Knowledge Assets in the Supply Chain

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 and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

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Summary

Knowledge Assets in the Supply Chain

In the *global economy* we are witness to the outcomes of *supply chains* in all of our diverse demand-driven purchasing decisions, be it fast moving consumer goods, electronic equipment or even automobiles. A great deal of exposure relating to the topic of supply chain is based on talk about supply chains and how they are delivering enormous value to companies such as General Electric, Dell and Wal-Mart. But what does all of this really mean? How can an even further exploitation of supply chains be used to gain *competitive advantage* over ever advancing competitors? Average is no longer sufficient to stay ahead of the pack in the demand vs. supply rat-race. Companies have to find and exploit unique characteristics in order to achieve true differentiation over companies competing in similar environments and sharing a common customer base.

The exploitation of the capabilities of *Supply Chain Management* requires a theoretical and conceptual understanding of their underlying *business processes* as well as capabilities. It requires the fostering of an understanding of *Business Process Reengineering* via segmentation and analysis of the overall supply chain into the various basic components. The identification and evaluation of the associated *measures and metrics* within in the supply chain provides insight of how *embedded knowledge* is created and utilised in day-to-day operations, in order to ultimately deliver not only business value but a unique value proposition for the distinct market sectors. The scrutiny of the *lubricants supply chain* is used to gain an understanding of an application of supply chain principles in the *oil and gas* industry in South Africa, detailing the intrinsic business processes as well as their inherent measures and metrics. Particular attention is paid to the underlying *measures and metrics* developed and how they are utilised to enhance inherent decision making capability.

Subsequent to the analysis of the *lubricants supply chain,* an exploration of *core competencies* is used to illustrate how the lubricants supply chain can be differentiated from competitors. These core competencies ultimately allows for greater competitive advantage, leapfrog of competitors and staying ahead of the pack. The final outcome of the thesis is to develop a framework using Boisot's information space pertaining to *codification* and *abstraction* in order to map the processes required to plan, implement and review a generic lubricants supply chain.

Opsomming

Kennis Bates in die Voorsieningskanaal

In die globale ekonomie is ons getuie aan die uitkomste van *voorsieningskanale* in al ons diverse vraag-gedrewe aankope besluite, insluitend vinnig bewegende verbruikersgoedere, elektroniese toerusting of selfs motors. Daar is baie van blootstelling met betrekking tot die onderwerp van voorsieningskanale gebaseer op praat oor voorsieningskanale en hoe hul besig is om groot waarde aan maatskappye soos General Electric, Dell en Wal-Mart te lewer. Maar wat beteken dit alles nou eintlik? Hoe kan selfs 'n verdere ontginning van die aanbod van voorsieningskanale gebruik word om *mededingende voordeel* te verkry oor ons bevorderinge kompetisie? Middelmatigheid is nie meer voldoend om voor die pak te bly nie in die vraag vs. aanbod reis. Maatskappye moet unieke eienskappe vind en benut om ware differensiasie te bereik oor maatskappye meeding in' n soortgelyke omgewing en die deel van 'n gemeenskaplike kliënte basis.

Die uitbuiting van die vermoëns van *Voorsieningskanaal Bestuur* vereis 'n teoretiese en konseptuele begrip van hulle onderliggende *besigheids prosesse* asook vermoëns. Dit vereis dat die bevordering van 'n begrip van *Besigheidsprosesse Heringinering* via segmentering en analise van die totale voorsieningskanale in verskillende basiese komponente. Die identifisering en evaluering van die gepaardgaande *maatreëls en statistieke* binne in die voorsieningskanaal bied insig van hoe *vasgelegde kennis* geskep is en benut word in dag-tot-dag bedrywighede, ten einde te maak om uiteindelik nie net maatskappy se waarde, maar 'n unieke waarde proposisie te lewer vir die verskillende mark sektore.

Die toetsing van die *smeermiddels voorsieningskanaal* word gebruik om 'n begrip van 'n aansoek van voorsieningskanaal beginsels in die *olie en gas* industrie in Suid-Afrika te verkry, met besonderhede oor die intrinsieke besigheid prosesse, sowel as hul inherente maatreëls en statistieke. Besondere aandag word geskenk aan die onderliggende *maatreëls en statistieke* ontwikkel en hul aanwending om inherente vermoë besluitneming te verbeter.

Na afloop van die analise van die *smeermiddels voorsieningskanaal*, word 'n verkenning van *kern vaardighede* gebruik om te illustreer hoe die smeermiddels *voorsieningskanaal* kan onderskei word van die kompetisie. Dit kan uiteindelik kernvaardighede vir 'n groter mededingende voordeel lewer, die haasje van mededingers en die pak aanloop. Die finale uitkoms van die tesis is om 'n raamwerk te ontwikkel met behulp van Boisot se inligting spasie met betrekking tot *codificasie en abstraksie* om die prosesse wat nodig is vir die beplaning, implementering en hersiening van' n generiese smeermiddels voorsieningskanaal te skep.

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APICS	American Production and Inventory Control Society
ASR	Automatic Stock Replenishment
ATF	Automatic Transmission Fluid
ATP	Availability to Promise
B2B	Business-To-Business
BOM	Bill of Materials
BP&A	Business Planning and Administration
BPR	Business Process Reengineering
CAPEX	Capital Expenditure
CDRM	Customer Delivery Reliability Metric
COF	Customer Order Fulfilment
CPL	Cents per Litre
CR	Critical Ratio
CRP	Capacity Requirements Plan
DC	Distribution Centre
DRP	Distribution Requirement Plan
EIA	Environmental Impact Assessment
EDD	Earliest Job Due Date
EODD	Earliest Operation Due Date
ERP	Enterprise Resource Planning
FCFS	First Come First Served
FIFO	First In First Out
HSEQ	Health, Safety, Environment and Quality
LDC	Laid Down Cost
LIFO	Last In First Out
LTL	Less than Truck Load
M&A	Mergers and Acquisitions

MLT	Manufacturing Lead Time
MM	Materials Management
MAP	Moving Average Price
MPS	Master Production Schedule
MRO	Maintenance, Repair and Operational Supplies
MRP	Materials Requirements Planning
MRP II	Manufacturing Resource Planning
OEM	Original Equipment Manufacturer
OPEX	Operating Expenditure
OTIF	On-Time in Full
OTIS	On-Time in Short
PAB	Projected Available Balance
PAC	Production Activity Control
PP	Production Plan
QA	Quality Assurance
RCCP	Rough Cut Capacity Planning
ROI	Return on Investment
S&OP	Sales and Operations Planning
SCM	Supply Chain Management
SCOR	Supply Chain Operations Reference Model
SKU	Stock keeping Unit
SLA	Service Level Agreement
SNP	Supply Network Planning
SPT	Shortest Process Time
TL	Truck Load
TPOP	Time Phased Order Point
TQM	Total Quality Management
WMS	Warehouse Management System
WIP	Work In Progress

Chapter 1
Introduction

1 Overview

1.1 Thesis Objective and Focus

The primary focus of the thesis “Knowledge Assets in Supply Chains” will be the *codification* and *abstraction* of information embedded in the *lubricants supply chain* of companies within the *oil and gas* industry in South Africa. The thesis will show how *explicit knowledge* is created and effectively used within the inherent business units of these companies, consisting of standardised business processes and procedures, via the mechanisms of *codification* and *abstraction*.

As usage of the embedded information to be extracted is crucial for decision making in organisations, the thesis touches briefly on *scanning and problem solving* which for all intents and purposes are outside the scope of the thesis as they are separate topics due to their vast reach and impact across organisations.

The outcome will be a *supply chain framework* to be used for the definition and implementation of an end-to-end supply chain along with metrics and knowledge structures. The final objective of the research will be to illustrate how *knowledge assets* in turn are used for enhancement of decision making capability and ultimately creation of core competencies in alignment to the business organisation’s strategy, structure and systems as well as “softer” shared values, style, skills and staff.

In order to understand the difference between data, information and knowledge, Boisot refers to the following: “Whereas data can be characterised as a property of things, knowledge is a property of agents disposing them to act in particular circumstances. Information is that subset of the data residing in things that activates an agent – it is filtered from the data by the agent’s perceptual or conceptual apparatus. Information, in effect, establishes a relationship between things and agents. Knowledge can be conceptualized as a set of probability distributions held by an agent and orienting his or her actions.”[1]

[1] Boisot MH. 1995 p12

1.1.1 Lubricants Industry

The broader lubricants industry is characterised by various role-players who either import or manufacture lubricants products for customers. These include BP/Castrol, Shell, Engen, Chevron/Caltex, Total and Sasol who have *lubricants blending and storage* facilities in the Durban harbour where they manufacture (i.e. blend) various *lubricants* using local or imported base oil, additives and wax.

The *lubricant finished products* are stored in tanks (bulk lubricants) or pallets (packaged lubricants) and are shipped to national customers either directly from the manufacturing facilities (make to order) or via various decentralised storage locations / depots which store products based upon customer forecasts and predicted customer orders (make to stock).

Product distribution from the manufacturing facility or depot takes place using different modes of transport depending upon expected delivery timescales, primarily via *road* as well as *rail* infrastructure within South Africa. At the customer sites, the lubricants are used during routine maintenance of equipment and vehicles in order to ultimately prevent corrosion of internal moving parts within their operational equipment and vehicles, and as a result play a role in reducing corrosion and ultimately overall wear and tear of components.

Supply Chains are often prone to outages and bottlenecks as a result of lack of availability of raw materials and containers, manufacturing line congestion, lack of storage for finished products, limited trucks to cart finished products to depots and/or warehouses, dead/obsolete stock (incorrect inventory) at depots and/or warehouses, late/incorrect customer deliveries and excessive product returns, amongst others. These are evident in the *lubricants supply chain* and will be the subject of scrutiny of the thesis.

1.1.2 Research Methodology

Supply Chains may contain useful *knowledge assets* which might not being leveraged for decision making capability and development of core competencies within companies.

An understanding of the theory of business process definition and the underlying business processes within the overall supply chain, as well as the embedded implicit and explicit knowledge, will play an important role in providing a better understanding of supply problems and challenges evident in supply chains (e.g. lack of or incorrect forecasting, many emergency orders disrupting production schedules, raw material shortages, underutilised manufacturing lines, lack of storage space, too much of the wrong inventory).

