process was mentioned in Chapter 7 of this thesis.

Though there were a good number of respondents for the FMEA form, better insights of the bidding process would have been attained if there had been more respondents from the acquisition management stage of the SCM.

6.2 Assumptions

Several assumptions were made by the researcher for this particular research study. The first assumption was that the data collected from the team members of the SC were sufficient for analysis. Secondly, performance metrics were formulated because the current SC does not have an existing performance measurement system on every level of the SC.

6.2.1 Data Collection

During the data collection process, many team members in the acquisition management decided to keep most useful information confidential which really provided fewer data at this stage of the SC. Operations in PRASA Procurement SCM cannot be effectively complete without acquisition management. Hence, the researcher endeavoured as much as possible to engage team members in both demand management and the materials management. Their responses, as well as their opinions about acquisition management, were received and assumed to be sufficient for analysis as they are also well experienced in the organisation.

6.2.2 Metrics for Performance

In this particular environment of study, performance indicators were lacking on every level of the supply chain. These facts were confirmed by various team members who were involved in the research study. From broader knowledge and perspective, performance indicators are used by organisations to estimate and fortify how successful they are both in short and long term. Nowadays, medium- and large-scale businesses need efficient systems for flexibility and competitiveness in their related environment. With this in mind, the researcher adopted the SCOR metrics and evaluated how it fits into the current supply chain. Though some of these indicators cannot be fully calculated due to the absence of information, they can prove useful when constantly applied for process performance assessment.

6.2.3 Framework Limitations

The framework designed in Chapter 5 has certain limitations. The first limitation is that the SCM elements contained in the framework are only applicable to the bidding process of PRASA Procurement SCM. All of these elements may not necessarily be applicable for other procurement SCMs. There can either be more or fewer elements or even a different form of elements in place of some of the SCMs.

Another limitation of the framework is that the improvement methodology for the process is subjected to only the SCM element found in the case study, hence the identified KPIs are also applicable to only this type of SCM.

7.0 CHAPTER SEVEN: CONCLUSION AND RECOMMENDATION

7.1 Introduction

PRASA information on material procurement was carefully observed. It was noticed that most procurements of materials for both categories (below R350 000 and above R350 000) are from numerous suppliers. These vendors often operate on a short-term contract basis after which PRASA procurement SCM opens up a new tendering process for another set of suppliers for required materials or services. The downside of this can range from bad supplier relationship management to high cost of the tendering process. The process of vendor approval without considering negotiations on the basis of engineering cost estimation and other necessities sometimes creates an environment of cartelization, mistrust and corruption. An improvement on the present pattern of procurement can create a huge impact in improving the efficiency and effectiveness of PRASA.

In conclusion, this study shows that the understanding of underlying issues in the Procurement SCM must be established for the recommendation of appropriate Lean tools. This, therefore, means that Lean thinking can be applied to this SCM provided the process resolution team work together to resolve the identified issues. Further to the conclusion, answers to the research questions posed in section 1.3 are provided in the next section (7.2).

7.2 Answers to Research Questions

Question 1: What does the current SC look like?

The implementation of Value Stream Mapping tools through the use of current state mapping was used to determine the current state of the SCM. A diagrammatic illustration of the current state map is shown in Figure 10 and Figure 11. The FMEA form was also used to determine the present situation in the SCM.

Question 2: What concepts of lean thinking are relevant to the current supply chain?

The case study is a typical example of a non-manufacturing procurement service organisation. It was found that not every tool that applies in the manufacturing environment necessarily applies in this specific environment. Some of the important lean tools that were applicable in this environment are stated below:

- Value Stream Mapping;
- Waste Analysis;

- Standardisation;
- Visual Management;
- Poke-yoke;
- Supplier development;
- JIT;
- Kanban.

Question 3: What measures should be in place for successful process change?