The understanding of business processes and associated knowledge will play an important role in the alleviation of these supply problems and challenges by the effective categorisation and utilisation of knowledge assets via the process of codification and abstraction.

The knowledge assets will further be used to define measures and metrics intrinsic in the supply chain to further measure against industry benchmarks in order to highlight areas for intervention and ultimately improvement.

The research questions upon which the thesis is based on relates to the statement:

If the of types of knowledge assets that exist within supply chains are well formulated then their utilisation for a decision making capability and the creation of core competencies will be enhanced.

The core argument of the thesis relates to how information gathering (codification) and knowledge usage and application (abstraction) will lead to planning viz. forecasting and scheduling, which in turn necessitates communication (diffusion) for decision making.

The following research questions will be addressed:

- How does categorisation of measures and metrics take place in the formulation of *knowledge assets in supply chains* via the processes of *codification* and *abstraction*?
- How can a *supply chain* be measured against a benchmark to determine effectiveness in meeting sales requirements?

Codification is the process that creates conceptual and perceptual categories that facilitate the classification of phenomena. Whereas codification gives form to phenomena, *abstraction* gives form to structure. If codification allows us to save on data-processing resources by allowing us to group the data of experience into categories, abstraction allows us to realize further savings in data-processing by minimizing the number of categories that we need to draw on for a given task.[2]

The methodology to conceptualise and define how *knowledge assets* are formed and utilized within supply chains will encompass the definition of the types of *implicit* and *explicit knowledge* inherent in the *supply value chain* relating to supply chain management, inbound logistics, manufacturing and primary distribution to warehouses and depots.

[2] Boisot MH. 1995 p42-49

The methodology will further illustrate the process of formation of *knowledge assets* via the categorisation processes of codification and abstraction (based upon measures and metrics) and how they are subsequently used (diffusion) by the *supply chain management* processes of resource planning, scheduling and operational execution and control, amongst others for decision making

The definition of *business process management* depicts the underlying business processes embedded within supply chains (with the view to extracting possible *embedded knowledge assets*). The scope of business processes will include the end-to-end *supply chain processes* relating to *supply chain management* to encompass inbound logistics, manufacturing and primary distribution to warehouses and depots. It will exclude secondary distribution from warehouses and depots to customers as part of a broader order fulfilment process viz. product orders, scheduling, delivery and product returns.

The various components of the supply chain relate to the flow of materials from suppliers (internal and external) to customers. This includes definitions of:

- Resource Planning – Sales end operational planning and demand forecasting
- Scheduling – Materials and capacity scheduling
- Operational Execution and Control – Prioritisation & sequencing, executing work plans, implementing controls, reporting activity results & evaluating performance feedback

The theoretical framework will be based primarily on the Boisot Information Space[3] where knowledge assets are created via the processes of *scanning*, *problem solving*, *absorption, impacting, abstraction* and *diffusion*. Even though many of the processes in fact exist within the lubricants supply chain, to map each of the processes to the lowest level viz. procedures, will be impractical due to the limitations set out in the scope and timescales of the thesis.

The focus will be on the codification and abstraction phases within the lubricants supply chain, prior to the definition of *measures and metrics* and their overall role in decision making via *diffusion* and generation of core competencies. The theory pertaining to the thesis will be based upon business process definition and in particular business process reengineering and their inherent application within the supply chain processes, where particular knowledge is codified and abstracted as required for effective decision making.

[3] Boisot MH. 1995 p60

The focus on *business process management* requires that the inherent business processes of the *lubricants supply chain* be monitored and measured for effectiveness and efficiency. This is where business process reengineering plays an important role to streamline the functioning and operations of the business processes. Metrics and measures were defined for monitoring and measurement along with corrective action taken to improve the overall effectiveness and efficiency of the broader supply, manufacture and distribution processes of the supply chain.

The limitations of *supply chains* as mentioned above as supply problems and challenges particular to the *lubricants supply chain* will be addressed by the research in terms of the definition of the *value chain* and *business processes* along with their inherent *measures* and *metrics*.

The current state will be used for a gap analysis and related intervention initiatives in order to achieve an expected future state listed as principles of the broader business strategy e.g. reduce raw material procurement lead time, increase manufacturing throughput, reduce depot/warehouse inventory costs, reduce dead/obsolete stock, improve customer order fulfilment, etc.

The ultimate objective of the research is to show how *decision making* is enhanced via information availability for effective management of desired outcomes in the *lubricants supply chain*. The inherent business processes within the supply chain were categorised by supply, manufacture and distribution activities, each of which were dissected to determine where information is used and ultimately where knowledge is created and used for decision making.

For each of the underlying business processes various *measures and metrics* are defined and their unique characteristics extracted in terms of various differentiators (categorised by cost, quality, flexibility, reliability, service and innovation).

These are further analysed and exploited to describe how these differentiators can be used to define core competencies which enhance the uniqueness of company offerings and services beyond those of competitors.

The research methodology encompasses the investigation and analysis of the various lubricants supply chains in South Africa via site visits to the facilities as well as engagement with the role players in the broader industry, in alignment with theoretical and literature sources on the topic of *supply chains*. The site visits were used to gain an understanding of the overall *lubricants supply chain* in the broader context of *supply chain management*; where numerous decisions need to be made about product demand and forecasts, raw materials, buffer stock, manufacturing volumes, manufacturing line utilisation, inventory levels, depot product volumes, customer priority, customer delivery schedules, truck availability, etc. to ensure that customer *Service Level Agreements* (SLA's) are achieved.

The research is based on quantitative and qualitative information which was used for the analysis of measures and metrics being used to understand how knowledge assets are formed within supply chains, as well as their applicability on the *lubricants supply chain*.

The qualitative aspects will be defined and analysed using a pragmatic approach based upon experience. "Pragmatism is a combination of two main tendencies (1) On the one hand, there is the belief that experience is the starting point and the terminus for all knowledge. Most pragmatists believe that we cannot know anything beyond our experience (2) Humanity must be understood as part of the natural world, and that this includes what was taken to be the most distinctively human phenomenon: rational thought".[4]

The research is based upon literature research, experience and exposure to supply chains as well as site visits and observations. The start to the research centred primarily on literature research in order to obtain a theoretical background to supply chains and to gain a deeper understanding of the inherent processes and required business functions; encompassing supply, manufacture and distribution.

In order to understand the applicability of the concepts and processes to the *lubricants supply chain* in South Africa, various site visits and informal interviews of stakeholders were undertaken as part of a *strategic project management* role for various supply chain initiatives including procurement, manufacturing optimisation, Distribution Centre (DC) optimisation, reverse logistics (product returns) as well as engagement in customer forums.

[4] Hammersley M, 1990. P45-46

The site visits and informal interviews, in the region of twenty (20) visits over a period of five (5) years, were targeted at various companies in the *lubricants* industry, in particular their procurement departments (to investigate how supplier selection and management takes place for purchasing raw materials), lubricants blend and packaging plants as well as some of the distribution centres in the major cities in South Africa, Zimbabwe, San Francisco and UK (in order to view their operations planning, distinct operations, administration functions, decision managing and reporting requirements).

The company facilities visited were:

- Chevron/Caltex – Lubricants manufacturing plant in the Durban harbour as well as depots in South Africa, Zimbabwe, San Francisco and the UK
- Imperial Logistics – Warehouse in Wadeville (Johannesburg)
- Engen – Refinery and Lubricants blend plants in the Durban harbour viz. Zenex Blend Plant (ZBP) shared with Sasol and the Lubricants Operations Blend Plant (LOBP) as well as depots in Durban, Isando (Johannesburg) and Epping (Cape Town)
- Fuchs – Lubricants blend plant in Johannesburg
- Sachi Corporation – Blend plant in Chamdor, Krugersdorp, Johannesburg
- BRS – Bitumen Based Grease manufacturing facility in Durban
- Blendrite / Blendcor – Small independent blenders in the Durban harbour

The site visits and investigations were in conjunction with a strategic project management role in two (2) multinational oil and gas companies over the last five (5) years viz. Chevron/ Caltex/Texaco and Engen/Exxon/Mobil/Petronas Lubricants International who are prominent in the lubricants supply chain in South Africa.

For Chevron South Africa (Pty) Ltd, the role of Account Manager for Global Lubricants Africa Europe Pakistan entailed investigation and implementation of strategic projects.

For Engen Petroleum Limited, the role of Manager: Strategic Projects entailed the structuring and framing of a Supply Chain Management (SCM) programmes within the Engen Sales & Marketing division to streamline the blending, storage and distribution of lubricants & chemicals as well as various retail programmes.

The strategic project management roles included projects encompassing procurement, supply chain strategy development and implementation, manufacturing optimisation, DC optimisation, reverse logistics (product returns) and customer order fulfilment. Informal interviews were conducted with peers in other oil majors in the lubricants market viz. BP/Castrol and Shell.

The various initiatives and projects, along with detailed analysis of processes and environments, allowed the researcher to view first hand and gain exposure to how companies within the *lubricants supply chain* were planning and managing their operations and ultimately their usage of knowledge assets for day-to-day decision making. In the long run, the knowledge assets were used to formalise differentiators and core competencies, which competitors would find difficult to replicate in their own respective supply chains.

Thereafter, the researcher attended courses related to the major themes in *supply chain* and personally became involved in various diverse lubricants supply chain projects and initiatives i.e. supplier relationship management, supply chain management, demand planning, sales and marketing, forecasting, Sales and Operations Planning (S&OP), Supply Network Planning (SNP), Supply Chain Operations Reference (SCOR) model, facilities and operational management, packaging, warehousing and distribution.

This allowed the researcher to gain insight into the end-to-end operations and business functions involved in the *lubricants supply chain* and to develop case studies which depicted the project scope, business requirements, business rules and controls, structural architecture and interventions (as well as various lessons learnt). This inevitably led to the integration of the various business areas involved in the *lubricants supply chain,* ultimately the creation of an integrated lubricant supply chain with common performance measures & customer centricity metrics.

For each of the strategic initiatives and related projects, roadmaps of various *lubricants supply chains* in South Africa were constructed in order to identify gaps via formal workshops and a gap analysis per company, which will be illustrated in "Chapter 4 – The Lubricants Supply Chain" as well as "Chapter 5 – Conclusion" of the thesis to map the generic *lubricants supply chain* activities and to provide further recommendations, respectively.

A *framework* was created to depict the activities required to plan, implement and review the various activities inherent in the *lubricants supply chain*, which in turn allows for the benchmarking of lubricants supply chains against the framework. This inevitably creates a culture of measurement and continuous improvement which are evident in many of the major car manufacturing supply chains in the Far East viz. Toyota and Hyundai.

Measurement and continuous improvement has ultimately allowed these companies to implement more efficient and effective supply chains using component standardisation, better inventory management (e.g. *just-in-time* processing to reduce inventory and a systems of signals called *kanban* to minimise *work-in progress* inventory) as well as faster manufacturing turnaround; with potential cost reduction and improved customer satisfaction.

Chapter 1 provided an introduction to the thesis by providing an overview of the objectives of the thesis, an overall view of the lubricants industry as well as highlighted the research methodology followed in order to identify and analyse the intrinsic knowledge assets embedded in the *lubricants supply chain*.

The overall supply chain consists of various business processes which require deeper understanding and analysis of knowledge assets in order to achieve effective supply chain management. Chapter 2 will thus list the various components of *business process management* in order to provide a theoretical understanding of *business process* and related *value chain* concepts, along with the mechanisms to address operational deficiencies in supply chains viz. quality control and improvement, eliminate or reduce process variations, task orientation and wastage. The concepts of *measures* and *metrics* will further be defined in Chapter 2 as a basis for their identification in the *supply chain* in Chapter 3 (information gathering/codification) and further analysis of knowledge assets in the *lubricants supply chain* in Chapter 4 (knowledge usage and application/abstraction); followed by Chapter 5 for a summary of findings, conclusion, recommendations and possible future research.

Chapter 2
Business Process Management

2 Business Process Reengineering

"Business process management is itself a process that ensures continued improvement in an organisation's performance. At times, this means taking a radical change perspective, meaning that the fundamental tenets of the process are under re-examination and perhaps renewal." [5] This is referred to as *business process reengineering*. In order to understand how *business process reengineering* can be used to redefine supply chains, a definition of the term *business process* is required. Subsequently, an analysis of business processes applicable to the *lubricants supply chain* processes is performed as they pertain to the broader process categories of Supply, Manufacture and Distribution.

2.1 Business Process

A business process describes how something is done in an organization.[6]

If one then segments these terms further into *business* and *process* then we can describe:

- Business as '*an organizational entity that deploys resources to provide customers with desired products and services'*
- Process as '*a series of actions or operations conducing to an end'* [6]

Business process within the context of the *lubricants supply chain* can thus be described as the set of steps performed by the lubricants manufacturing company (organizational entity) to provide customers with desired lubricants products and services via procurement, blending, filling, packaging, storage and distribution (operations).

It consists of the following *value chain* along with associated high-level categorised (codified) business processes:

- Inbound Logistics – Procurement and storage of raw materials and packaging
- Manufacturing – Blending, Filling, Packaging and Storage operations
- Distribution – Primary Distribution to warehouses/depots and Secondary Distribution to customers

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[5] Burlton RT, 2001. p73

[6] Laguna M, 2005. p1-3

Business process reengineering will be of concern to determine how these lubricants products and services can effectively and efficiently be manufactured and thereafter distributed to customers in terms of order turnaround and delivery expectations of customers.

The following excerpt depicts why *business process definition* is crucial for the success of companies to meet customer needs and expectations in order to prevent loss of business opportunities:

> Booming competition in an increasingly global marketplace leaves no room for successful companies to harbour internal inefficiencies. Even more importantly, customers are becoming more demanding; if one product or service does not live up to their expectations, there are many more from which to choose. The stakes are high, and so is the penalty for not satisfying the right customers with the right products and services. The quest for internal efficiency and external effectiveness means that organizations must align their internal activities and resources with the external requirements, or to put it differently, business processes must be designed appropriately.[7]
>
> In these turbulent times, characterised by globalisation and increasing competition, companies are faced with challenges to become more customer driven through competitive products and services. Many organisations are experiencing poor performance and are unable to respond to competition and customers due to outdated structures, policies, procedures, rules, tall layers of management and unresponsive management systems.[8]

Upon further inspection we can deduce that *business process definition* is ultimately achieved by aligning the internal *supply chain* processes for efficiency in order to effectively meet external customer requirements and expectations (abstraction).

The following *process management* mechanisms aim to address operational deficiencies:

- Quality Control and Improvement
- Eliminate or Reduce Process Variations
- Task Orientation
- Wastage

[7] Laguna M, 2005. p1

[8] Edosomwan JA, 1996. p1

2.2 Quality Control and Improvement

In order to be more responsive organisations have to review their business processes and related procedures and actively seek to improve their overall effectiveness by quality control and improvements mechanisms.

Process management has a central role in quality control and improvement. A process is a unique set of elements, conditions, or causes that collectively produces a given outcome or set of results. The steps of a process may be classified according to the Seven M's:

- Materials – Raw materials, components or documents awaiting processing
- Manpower – The human factor; better yet, people power
- Methods – Product and process design and operating procedures
- Machines – Tools and equipment used in the process
- Measurement – Techniques and tools used to gather process performance data
- Maintenance – Machinery and equipment maintenance procedures
- Management – Policy, Work Rules and environment

Process performance (output, intended or incidental) depends on how the process has been designed, built or installed, operated, and maintained.[9]

Within the *lubricants supply chain* the Seven M's are applied to Quality Control and Improvement as follows via codification and abstraction:

- *Materials* (viz. base oil, additives and wax) are purchased in bulk and stored in tanks for later consumption in blending of bulk lubricants. Blending is performed by the mixing of raw materials using product formulation percentages as defined in a bill of material per product. The bulk lubricants are subsequently packaged into varying containers viz. 500 ml tins, 1L or 5L plastic bottles, 20L pails and 210L drums, or bulk Trucks for distribution to customers. Each container size for packaged lubricant is filled by a separate continuous manufacturing line consisting of filling, capping and shrink wrapping operations (*machines*) manned by operators (*manpower*) who apply defined operating procedures based upon product and process design standards (m*ethods*). Bulk trucks with 5 compartments of 42 kilo litres each are filled using a gantry.

[9] Schonberger RJ, Knod EM Jr, 2003. p93

Process performance is measured (m*easurement*) by the throughput of packaged lubricants across the various manufacturing lines as well as bulk lubricants via the gantry. These are measured against flow rates i.e. average number of containers filled per hour for the current month against an average for the prior month as well as the prior year (used as a benchmark of manufacturing efficiency). The actual flow rate per container in the *lubricants supply chain* is listed in Table 3.7, used as a target which is measured at the end of each month.

The manufacturing / blending and packaging environment is managed by strict operational management and safety rules governed by broader policies based upon occupational health and safety legislation (m*anagement* & m*aintenance*).

2.3 Eliminate or Reduce Process Variations

According to Schonberger and Knod, process components change over time.[10] One data-entry person replaces another, materials come from a different supplier, a machine or its cutting tool is changed, a different maintenance schedule is started, and so on. Traditional thinking was that any change automatically created a new process that had to be re-stabilised before improvement could be considered.

One aim of *Total Quality Management* (TQM), by contrast, is to make process elements easily substitutable without the burden of re-stabilization and with no negative impact on process performance. Fail safe designs, training for mastery of multiple jobs, supplier certification and toll and equipment maintenance programs support that aim. But how do we know whether a substitution has changed a process? We analyse the process output where variations are either eliminated or reduced. Quality Control mechanisms play an important role in the sampling of batches for identification of problems and their reduction and/or elimination. The batches are categorised (codification) into groups and further refined for common root causes (abstraction).

Every process output distribution is subject to two kinds of variation: variation attributable to special or assignable causes and variation attributable to natural or common causes.
Special cause variation is created by (assignable to) a certain problem, for example a machine malfunction, an incorrect tool setting, a server not following procedures, or a bad match of raw materials. Correct the specific problem and the specific variation goes away.

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[10] Schonberger RJ, Knod EM Jr, 2003. p93-96

Common cause variation (also called chance or random variation) is more difficult to trace; it is due to the multitude of small chance fluctuations that occur within the process. Common variation is usually attributed to the process as a whole.

Since less variability is a basic customer want, a process improvement team can gauge its success by observing whether process output falls:

- *Eliminate the special cause variation by eliminating the problems* – When process output distribution is free of all special cause variation, that process is said to be in a state of *statistical control*, or simply in control. Removal of special causes results in a stable, predictable process output. A process that is in control still has *common variation*.
- *Reduce the common variation* – Required actions might include product or process redesign or some other substantial investment.

Variables and Attributes – Those studying variation need process output *data*, which comes in two forms: variables data and attributes data:

- *Variables data* results from measuring or computing the amount of (or degree or value of) a quality characteristic. Variable data are continuous; any value within a given output range may occur. For the *lubricants supply chain*, variables data for Raw Materials include Inventory, Order Quantity, Order Received and Allocated.
- *Attributes data* result from classification or counting. Simpler than variables data, it doesn't require a measurement, just a classifying judgement. For the *lubricants supply chain*, attributes data for Raw Materials include Intermediate Volumes (Work In Progress) and Finished Products per Pack Size.

While attributes data are easier to collect, variables data yield more information.[11]

For the *lubricants supply chain*, special cause variation is managed by identification and resolution of problems in the blending and filling processes. For blending, typically random samples of product formulations are taken and tested in a laboratory to determine quality of product based upon formulation percentages. Adjustments are made to the mix of raw materials to achieve formulations according to required specifications. For filling, problems are recorded on the filling line and either addressed immediately or later by a special working group, depending upon severity and impact of output disruption on the filling line.

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[11] Schonberger RJ, Knod EM Jr, 2003. p93-96

The creation of problem categories (codification) and their further refinement via abstraction is used to group similar problems and interventions for speedier resolution.

Common cause variation, being more difficult to identify and remedy, is evidenced in fluctuations of output quality e.g. leaking bottle caps requiring a new capping machine or changes in container configuration. For the reduction of common variation, *business process reengineering* plays a role in redefining the underlying *business processes* for improved efficiency (line throughput) and effectiveness (product quality). Improvements ultimately result in enhanced customer satisfaction for order fulfilment and product quality expectations.