To monitor the successful progress of the application of Lean, some KPIs have been identified. In Chapter 5, five SCOR metrics were identified and evaluated for utilisation. Some benchmarking KPIs from Indian Railway were used for current performance analysis.

7.3 Recommendation

7.3.1 Reformation of tendering process

A high percentage of issues with the PRASA RS procurement SCM lies in the tendering process. Therefore, for continuous solutions regarding this issue, the tendering process needs to be reformed. This reformation can be achieved by applying the steps listed in Figure 26 to enable the process to reach an ideal state of effectiveness and efficiency.

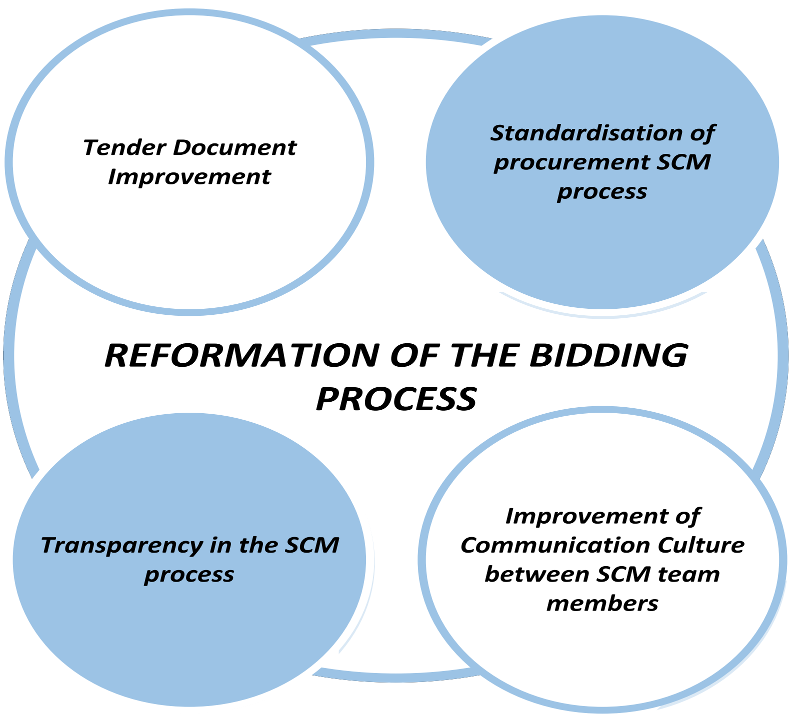

Figure 26: Bidding process reformation

Tender document improvements:

The documents required for the tendering process should be user-friendly and easy to understand. The number of tender documents necessary for the tendering process should be significantly reduced with a simpler layout that is easy to use and the language used should be unambiguous and easy to understand. Standardisation of the document should be done in a way where it will be relevant for the kind of procurement to be undertaken. For example, the process for buying a bogie should be clearly distinguished from the process of procuring a crane remote. For efficiency, standard operating procedures for the SCM processes should be developed and constantly reviewed.

***Standardisation of SCM process for proper streamlining*:**

It is important to remove unnecessary steps in the procurement process. A centralised database should be adopted which will significantly reduce the burden of administration within the system. With this, mandatory administrative documents must be submitted once in a set period. System automation will result in substantial cost reduction for suppliers. It will also bring about improvement in transparency and supervision.

Improvement of communication culture between suppliers and SC managers of PRASA:

For the development of good working relationships, organised communication with suppliers must be encouraged. Regular distribution of procurement-related information about departmental work, procurement policies and procedures, planned procurement opportunities and general matters should be considered under structured discourses.

Transparency in the SCM Process:

At the beginning of every fiscal year, a reporting framework for the procurement of scheduled products should be done. Personnel across the chain of procurement (support managers, BEC, technical representatives, etc.) must be involved in reporting a range of information for appropriate alignment and understanding. This information will include procurement plans, tenders to be advertised, awarded tenders, information of supplier companies, the value of each award and progress in tender implementation. Depending on the type of information, communication of information should be done either monthly, quarterly or yearly. Aside from a reporting framework, provision for equal opportunity for every vendor is very key to PRASA RS procurement SCM.

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APPENDICES

APPENDIX A – VALUE STREAM MAPPING ICONS

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<tr><th>Material Icon</th></tr>
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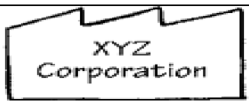
<tr><td>
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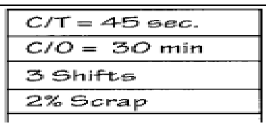
<tr><td>
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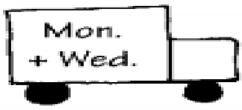
<tr><td>
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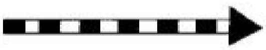
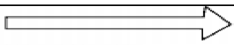
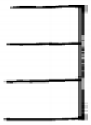
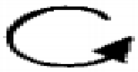
<tr><td></td></tr>
<tr><td></td></tr>
<tr><td></td></tr>
<tr><td></td></tr>
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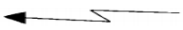
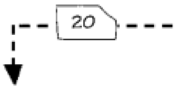
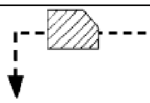
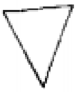
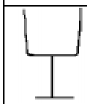
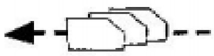
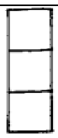
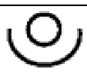
</table>

Information Icon	Symbolises	Description
	Manual Information Flow	Such as: shipping schedule or production schedule
	Electronic Information flow	Such as: electronic data transfer
	Information	Information flow description
	Production Kanban (the dotted lines indicates Kanban flow)	This shows “one-per-container” Kanban. It is a device or card that controls the production in a process by alerting on the specific amount of production
	Withdrawal Kanban	This represents that card of process whereby a material transfers, i.e. from shop to end user
	Signal Kanban	One-per-batch Kanban. Indicates the attainment of reorder point and need for another batch of production
	Sequence-Pull Ball	Instructs for immediate production of predetermined type and quantity, usually one unit.
	Kanban Post	Positioned at the point Kanban are collected and held for conveyance
	Kanban arriving in Batches	
	Load levelling	Tool for the interruption of Kanban batches. Also means for levelling the volume and mix of Kanban over a period of time

	"Go See" production Scheduling	Adjusting Schedules based on checking inventory levels

General Icon	**Symbolizes**	**Description**
	"kaizen Lighting Burst"	The point at which improvement is needed to achieve the vision of the value stream. This can be utilised in the planning of kaizen workshops
	Buffer or Safety Stock	'Buffer' or 'Safety' stock should be noted
	Operator	Signifies an individual viewed from above.

APPENDIX B – MATERIAL PLANNING PERSONNEL ROLES

08 – MATERIAL PLANNING SYSTEM PROCEDURE				
File Ref	DOCS_MHQ-#91585-v1-08_-_Material_Planning_System_Procedure.DOC			
Creation Date	2012-02-03		Last Edit Date	2012-02-15
Doc No. & Version	91585-v1	Author	QMARINUSJHB	Page 2 of 10
Volume and Addition	Vol. 1, 1st Addition	Approved	Dr. D. Mtimkulu	
Supply Chain Management Approved				

1. OBJECTIVE

The purpose of this procedure is to describe the workflow process to be followed for material planning.

2. SCOPE

This workflow procedure covers the material planning requirements for the preservation of the physical assets. All scheduled and unscheduled maintenance activities are covered within the scope of this procedure.