2.4 Task Orientation

The central tenet of *business process reengineering* is that organising business activities around processes rather than functions will generate significant improvements in operational effectiveness, customer satisfaction & cost reduction, thus enhancing competitive advantage. Organizing around outcomes eliminates the need for hands-off, resulting in greater speed, productivity, and customer responsiveness; and provides a single focal point of contact. This means assigning a person or a team to do a task, rather than using the traditional assembly line approach with many different people working on a task in many different steps.[12]

The major advantage of *task orientation* in the supply chain relates to the reduction of inventory between the various tasks in the supply chain, referred to as Work In Progress (WIP). "It is no longer company versus company; it's value chain versus value chain, where the average value chain may involve 20 or more discrete participants."[13]

For the *lubricants supply chain* this is evidenced by task orientation in the packaged lubricants operations categorised (codified) and segmented (abstraction) between filling, capping and shrink wrapping within each of the filling lines as sequentially interdependent operations.

[12] Tsai H, 2003. p40

[13] Smith H, Fingar P, 2003 p44

2.5 Wastage

Business Process Engineering will assist companies in gaining competitive advantage in order to improve their performance in response to competition and customers. This is achieved by streamlining their business processes to; firstly, remove w*aste i.e.* any activity, task, work element, or process that does not add value to the final output or outcome desired by an organisation or individual can be defined as waste. Wastage results in delays, increased costs, increased cycle time, decreased productivity and an increase in rework.[14]

In the context of business processes, *waste* can be defined as process steps or activities which add cost, but at no value, to the outcome of the overriding business process.

If a business process step is defined as a mechanism to transforms inputs into value-adding outputs, then the business process step has to add some value in the overall transformation procedure. This relates to steps which seek authorisation or approval from management to progress to further steps and do not add value to the overall business process and usually delays the completion of the business process.

The delaying business process steps have to be analysed to determine whether they really add value (to achieve organisational compliance to company policy) or are simply formalities that are inevitably approved and inadvertently cause delays in the successful completion of the overall business process.

Organisation transformation and process reengineering require eliminating outdated processes that affect organisational operations. Here the transformation process includes a focus on the *management system*, pertaining to the way that policies, procedures, practices, protocols, and directives are established, enforced and maintained.

The *management system* carries into effect strategies, processes and project management, and it accomplishes the vision, mission and values of the organisation.[15]

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[14] Edosomwan JA, 1996. p21

[15] Edosomwan JA, 1996. p2

2.6 Measures and Metrics

Organisation structures consist of various business units, each of which has a defined set of business systems, processes and procedures for their operational management and control. Measures and metrics are defined to enhance the management and control functions. If the performance of any system or process is not measured, it cannot be meaningfully improved. Quantitative and qualitative measures that address both objective and subjective elements should be implemented.[16]

It is in the definition of *measures and metrics* where *codification and abstraction* will take place to group and summarise both quantitative and qualitative data for better management and control of the intrinsic business processes.

Information is categorised and grouped in hierarchies for improved extraction and ultimately better decision making (via utilisation of more enhanced quantitative and qualitative information represented as groups and summaries).

2.6.1 Measures

To understand *measures* we firstly have to define measurement, performance measures, performance standards and how they can be used to monitor performance in the *lubricants supply chain*.

Measurement is the process of estimating the magnitude of some attribute of an object relative to some unit of measurement. Performance Measures must be both qualified and objective and contain at least two (2) parameters (e.g. quantity and time). Transforming company policies into objectives and specific goals creates Performance Standards, with each goal having target values.[17]

Performance Standards set the goal whereas Performance Measures indicate the closeness to the attainment of the goal. When standards are put into use, management can begin to monitor the company.[18]

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[16] Edosomwan JA, 1996. p23

[17] Nagel E, 1931. p313-335

[18] Arnold JRT, Chapman SN, Clive LM, 1998. p16

Within the *lubricants supply chain*, the measurements and measures pertain to production and throughput of the various manufacturing lines. These are in relation to expected lubricants product output and benchmarks from similar lubricant filling facilities across the globe as well as prior year outputs.

These *measures* are aligned to cumulative company goals and targets (performance standards) whereby the *lubricants supply chain* is measured against for overall performance.

The value of measures for the *lubricants supply chain* is to have benchmarks of expected output and to track them over periods of time to determine whether services are either improving or degrading over time. The measures are often mapped visually on a chart to show increasing or decreasing values over the time period, usually over the course of a year in comparison to periods the prior year. Measures in the *lubricants supply chain* include production volume throughput, product returns and customer delivery failure.

Production volume throughput is converted into cents per litre (c/l) and the monthly value shown on a graph as the year progresses, compared to the same period for the prior year.

Product returns are shown as a matrix in terms of the number and monetary value per market segment and further segmented into a 'reasons for return' category.

Customer delivery failure is measured by the number of delivery failures per thousand (1000) deliveries for the month and the monthly value shown on a graph as the year progresses, and compared to the same period for the prior year. Any significant deviations from a performance target needs to be explained and interventions put in place to reduce the impact of the deviation.

2.6.2 Metrics

A Metric is a set of ways of quantitatively and periodically measuring, assessing, controlling or selecting a person, process, event, or institution, along with the procedures to carry out measurements and the procedures for the interpretation of the assessment in the light of previous or comparable assessments.[19]

[19] Edosomwan JA, 1996. p2

A *metric* is a verifiable measure stated in either quantitative or qualitative terms defined with respect to a reference point. Metrics provide:

- Control – Management of values outside of the reference point
- Reporting – Data provision to broader internal and external supervisory entities
- Communication – Data provision to broader stakeholders
- Learning – Understanding of current values pertaining to reference point
- Improvement – Intervention to achieve the reference point

Metrics communicate expectations, identify problems, direct a course of action and motivate people.[20]

Measures and metrics are defined during the codification and abstraction processes and are subsequently monitored during ongoing operations by supervisors and middle-management. Corrective action is taken when the measures and metrics indicate any deviation from set standards.

In the lubricants supply chain, *On Time in Full (OTIF)* is used to determine the percentage of deliveries which were on time and delivery the full volume as expected by the customer.

In summary, Chapter 2 listed the various components of *business process management* in order to provide a theoretical understanding of *business process* and related *value chain* concepts, along with the mechanisms to address operational deficiencies in supply chains viz. quality control and improvement, eliminate or reduce process variations, task orientation and wastage. As the supply chain consists of various processes along with intrinsic measures and metrics, the concept of *measures* and *metrics* were defined as a basis for their identification in the *supply chain* and the further analysis of knowledge assets in the *lubricants supply chain*.

Chapter 3 will provide an overview of the supply chain and list the various supply chain processes and associated *measures and metrics* evident in the *supply chain* (information gathering/codification), with specific reference to their usage in the *lubricants supply chain* for further analysis of knowledge assets in Chapter 4 (knowledge usage and application/abstraction).

[20] Arnold JRT, Chapman SN, Clive LM, 1998. p15

Chapter 3
The Supply Chain

3 Supply Chain Processes

3.1 Overview

The following section will provide an overview of supply chains in order to provide an understanding of supply chains and the expectations of its various stakeholders, prior to a detailed analysis of processes and inherent measures and metrics via information gathering (codification) and further analysis of knowledge usage and application (abstraction).

Codification articulates and helps to distinguish from each other the categories that we draw upon to make sense of our world. The degree to which any given phenomenon is codified can be measured by the amount of data processing required to categorize it. Generally speaking, the more complex or the vaguer a phenomenon or the categories that we draw upon to apprehend it – i.e. the less codified it is - the greater the data processing effort that we will be called upon to make.[21]

Abstraction, by treating things that are different as if they were the same, reduces the number of categories that we need to draw upon in order to apprehend a phenomenon. When two categories exhibit a high degree of association – i.e. they are highly correlated – one can stand in lieu of the other. The fewer the categories that we need to draw upon to make sense of phenomena, the more abstract our experience of them.[22]

Knowledge assets can be classified along 2 dimensions; according to how far they can be given form or as a function of their degree of abstraction.[23]

Codification thus refers to categorisation of information gathered from information sources; whereas aggregation, summarisation, calculation and compilation are regarded as abstraction.

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[21] Boisot M, Canals A, MacMillan I, 2003 p7

[22] Dretske, 1981

[23] Boisot, MH. 1995 p13-14

An understanding of the *supply chain* requires answers to the following questions:

- What is a supply chain?
- How is the performance of a supply chain measured?
- How do firms achieve competitive advantage via the supply chain?

What is a supply chain?

Supply Chains encompass the companies and the business activities needed to design, make, deliver, and use a product or service.[24]

A Supply Chain is a network of facilities and distribution options that perform the functions of procurement of materials, transformation of these materials into intermediate and finished products, and the distribution of these finished products to customers.[25]

Supply Chains could consist of 3 major entities (viz. supply, production and distribution [26]) connected via the flow of materials as follows:

- Manufacturing Demand – Manufacturers either receive or predict (*forecast*) customer orders for the manufacture of goods, which in turn leads to orders being placed upon suppliers of components or component goods for procurement.
- Suppliers to Manufacturers – Suppliers manufacture components which are used as input to the overall manufacturing process of producing commodity goods.
- Manufacturers to Customers – Manufactured commodities are despatched to Customers via a Distribution System using various modes of transport for associated carriers of either bulk or packages products.

For the *lubricants supply chain*, the high-level supply is managed by the procurement of packaging and raw materials (including base oils, polymers, wax and additives) from suppliers for their manufacture (blending, filling, packaging and storage) into the finished products which are distributed to customers as either bulk in tankers or packaged lubricants. The raw materials are codified from various product types e.g. Group I, II and II for abstraction as Base Oils. Similarly, manufacture is codified from various manufacturing types e.g. Diesel Lubricants Blending, Automatic Transmission Fluid (ATF) Blending for abstraction as Blending.

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[24] Hugos M, 2003. p1

[25] Ganeshan R, Harrison TP, 1995.

[26] Arnold JRT, Chapman SN, Clive LM, 1998. p5

How is the performance of a supply chain measured?

The goal or mission of supply chain management is to 'increase throughput while simultaneously reducing inventory and operating expense'[27]

Factors which influence the profitability of the organisation (and inevitably the operations of the Supply Chain) include Customer Service, Production, Inventory and Distribution.