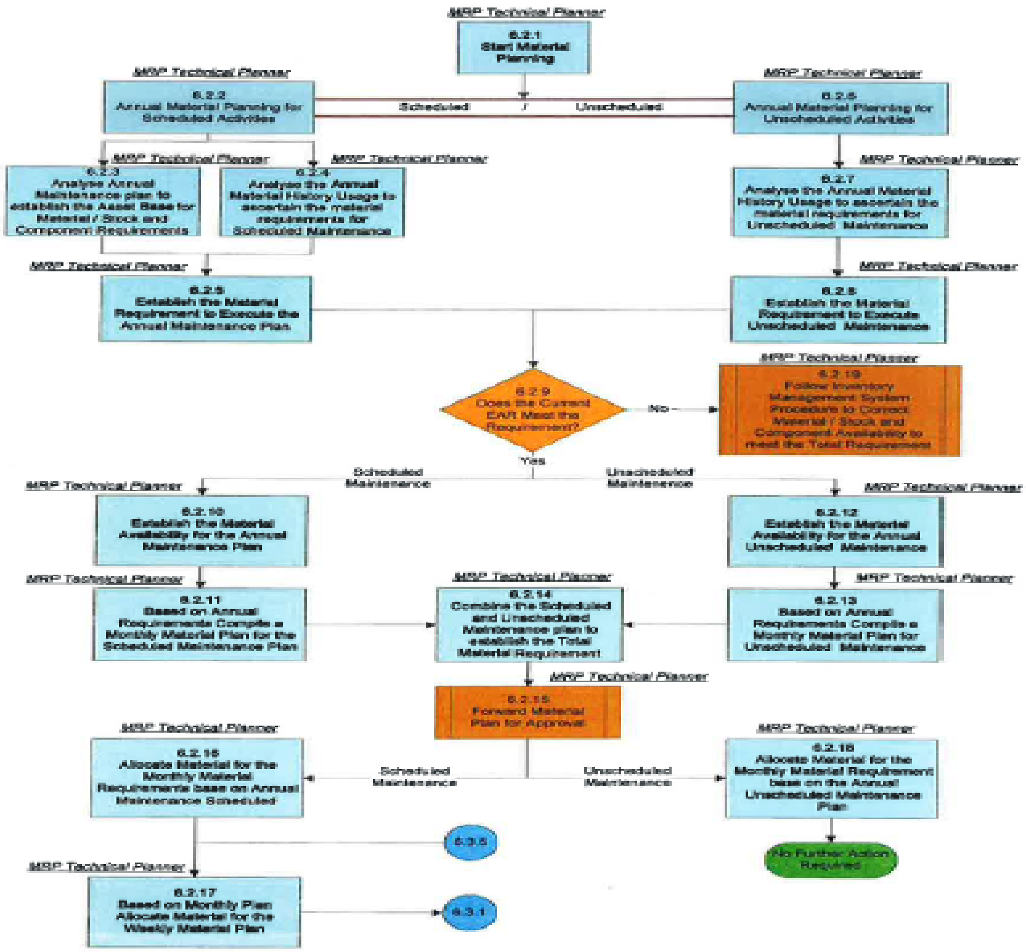
3. RESPONSIBILITY

1 = Manage the process 2 = Do the activity (carry out the actual work) 3 = Informed by 2 (memo, e-mail, etc – not verbal) 4 = Consulted (asked advice, informed etc.) 5 = Approve and Responsible ACTION	Executive Engineering Services	National Systems Manager	Engineering Manager	Maintenance Operations Manager	Maintenance Support Manager	MRP Technical Planner	Technical Supervisor	Technician	SCM Store Man	
Approval of this Procedure	5									
Author and Change Control of this Procedure		1,3								
Implementation of Procedure			2,3,4	2,3	2,3	2,3,4				
Planning of Material						2,3,4				
Material Plan Approval Process				2,3,4	3,4					
Material Collection at Store							2,3			
Issuing of Material									2,3	
Use of Material								2,3		
Return of Surplus Material								2,3		
Credit Material Back in Store									2,3	
Material Usage Validation							2,3,4			
Apply Lean Maintenance Practice						2,3	2,3	2,3		
Limitation of Material Wastage			3	3,4	3,4	2,3,4	2,3	2,3	2,3	
Audit effectiveness of procedure			2,3	2,3	2,3					

APPENDIX C – PROCEDURE FOR MATERIAL PLANNING AND BUDGETING

08 – MATERIAL PLANNING SYSTEM PROCEDURE				
File Ref	DOCS_MHQ-#91585-v1-08_-_Material_Planning_System_Procedure.DOC			
Creation Date	2012-02-03		Last Edit Date	2012-02-15
Doc No. & Version	91585-v1	Author	QMARINUSJHB	Page 4 of 10
Volume and Addition	Vol. 1, 1st Addition	Approved	Dr. D. Mtimkulu	
Supply Chain Management Approved				

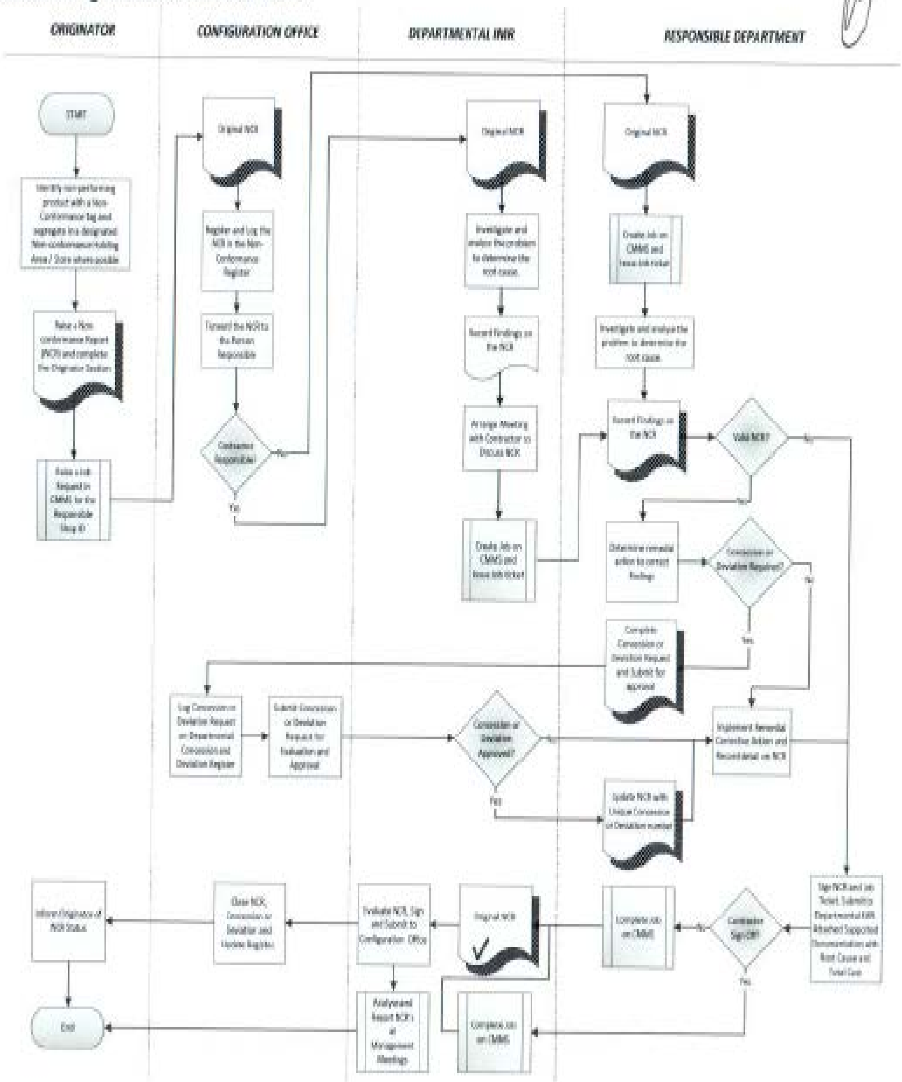
6.2. Material Planning and Budgeting



APPENDIX D – PROCEDURE FOR CONTROLLING NON-CONFORMING PRODUCT

CONTROLLING OF NON-CONFORMING PRODUCT PROCEDURE					
File Ref	DOCS_MHQ-#98401-v1-Control_of_Non-Conforming_Product				
Creation Date	2012-01-30			Last Edit Date	2013-09-16
Doc No. & Version	#98401-v1		Author	QMARINUSJHB	Page 4 of 7
Volume and Addition	Vol. 1, 2[st] Addition		Approved	Dr. D. Mtimkulu	

4.1 Control of Non-conforming Product Process Flow:



APPENDIX E – NON-CONFORMANCE REPORT FORM

CONTROLLING OF NON-CONFORMING PRODUCT PROCEDURE					
File Ref	DOCS_MHQ-#98401-v1-Control_of_Non-Conforming_Product				
Creation Date	2012-01-30		Last Edit Date	2013-09-16	
Doc No. & Version	#98401-v1	Author	QMARINUSJHB	Page 6 of 7	
Volume and	Vol. 1, 2st Addition	Approved	Dr. D. Mtimkulu		

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Non-conformance Report (NCR)

Dept Prefix	No.

ORIGINATOR	DATE: / /	ORIGINATOR:	
	Department:	Non-Conformance Quantity:	
	Non-Conforming Product:		
	Description of Non-Conformance:		
RESPONSIBLE PERSON (HOD)	Cause of Problem:		
	Remedial Action Taken:		
	REWORK	**SCRAP**	**CONCESSION**
	Hours:	Quantity:	No:
	Cost: R		
	Corrective Action Taken to Prevent Recurrence:		
	HOD (Name):	Sign:	Date: / /
IMR	Has the Necessary Remedial and Corrective Action Been Taken?	Y	N
	Comments:		
	Close Out:	Sign:	Date: / /

APPENDIX F – SAMPLE FMEA FORM