In order to achieve most profit, a company must have at least the following objectives:

- Best Customer Service – Cost, quality, flexibility, reliability and innovation
- Lowest Production Costs – Low manufacturing throughput and cents per litre (c/l) costs
- Lowest Inventory Investment – Low buffer inventory and associated holding costs at warehouses and/or depots
- Lowest Distribution Costs – Low *primary distribution* (transhipping) costs from manufacturing plants to warehouses/depots as well as *secondary distribution* to customers

These require trade-offs between the marketing, production and finance departments as they have different objectives in conflict with one another. Marketing's objective is to maintain and increase sales and revenue; it must provide the best customer service possible which can further be defined as lowest cost, highest quality, flexibility of orders and product offering, reliability of products and services as well as innovation (as a differentiator of services to customers to gain competitive advantage).

The ability to respond flexibly by customising processes can create considerable competitive advantage.[28] There are several ways of doing this: (1) Maintain high inventories so goods are always available to the customer which has an impact on inventory investment and holding costs as well as the management of slow moving, dead and obsolete stock due to the limited shelf life and expiration of products. (2) Interrupt production runs so that a non-inventories item can be manufactured quickly as emergency orders (having an impact on start-up costs of manufacturing lines and ultimately economies of scale and production throughput). (3) Creating an extensive and costly distribution system so that goods can be shipped to the customer rapidly in terms of customers' needs and expectations, with smaller uneconomical quantities per shipment to the customer.

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[27] Goldratt E, 1984.

[28] Smith H, Fingar P, 2003 p56

Finance must keep investment and costs low by reducing inventory so inventory investment and holding costs are at a minimum, decrease the number of plants and warehouses in the distribution network and as a result reduce investment and associated capital outlays, produce large quantities of products using long production runs to achieve better economies of scale and to manufacture only to customer order (make to order) with no safety/buffer stock on hand to service future orders.

Production must keep operating costs as low as possible by making long production runs of relatively few products (fewer changeovers will be needed and specialised equipment can be used, thus reducing the cost of making the product), maintain high inventories of raw materials and work-in-process inventory so that production is not disrupted by shortages.[29]

Each of these departments has embedded *measures* and *metrics* which will be the subject of *codification* and *abstraction* for operational management and control. These will be explored in the subsequent sections of the thesis in relation to the *lubricants supply chain*.

How do firms achieve competitive advantage via the supply chain?

Considering the overall objectives of *Supply Chain Management* (SCM) of creating value for customers, and competitive advantage and improved profitability for supply chain firms, the dimensions of value that may be important to customers and the mechanisms whereby competitive advantage and improved profitability can be achieved for supply chain members concluded that the means to achieve *competitive advantage* is through creating value for downstream customers greater than that offered by competitors. Customer value is created through collaboration and cooperation to improve efficiency (lower cost) or market effectiveness (added benefits) in ways that are most valuable to key customers. Since the value (perceived as important) will differ across customer segments, a firm must identify the customer segments important to its' long term success and match the capability of the firm to delivering value important to key customers. By satisfying customers and achieving competitive advantage, firms in a supply chain influence customers to make choices and behave in ways that improve the financial performance of the supply chain and the firms within it.[30]

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[29] Arnold JRT, Chapman SN, Clive LM, 1998. p9

[30] Mentzer J, 2004. p7

A supply chain strategy involves many inter-locking facets and hundreds of decisions, large and small. *Fit* highlights the notion where a group of activities all support a chosen competitive strategy.[31]

Any single activity can be copied but taken together they form a system that is virtually impossible to duplicate. The same concept is applicable to *supply chain strategy*. Taken together, the choices you make create a supply chain which is uniquely yours, and tough for other to replicate. That's a source of Competitive Advantage.[32]

Traditionally, marketing, distribution, planning, manufacturing, and the purchasing organizations along the supply chain operated independently. These organizations have their own objectives and these are often conflicting. The marketing objective of high customer service and maximum sales dollars conflicts with manufacturing and distribution goals. Many manufacturing operations are designed to maximize throughput and lower costs with little consideration for the impact on inventory levels and distribution capabilities. Purchasing contracts are often negotiated with very little information beyond historical buying patterns. The result of these factors is that there is not a single, integrated plan for the organization; there were as many plans as businesses. Clearly, there is a need for a mechanism through which these different functions can be integrated together. Supply chain management is a strategy through which such integration can be achieved.[33]

There are four major decision areas in supply chain management: location, production, inventory and transportation (distribution):[33]

Location decisions are the geographic placement of production facilities, stocking points and sourcing points is the natural first step in creating a supply chain. The location of facilities involves a commitment of resources to a long-term plan. Once the size, number, and location of these are determined, so are the possible paths by which the product flows through to the final customer. These decisions are of great significance to a firm since they represent the basic strategy for accessing customer markets and will have a considerable impact on revenue, cost, and level of service. Transport is used to bridge distances due to location advantages.

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[31] Porter M, 1996

[32] Cohen S, Roussel J, 2005. p35

[33] Ganeshan R, Harrison TP, 1995.

Production decisions are the strategic decisions that include what products to produce, and which plants to produce them in, allocation of suppliers to plants, plants to distribution centres, and distribution centres to customer markets. As before, these decisions have a big impact on the revenues, costs and customer service levels of the firm. Another critical issue is the capacity of the manufacturing facilities; and this largely depends on the degree of vertical integration within the firm.

Operational decisions focus on detailed production scheduling. These decisions include the construction of the master production schedules, scheduling production on machines and equipment maintenance. Other considerations include workload balancing and quality control measures at a production facility.

Inventory decisions refer to means by which inventories are managed. Inventories exist at every stage of the supply chain and are categorised into inventory types via codification and further abstraction as either raw material, semi-finished or finished goods. They can also be in-process between locations.

Their primary purpose is to buffer against any uncertainty that might exist in the supply chain. Since holding of inventories can cost anywhere between 20 to 40% of their value, their efficient management is critical in supply chain operations. These include deployment strategies (push versus pull), control policies; the determination of the optimal levels of order quantities and reorder points, and setting safety stock levels, at each stocking location. These levels are critical, since they are primary determinants of customer service levels.

Transport decisions are the mode choice aspect of these decisions and are the more strategic ones. These are closely linked to the inventory decisions, since the best choice of mode is often found by trading-off the cost of using the particular mode of transport with the indirect cost of inventory associated with that mode. Various types of transport are categorised via codification and grouped together via abstraction as Road, Pipeline, Rail, Sea and Air. Companies may choose a variety of modes depending on their ultimate value as well as reliability. While air shipments may be fast, reliable, and warrant lesser safety stocks, they are expensive. Meanwhile shipping by sea or rail may be much cheaper, but they necessitate holding relatively large amounts of inventory to buffer against the inherent uncertainty and sometimes unreliability associated with them.

Customer service levels and *geographic location* play vital roles in such decisions. Since transportation is more than 30% of the logistics costs, operating efficiently makes good economic sense. Shipment sizes (consolidated bulk shipments vs. lot-for-lot i.e. split loads for delivery to multiple end points), routing and scheduling of equipment are key in effective management of the firm's transport strategy.

The decisions made to create the *lubricants supply chain* are a source of *competitive advantage*. These decisions including the creation of customer segments based upon value, product portfolio per customer segment, raw materials to be used in blending of lubricants products, suppliers of raw materials, manufacturing lines to be built for particular packaging configurations, packaging suppliers and a common bottling footprint, distribution centres and distribution channels / modes of transport, amongst others. The percentage of make to stock, configure to order and make to order is unique to the particular lubricants supply chain, usually "60/20/20" [34] as a benchmark for the chemicals / pharmaceuticals industry.

Next generation supply chain strategies will support continuing improvements in productivity but will also drive the achievement of business-level outcomes, with a strong focus on the customer. It will be important in the future to identify these objectives, which will include new revenue generating services and time-to-market, time-to-volume and customer segment-specific capabilities.[35]

For the *lubricants supply chain* the new revenue generating services and their time-to-market before competitors will be crucial to retain loyal customers by offering unique *value-added services* which competitors cannot easily replicate (e.g. customer stock management systems linked to stock saving volume targets). Examples of these unique offerings and services include in the lubricants industry in South Africa include consignment stock (Shell), Oil-On-Tap kiosks (Engen), outsource logistics (BP/Castrol), joint ventures with other oil companies (Sasol/Engen) and joint ventures with customers (Total/Colas). Time-to-volume can be achieved via reduction of *order-to-billing* turnaround times with a dedicated truck fleet for the larger market sectors consuming large amounts of lubricants (including the automotive and mining sectors). Customer segment-specific capabilities will be beneficial to further entrench customer loyalty in these sectors. An example will be to offer technical support for effective turbine maintenance in order to reduce wear and tear for cement factories.

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[34] Cohen S, Roussel J, 2005. p12

[35] Cohen S, Roussel J, 2005. p36

3.2 Materials Management

3.2.1 Overview

Materials management is defined as the coordination function responsible for planning and controlling materials through the *supply*, *production* and *distribution* focus areas including manufacturing planning and control i.e. planning and control of the flow of materials through the manufacturing process, and *physical supply / distribution* i.e. all activities involved in moving goods, from the supplier to the beginning of the production process, and from the end of the production process to the consumer.

Manufacturing planning and control includes:

- *Production Planning* – Planning the production function to meet the demand of the marketplace by establishing priorities with matching capacity via forecasting, master planning, materials requirements planning and capacity planning.
- *Implementation and Control* – The action of production plans via production activity control and purchasing.
- *Inventory Management* – Inventories are materials and supplies carried on hand either for sale or to provide materials or supplies to the production process. They provide a buffer between demand and production.[36]

The *lubricants supply chain* has distinct *manufacturing planning and control* along with *physical supply / distribution* systems which includes both bulk and packaged raw materials which feed into the *manufacturing* process as well as bulk and packaged lubricants products for distribution to customers (determined by codification and abstraction of bulk or packaged raw materials and products).

Bulk raw materials and products are stored in storage tanks as *inventory* based upon the expectations of *sales forecasts* and the resulting *production plan*, along with *buffer / safety stock* for use during times of shortages of imported raw materials. The packaged raw materials are stored in 210L drums or tanks, and the packaged products for distribution to customers in various container sizes viz. 500 ml tins, 1L or 5L plastic bottles, 20L pails and 210L drums.

[36] Arnold JRT, Chapman SN, Clive LM, 1998. p13

The *lubricants supply chain* necessitates a forecast and resulting *production plan* of products for impending customer orders, to be available at various depots throughout South Africa for subsequent delivery.

If market intelligence and associated *sales forecasts* (depicting expected product availability to the market and customers) deviate significantly from actual demand placed on manufacturing, then forecast accuracy for product family groups need to be calculated and considered in the creation of the *production plan*.