Failure Mode and Effect Analysis Form

Project name:	*Application of Lean tools in Rolling Stock Supply Chain Management*		
Process Responsibility:			
Prepared By :	*Umeh Nicholas*	*Sign:*	
Approved by:	*Professor C.J Fourie*	*Sign:*	
FMEA Number:			
FMEA Date:			

Process Step/Input	Potential Failure Mode	Potential Failure Effect	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Actions Recommended
Need Assessment									
Supplier Database									
Tendering Process									
Contract Preparation									
Procurement									
Inventory Management									
Vendor Performance									

APPENDIX G – FMEA EVALUATION CRITERIA

SEVERITY EVALUATION CRITERIA

Effect	Criteria: Severity of Effect	Ranking
Hazardous- Without warning	Very high severity ranking when a potential failure mode effects safe system operation and/or involves noncompliance with a government regulation without warning	10
Hazardous- With warning	Very high severity ranking when a potential failure mode effects safe system operation and/or involves noncompliance with a government regulation with warning	9
Very High	System/item inoperable, with loss of primary function	8
High	System/item operable, but at a reduced level of performance. Customer dissatisfied.	7
Moderate	System/item operable, but comfort/convenience item(s) inoperable. Customer experiences discomfort.	6
Low	System/item operable, but comfort/convenience item(s) operable at a reduced level of performance. Customer experiences some dissatisfaction.	5
Very Low	Fit & Finish/Squeak & Rattle item does not conform. Defect noticed by most customers.	4
Minor	Fit & Finish/Squeak & Rattle item does not conform. Defect noticed by average customers	3
Very Minor	Fit & Finish/Squeak & Rattle item does not conform. Defect noticed by discriminating customers	2
None	No effect	1