If forecast accuracy for a particular product family group is historically low then a factor needs to be added to the *production plan* for the particular product group until such time as forecast accuracy improves, typically beyond a target of 80% accuracy. Seasonality needs to be considered and forecast accuracy for the same period in the prior year is also a factor when adjusting the forecast based upon forecast accuracy.

The level of *buffer / safety stock* to safeguard against product stock-outs also needs to be taken into consideration in the *production plan*. Each product group will have a defined level of *buffer / safety stock* which needs to be available at either the manufacturing plant or warehouse/depot, sometimes even at the customer site for scarce products e.g. wire rope lubricants which requires oxidised bitumen (which in turn is a scarce product in South Africa due to the older refinery configurations in the South African market where bitumen is treated as a by-product of crude oil refining).

Manufacturing includes processes, machinery, equipment, labour skills and material; each of which has to be organised to make the 'right goods at the right time as economically as possible'. A good *planning and control system* is required as it is complex to determine which products to make, which facilities to use, what currently exists and what is needed.

A consideration of *priority* (demand) and *capacity* (resources), and how to resolve conflict between them is required. Priority indicates what products are needed, how many and when whereas capacity refers to the manufacturing capability to produce the goods and services required, which in turn depends upon available machinery, labour and financial resources as well as the availability of material from suppliers.

For the *lubricants supply chain*, building additional capacity for manufacturing is a long term process, typically 2 years or more depending on the design of manufacturing line(s). The build of manufacturing line(s) requires significant capital outlays after a feasibility study and subsequent approval of a business case as justification.

One of the legislated pre-requisites before building new lubricants manufacturing line(s) is an Environmental Impact Assessment (EIA) which can take 12-18 months for approval by the legislative authorities in South Africa i.e. Department of Water Affairs.

The *manufacturing planning and control system* consists of the strategic business plan, production plan, master production schedule, master requirements plan and purchasing and production activity control. Codification will take place during information gathering for the various plans, abstraction for the creation of the plans and diffusion for the communication and implementation and tracking/monitoring of plans along with decision making for managing interventions as required e.g. emergency orders, overtime, etc.

Each of these levels varies in the degree of time span and detail as follows:

- Business Plan – The goals and objectives the company expects to achieve within a longer time horizon. It depicts the broad direction of the firm and shows the type of business the firm wants to do in the future.
- Production Plan – Satisfies market demand based upon the available resources of the company by indicating quantities of each product group to be produced in each period, resources required (equipment, material and labour) in each period and their availability.
- Master Production Schedule – Quantity of end items (models) per period, dependent upon the manufacturing and purchasing lead times.
- Materials Requirements Plan – Production and purchase of components used in making the end items, depicting quantities needed and when required in manufacturing.
- Purchasing and Production Activity Control – Purchasing is required to establish and control the flow of raw materials into the manufacturing process, whereas production activity control is responsible for planning and controlling the flow of work.[37]

Knowledge can be conceptualised as a set of probability distributions held by an agent and orienting his or her actions.[38] The creation of the knowledge assets depends upon accurate and reliable information for the creation of the various plans and schedules. For example, forecasting not only depends on information but also knowledge of the knowledge agent.

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[37] Arnold JRT, Chapman SN, Clive LM, 1998. p15

[38] Boisot, MH. 1995 p12

Each of the activities as depicted in Figure 3.1 below will be defined in terms of the *lubricants supply chain* in the subsequent sections of the thesis.

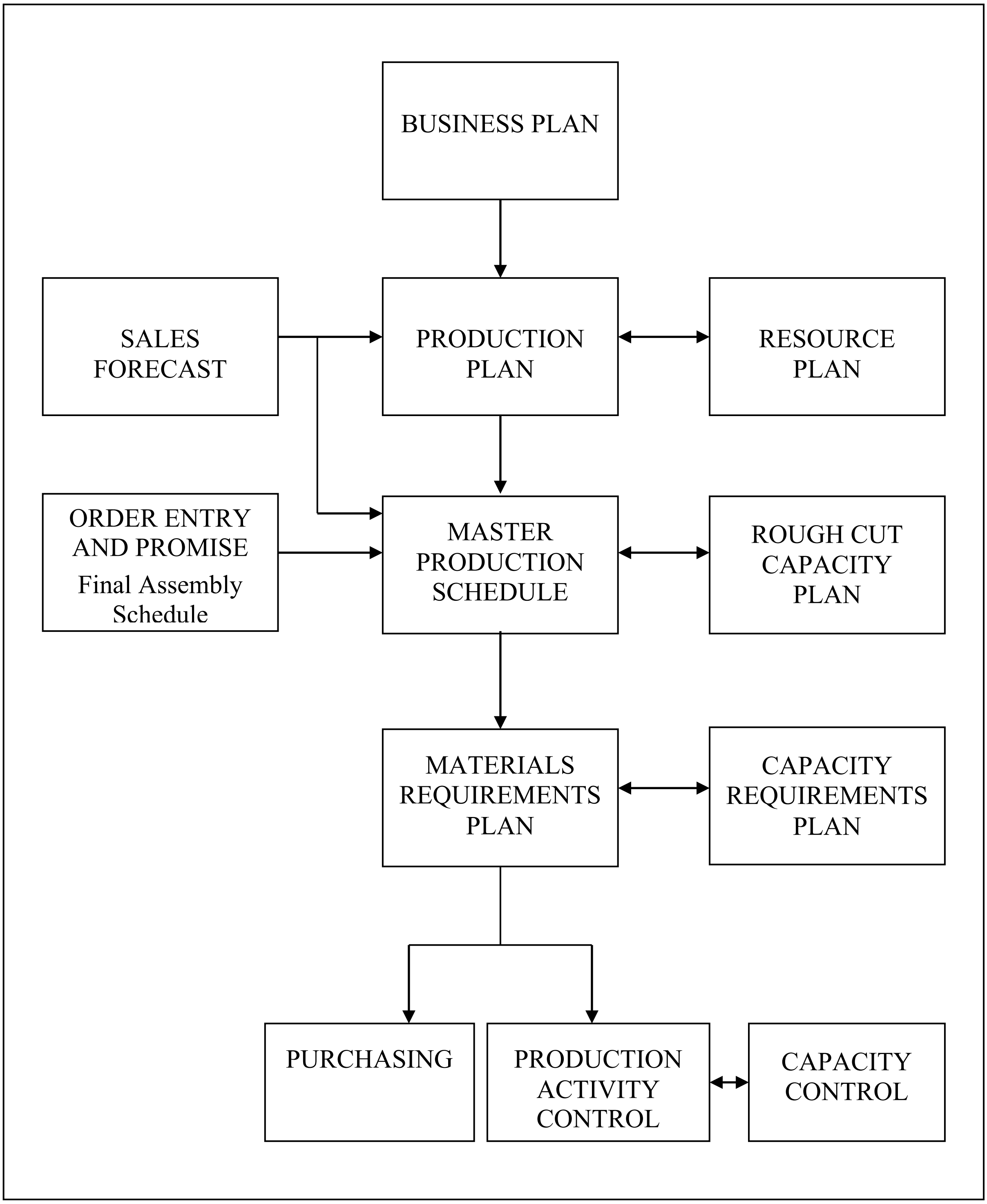

Figure 3.1: Materials Management

Source: Arnold JRT, Chapman SN, Clive LM, 1998.

3.2.2 Production Plan (PP)

The *production plan* is the formal plan of where the company is going, created by senior management. The main inputs are the forecast or marketing plan, long term or strategic plan and the budget or financial plan. The *production plan* is defined in family groups and in course time periods (months or quarters). It is the executive's plan stating the agreed volume, per family, per period. It is the management's plan for the master scheduler to turn into a manufacturing plan. The purpose of the production plan is to provide the means of comparing the resources available against those required, out into the future. If the resources do not match the requirements, adjust the plan or increase the resources.[39]

For the *lubricants supply chain* the families of products will be categorised (codified) based upon similar product characteristics and input raw materials e.g. diesel lubricants which is a family of products for usage on diesel driven cars and power oil which is the family of products which includes both inhibited power oil (with an additive to be added) and uninhibited power oil (no additive).

An example of a *production plan* in the *lubricants supply chain* is depicted in Table 3.1 (weeks run from Sunday to Saturday i.e. week 1 runs from Sunday 1 July to Saturday 7 July): Month: July 2012

Manufacturing Line No.	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**
1.	Automotive Lubricants	Automotive Lubricants	Automotive Lubricants	Automotive Lubricants	Automotive Lubricants
2.	Diesel Lubricants	Diesel Lubricants	Diesel Lubricants	Diesel Lubricants	Power Oil
3.	Industrial Lubricants	Industrial Lubricants	Industrial Lubricants	Industrial Lubricants	Railroad Oils
4.	Open Gear Lubricants	Open Gear Lubricants	Open Gear Lubricants	Open Gear Lubricants	Chainsaw Lubricants

Table 3.1 – Production Plan

Source: compiled by researcher

The *production plan* is the result of gathering of product orders and forecasts (codification) and grouping them into families of products filled on a common manufacturing line (abstraction). The information is used to compile the production schedules of the various manufacturing lines for subsequent tracking (diffusion).

[39] Willcox B. p35

If resources are not available to fulfil the plan, the plan will be adjusted as specialised resources are not easily added to the lubricants supply chain. An increase in human resources can be achieved via overtime in the short term, but this is not preferable as safety compromises may result in the long run due to fatigue of employees who are operating hazardous products and equipment.

It is more costly to change the production quantity of items produced than the kind of items produced because to adjust the production rate one needs to hire extra labour, pay overtime or fire labour as needed.[40]

Strategies to develop the Production Plan include:

- Chase Strategy – Producing the amounts required at any given time (resulting in peaks and troughs). Inventory can be kept to a minimum.
- Production Levelling – Continually producing an amount equal to the average demand (resulting in a smooth level of operations). No excess capacity is required to meet peak demand, although an inventory build-up will occur in low-demand periods.
- Subcontracting – Producing at the level of minimum demand and meeting additional demand via subcontracting.[41]

Each strategy has its own costs pertaining to equipment, hiring/layoff, overtime, inventory and subcontracting. *Production management* has to find a combination of the strategies to minimise the costs, provide required service levels and to meet the objectives of the *financial* (including capital and operating expenditure) and *marketing plans* (product availability at the right place and the right price).[41]

The *production planning* is usually done at aggregate level, both for products and resources. Distinct but similar products are combined into aggregate product families that can be planned together to reduce planning complexity. Similarly, production resources such as distinct machines or labour pools are aggregated into aggregate machine/labour resources. [42]

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[40] Daganzo CF. p152

[41] Arnold JRT, Chapman SN, Clive LM, 1998. p32-35

[42] Graves SC, 1999. p4

The *aggregate plan* becomes the framework within which short term decisions are made about production, inventory and distribution. Production decisions involve setting parameters such as the rate of production and the amount of production capacity to use, the size of the workforce, and how much overtime and subcontracting to use. Inventory decisions include how much demand will be met immediately by *inventory on hand* and how much demand can be satisfied later and turned into backlogged orders.[43]

The aggregation of Machines and Labour for the lubricants supply chain relates to the *product capacity* to be blended in blending kettles irrespective of pack type; prior to their filling, capping and sealing into the distinct product containers per manufacturing line.

The measure for Production Planning is Production[44] per Period and the metric is Ending Inventory in each period:

⇨ *Production per Period = (Production + Ending Inventory – Opening Inventory) / No. of Periods*

⇨ *Ending Inventory = Opening Inventory + Production – Demand*

An example of *production planning* for Diesel Lubricants in the *lubricants supply chain* is depicted in Table 3.2:

Manufacturing Line: #2 (210 litre drums with capacity of 3200 drums per week)						
Opening Inventory: 500 drums (buffer/safety stock 1000 drums)						
Monthly Forecast: 10000 drums						
Forecast Accuracy: 60% prior month, 80% month last year (target 90%, avg. variance 20%)						
Month: July 2012						
Period		**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**
Forecast		2500	2500	2500	2500	0
Forecast + 20% Variance		3000	3000	3000	3000	0
Production		3200	3200	3200	3200	3200
Ending Inventory	500	700	900	1100	1300	1300

Table 3.2 – Production Planning

Source: compiled by researcher

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43 Hugos M, 2003. p54

44 For the Production Plan, production is categorised as the annual forecast product whereas for the MPS, production is categorised as the Annual Product per Pack Size seen as separate Finished Products categorised as separate SKU in terms of Inventory Management

In the *lubricants supply chain,* various lubricants products are blended in kettles i.e. heated tanks, where various raw materials from tanks and drums are injected into the blending kettle based upon an aggregated product formulation, known as a *Bill of Material* (BoM). From the blend kettles they are fed into a particular manufacturing line.

Production levelling per manufacturing line is used as the strategy to produce the *production plan* segmented into a *product family* via categorisation. The assumption is that product group running on a particular manufacturing line will fill a particular container (viz. 500ml Cans, 210 litre drums, 20 litre pails and 5 litre bottles) where each manufacturing line has a particular capacity.

Each package size and capacity has a distinct continuous manufacturing line to fill, cap and seal product containers prior to their storage in a high-rise warehouse; from where they will be distributed to depots (primary distribution) and thereafter to customers (secondary distribution).

3.2.3 Master Production Scheduling

After *production planning*, the next step in the *manufacturing planning and control* process is to prepare a *master production schedule* (MPS).

The MPS is an anticipated build schedule for manufacturing end products or product options. It is a statement of production. It represents what the company plans to produce in terms of models, quantities and dates. It takes into account the demand forecast, the aggregate production pan, backlog, availability of material and capacity.[45]

The MPS:

- Is the link between *production planning* and what manufacturing will actually build
- Is the basis for calculating the *capacity* and *resources* needed
- Drives the *materials requirements plan*. As a schedule of items to be built, the MPS and bills of material determine the components required from manufacturing and purchasing
- Keeps priorities valid. The MPS is a priority plan for manufacturing[46]

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[45] Swamidass PM, 2000. p460

[46] Arnold JRT, Chapman SN, Clive LM, 1998. p49-50

The MPS for the *lubricants supply chain* is based upon a sales forecast, customer orders and depot demand where items are subtracted based upon inventory, purchase orders and work orders (codification). Net requirements are calculated and a determination is made of when the finished products will be required for blending and filling (abstraction). The blending of lubricants products in blending kettles in terms of the requirements of the *production plan*, *forecast* of individual products and *inventory*, in conjunction with the capacity of the manufacturing lines.

Depot stock management needs to be a focus of the *lubricants supply chain* ito the above categories as their impact on the MPS is significant.

One of the challenges in the *lubricants supply chain* is to manage underutilised stock at the depots which has a direct impact on the MPS and Depot Demand, categorised as follows:

- Slow Moving Stock – Inventory at a particular depot which is not being sold to customers serviced from the depot but is required by customers being serviced from another depot
- Dead Stock – Inventory at a depot is being sold to customers serviced from the depot but in small quantities but is required by customers being serviced from another depot
- Obsolete Stock – Inventory at a particular depot which is beyond expiry and cannot be sold to customers

For slow dead stock and slow moving stock, the manufacturing plant may be scheduling the manufacturing of products for a particular depot ito forecast for the customers serviced by the depot, but the inventory may be available at other depots. Inventory holding costs, transport costs and turnaround time should be a consideration based on the proximity of the depots to each other when deciding to move inventory between depots for plant to plant transfers.

For obsolete stock where viscosity has degraded, expiry needs to be managed and the stock returned to the manufacturing plant to be reworked (i.e. re-blended into other lower-grade lubricants based upon their viscosity) or sold to third parties which use the lubricants as fuel oil in furnaces.

The MPS determines what the company will expect to manufacture (blending and filling) based upon a target (business plan) and constraints (mainly budget and lubricants manufacturing capacity).

The master scheduled items are crucial for determining the impact on lower level resources viz. labour and filling machines as well as raw materials (additives, base oils and packaging).

Whereas the *production plan* deals in families of products, the *MPS* works with end-items. It breaks down the *production plan* into the requirements for individual end-items, in each family by date and quantity. The objective is to balance the demand (priorities) set by the marketplace with the availability of materials, labour and equipment (capacity) of manufacturing. The end-items made by the company are assembled from components and sub-component parts. These must be available in the right quantities at the right time to support the MPS. The *materials requirements planning system* plans the schedule of these components based upon the needs of the MPS.[47]

Once the *production planning* per product group and the *production plan* is compiled, the next step is to forecast demand for each of the items in the product family. The master scheduler then devises a plan as a possible iterative solution to fit the constraints.
An example of *forecast demand*, *master schedule* and *inventory* for Diesel Lubricants items in the *lubricants supply chain* is depicted in the Table 3.3, Table 3.4 and Table 3.5 for the month July 2012:

Opening Inventory: Diesel Lube 700 Super (250 drums) Diesel Lube 500 (150 drums) Winter Diesel Lube (100 drums)					
Period	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Total**
Diesel Lube 700 Super	2000	1500	1500	1500	6500
Diesel Lube 500	1000	1000	1000	1000	4000
Winter Diesel Lube (WDL)	0	500	500	500	1500
Total	3000	3000	3000	3000	0

Table 3.3 – Forecast Demand

Source: developed by researcher

Forecast Demand is the result of gathering of forecasts for various products by week (codification) and allocating them to manufacturing lines based upon packaging configurations e.g. drums allocated to manufacturing line 1 (abstraction). The information is used to compile the master schedules and inventory plans depicted below (diffusion).

47 Arnold JRT, Chapman SN, Clive LM, 1998. p49-50

Solution 1					
Period	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Total**
Diesel Lube 700 Super	3200	3200			6400
Diesel Lube 500			3200		3200
Winter Diesel Lube (WDL)				3200	3200
Total					12800
Solution 2					
Period	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Total**
Diesel Lube 700 Super	3200		3200		6400
Diesel Lube 500		3200			3200
Winter Diesel Lube (WDL)				3200	3200
Total					12800

Table 3.4 – Master Schedules

Source: developed by researcher

Inventory 1				
Period	**Week 1**	**Week 2**	**Week 3**	**Week 4**
Diesel Lube 700 Super	1450	3150	1650	150
Diesel Lube 500	(850)	(1850)	350	(650)
Winter Diesel Lube (WDL)	100	(400)	(900)	1800
Total				
Inventory 2				
Period	**Week 1**	**Week 2**	**Week 3**	**Week 4**
Diesel Lube 700 Super	1450	(50)	1650	150
Diesel Lube 500	(850)	1350	350	(650)
Winter Diesel Lube (WDL)	100	(400)	(900)	1800
Total				

Table 3.5 – Inventory

Source: developed by researcher

The challenge for the master scheduler in the *lubricants supply chain* is to minimise backlogs as evidenced by negative inventory.

The information needed to develop a MPS is the production plan (product families), forecast (individual products / end items), customer orders / stock replenishment, inventory levels and capacity constraints.[48]

The information gathered for the compilation of the MPS will be either static (master data) or dynamic (transactional data) as required for the MPS. Product families and capacity constraints of manufacturing lines will be static whereas opening inventory, forecasts and customer orders / stock replenishment are dynamic and will be categorised and summarised by week. This is where codification and abstraction takes place in the gathering of reliable information and their further categorisation.

The objectives in developing an MPS are to maintain the desired level of customer service by maintaining finished goods inventory levels or by scheduling to meet customer delivery requirements, to make the best use of material, labour and equipment; and to maintain inventory investment at the required levels. To reach these objectives, the plan must satisfy customer demand, be within the capacity of manufacturing, and be within the guidelines of the production plan.[48]

The creation of the MPS requires balancing the requirements from customers, as forecasts or orders, against the capacity from manufacturing within the objectives of the production plan. The is achieved by the development of a *preliminary MPS, c*hecking the preliminary MPS against *available capacity and r*esolve differences with capacity available.

The preliminary MPS determines when a manufacturing lot is to be manufactured based upon a shortfall of *product availability* (i.e. inventory – forecast demand) for each period where *forecast demand* is greater than *product availability*.[48]

For the *lubricants supply chain*, a preliminary MPS determines when particular lubricants *product group* should be blended and filled based upon the *forecast demand* where insufficient *inventory* / *projected availability* will be available to satisfy the demand. The lot size is the capacity of the manufacturing line in a shift. In the examples listed, for Manufacturing Line 2 it will be 3200 drums per 8 hour shift.