OCCURANCE EVALUATION CRITERIA

Probability of failure	Possible failure Rates	Ranking
Very High: Failure is almost inevitable	> or = 1 in 2	10
	1 in 3	9
High: Repeated Failures	1 in 8	8
	1 in 20	7
Moderate: Occasional Failures	1 in 80	6
	1 in 400	5
	1 in 2,000	4
Low: Relatively few failures	1 in 15,000	3
	1 in 150,000	2
Remote: Failure is highly unlikely	< or = 1 in 1,5000,000	1

DETECTION EVALUATION CRITERIA

Detection	Criteria: Likelihood of Detection by Process Control	Ranking
Absolute Uncertainty	Process Control will not and/or cannot detect a potential cause/mechanism and subsequent failure mode; or there is no Process Control	10
Very remote	Very remote chance Process Control will detect a potential cause/mechanism and subsequent failure mode	9
Remote	Remote chance Process Control will detect a potential cause/mechanism and subsequent failure mode	8
Very Low	Very low chance Process Control will detect a potential cause/mechanism and subsequent failure mode	7
Low	Low chance Process Control will detect a potential cause/mechanism and subsequent failure mode	6
Moderate	Moderate chance Process Control will detect a potential cause/mechanism and subsequent failure mode	5
Moderately High	Moderately high chance Process Control will detect a potential cause/mechanism and subsequent failure mode	4
High	High chance Process Control will detect a potential cause/mechanism and subsequent failure mode	3
Very High	Very high chance Process Control will detect a potential cause/mechanism and subsequent failure mode	2
Almost Certain	Process Control will almost certainly detect a potential cause/mechanism and subsequent failure mode	1

APPENDIX H – 5S EVALUATION SHEET

5S Evaluation Sheet		Year: 2015				Area: Demand Management, Acquisition Management and Materials Management																	
PRASA SCM		JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEP		NOV		DEC	
		Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N
1S - SIMPLIFY (Identify the needed and unneeded activities)																							
1	Are only necessary items procured?	Y		Y		Y		Y		Y		Y		Y		Y		Y		Y		Y	
2	Are non-value-added activities identified?	Y		Y		Y		Y		Y		Y		Y		Y		Y		Y		Y	
3	Are available procedures effective?	Y		Y		Y		Y		Y		Y		Y		Y		Y		Y		Y	
2S - STRAIGHTEN (Organising necessary activities and making it easier for team members to follow																							
4	Is there medium for recording NVA activities?		N		N		N		N		N		N		N		N		N		N		N
5	Are waiting times reduced between each process?		N		N		N		N		N		N		N		N		N		N		N
6	Is there proper categorisation of material/service delivered?	Y		Y		Y		Y		Y		Y		Y		Y		Y		Y		Y	
7	up to date for periodic assessment?		N		N		N		N		N		N		N		N		N		N		N
3S - SCRUB (Prevention of Instability resulting from errors in the process)																							
8	Are key activities free from longer processing time?		N		N		N		N		N		N		N		N		N		N		N
9	Are the Performance metrics updated?		N		N		N		N		N		N		N		N		N		N		N
10	Is Change Management often adapted for failed processes?		N		N		N		N		N		N		N		N		N		N		N
4S - STABILIZE (Maintaining the first 3 S's)																							
11	Are inspections carried out in the identified areas of improvement?	Y		Y		Y		Y		Y		Y		Y		Y		Y		Y		Y	
12	Is Change implemented in the process to identify waste	Y		Y		Y		Y		Y		Y		Y		Y		Y		Y		Y	
13	Are wastes in the system eliminated regularly?		N		N		N		N		N		N		N		N		N		N		N
14	Are applicable Lean tools effected into each process?		N		N		N		N		N		N		N		N		N		N		N
5S - Sustain (The system of maintaining the 5S)																							
	The Fifth step in the 5S Evaluation process can be awarded when the initial 4S's have been sustain for a substaintial amount of time		N		N		N		N		N		N		N		N		N		N		N