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[48] Arnold JRT, Chapman SN, Clive LM, 1998. p49-53

The measure for Preliminary MPS is Projected Available and the metric is MPS per period:

⇨ *Projected Available per Period = (Inventory of prior period – Forecast Demand)*

⇨ *MPS per Period = Manufacturing Lot where Projected Available is negative*

An example of a *preliminary MPS* for Diesel Lube 700 Super in the *lubricants supply chain* is depicted in Table 3.6 below:

Manufacturing Line: #2 (210 litre drums with capacity of 3200 drums per week)

Opening Inventory: 250 drums

Monthly Forecast: 14000 drums

Forecast Accuracy: 60% prior month, 80% month last year (target 90%, avg. variance 20%)

Month: July 2012

Period		**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Total**
Forecast		2000	1500	1500	1500	6500
Projected Available	500	1450	3150	3000	1500	
MPS		3200	3200			6400

Table 3.6 – Preliminary MPS

Source: developed by researcher

For the Preliminary MPS, the *forecast* is obtained and categorised from sales (codification) and the *projected available* and *MPS* is calculated per week (abstraction). The information is used to check the available capacity per manufacturing line (diffusion).

ROUGH-CUT CAPACITY PLANNING

Once the Preliminary MPS is made, they must be checked against the *available capacity* per *work centre*. Rough-Cut capacity planning checks whether critical resources are available to support the preliminary master production schedules. Critical resources include bottleneck operations, labour and critical materials (due to scarcity or long lead times).[49]

One of the problems the master scheduler has when converting the production plan into the MPs is to have a practical balanced schedule. Rough-Cut capacity planning is the capacity check module for the MPS. It analyses the resources required by the MPS and uses *load profiles* (bills of resources) for critical resources.[50]

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[49] Arnold JRT, Chapman SN, Clive LM, 1998. p54

[50] Willcox B, 2008. p3/40

For the *lubricants supply chain*, the resources for the product blending as well as the operations of the manufacturing lines are checked for availability to produce the expected *products per pack size* (product model). This requires reliable information supported by a knowledge base.

The *resource bill* is the sum of the blending and filling operations for all required products per pack size.

The measure for Rough-Cut Capacity Planning is Assembly Time per Product Model and the metric is the Resource Bill:

⇨ *Assembly Time per Product Model = (No. x Build Time of Product Model)*

⇨ *Resource Bill = sum (Assembly Times per Product Model)*

Assembly time per product model in the lubricants supply chain depends on which manufacturing line will be used as listed in Table 3.7 below:

Manufacturing Line	**Benchmark**	**Daily Units**	**Daily Volume (Litres)**	**Weekly Units**	**Weekly Volume (Litres)**	**Monthly Units**	**Monthly Volume (Litres)**
500ml Cans	300 Cans per min.	144,000	72,000	720,000	360,000	2,880,000	1,440,000
210 Litre drums	80 drums per hour	640	134,400	3,200	672,000	12,800	2,688,000
20 Litre pails	200 pails per hour	1,600	32,000	8,000	160,000	32,000	640,000
5 Litre Bottles	1500 Bottles per hour	12,000	60,000	60,000	300,000	240,000	1,200,000

Table 3.7 – Manufacturing Capacity

Source: developed by researcher

For example, based on the example in Table 3.4 we can calculate the Resource Bill for Diesel Lubricants assuming it is the only product family group being manufactured using the assembly time per product model:

- Diesel Lube 700 Super – 6400 drums / 80 drums per hour = 80 hours
- Diesel Lube 500 – 3200 drums / 80 drums per hour = 40 hours
- Winter Diesel Lube – 3200 drums / 80 drums per hour = 40 hours
- Resource Bill

  = sum (Assembly Time per Product Model for Diesel Lubricants)

  = Assembly Time Diesel Lube 700 Super + Diesel Lube 500 Super + Winter Diesel Lube

  = 80 + 40 + 40 = 160 hours

The resource bill is used to determine the required capacity for manufacturing (diffusion).

RESOLUTION OF DIFFERENCES

For the resolution of differences, compare the total time required to the available capacity of the work centre. If available capacity is greater than the required capacity (resource bill), the MPS is workable, otherwise methods of increasing capacity have to be investigated (overtime, extra workers, rerouting or sub-contracting).[51]

For the *lubricants supply chain*, emergency orders placed on the manufacturing plant i.e. orders not forecast but have to be manufactured, renders the MPS unworkable. The common mechanism to increase *capacity* is overtime, as external manpower resources for the product blending and operations of the manufacturing lines are not readily available to supplement the workforce due to the specialised nature of work.

Once the MPS is in place commitments to customers can be made using available to promise and projected available balance:

AVAILABLE TO PROMISE

In a *make-to-stock* environment, customer orders are satisfied from *inventory*. However, in a *make-to-order* environment, demand is satisfied from production capacity. In either case, sales and distribution need to know what is available to satisfy customer demand. Since demand can be satisfied either from *inventory* or from *scheduled receipts*, the MPS provides a plan for doing either. As orders are received they "consume" the *available inventory* or *capacity*. Any part of the plan that is not consumed by actual customer orders is available to promise to customers. In this way, the MPS provides a realistic basis for making delivery promises. Using the MPS, sales and distribution can determine the *Available to Promise* (ATP) i.e. that portion of a firm's inventory and planned production that is not already committed and is available to the customer. This allows delivery promises to be made and customer orders and deliveries to be scheduled accurately.[51]

For the *lubricants supply chain*, demand is satisfied both from *inventory* and *production capacity* in a mix between *make-to-stock* and *make-to-order* as characterised by the broader lubricants industry. If a stock-out occurred the *available inventory* will be negative in lieu of an unfulfilled order for consideration. Emergency orders are added to orders as they occur.

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[51] Arnold JRT, Chapman SN, Clive LM, 1998. p56-61

The measure for ATP is Inventory On Hand and the metric is ATP:

⇨ *Inventory On Hand = Available Inventory in Period 1*

⇨ *ATP (Period 1) = Inventory On Hand + MPS – Orders before next MPS*

⇨ *ATP = MPS Receipts – Orders before next MPS*

An example of ATP for Diesel Lube 700 Super in the *lubricants supply chain* is depicted in Table 3.8:

Opening Inventory: 250 drums

ATP (Period 1) = MPS + Opening Inventory – Orders = 3200 + 250 – 1500 = 1950

ATP (Period 2) = MPS + Orders before next MPS = 3200 – 4500 = -1300 = 0 (negative)

Period	**Week 1**	**Week 2**	**Week 3**	**Week 4**
Customer Orders	1500	1500	1000	2000
MPS	3200	3200		
ATP	1950	0		

Table 3.8 – Available To Promise (ATP)

Source: developed by researcher

For ATP, the *customer orders* are grouped per week (codification) and the *MPS* and *ATP* is calculated per week (abstraction). The information is used to determine the *projected available balance* (diffusion).

PROJECTED AVAILABLE BALANCE

The *Projected Available Balance* (PAB) is based upon *forecast demand*. We have to consider customer orders which can sometimes be greater than forecast demand and sometimes less.

PAB is calculated based upon whichever is greater and depending upon whether the period is before or after the *demand time fence* viz. the number of periods, starting with period 1, in which changes are not accepted due to excessive cost caused by schedule disruption.[52]

The *lubricants supply chain* has a demand time fence during the peak periods of product usage and resulting sales during December when product usage is at its peak and only actual orders are considered for manufacturing during the period after the demand time fence. A sales forecast will only be used if it is greater than the number of orders for the particular product.

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[52] Arnold JRT, Chapman SN, Clive LM, 1998. p63-64

During this period the MPS is "frozen" and any changes to the MPS are not accepted.

For Periods <u>BEFORE</u> the Demand Time Fence:

The measure for PAB is Inventory On Hand or Prior Period PAB and the metric is PAB:

⇨ *Inventory On Hand = Available Inventory in Period 1*

⇨ *PAB Period 1 (before Demand Time Fence) = Inventory On Hand PAB + MPS – Orders*

⇨ *Prior Period PAB = PAB in Prior Period*

⇨ *PAB (before Demand Time Fence) = Prior Period PAB + MPS – Orders*

For Periods <u>AFTER</u> the Demand Time Fence:

The measure for PAB is Prior Period PAB and the metric is PAB:

⇨ *Prior Period PAB = PAB in Prior Period*

⇨ *PAB (after Demand Time Fence) = Prior Period PAB + MPS – (greater of Orders/Forecast)*

An example of *Project Available Balance* (PAB) in the *lubricants supply chain* with a demand time fence after week 1 is depicted in Table 3.9:

Opening Inventory: 250 drums

Inventory On Hand = Available Inventory in Period 1 = 250 drums

PAB Period 1 (before Demand Time Fence) = Inventory On Hand PAB + MPS – Orders
= 250 + 3200 – 1500 = 1950

PAB Period 2 (after Demand Time Fence) = Prior Period PAB + MPS – >(Orders, Forecast)
= 1950 + 3200 – 1500 = 3650

PAB Period 3 (after Demand Time Fence) = Prior Period PAB + MPS – >(Orders, Forecast)
= 3650 + 0 – 1500 = 2150

PAB Period 3 (after Demand Time Fence) = Prior Period PAB + MPS – >(Orders, Forecast)
= 2150 + 0 – 2000 = 150

Period		**Week 1**	**Week 2**	**Week 3**	**Week 4**
Forecast		2000	1500	1500	1500
Customer Orders		1500	1500	1000	2000
Projected Available Balance (PAB)	250	1950	3650	2150	150
MPS		3200	3200		
ATP		1950	0		

<u>Table 3.9 – Projected Available Balance (PAB)</u>

Source: developed by researcher

For PAB, *forecasts* and *customer orders* are grouped per week (codification) and the *PAB, MPS* and *ATP* are calculated per week (abstraction), used to determine the *MRP* (diffusion).

3.2.4 Material Requirements Planning (MRP)

Materials Requirements Planning (MRP) is defined as a set of techniques that uses bills of material data, inventory data and the MPS to calculate requirements for materials. From the MRP recommendations are made to release replenishment orders for material. Further, because it is time phased, it makes recommendations to reschedule open orders when due dates and need dates are not in phase.

Time-phased MRP is accomplished by exploding the *bill of material*, adjusting for *inventory* quantities on hand or on order, and offsetting nett requirements by appropriate lead time. [53] Time-phased MRP begins with items listed on the MPS and determines the quantity of all components and materials required to fabricate those items, and the date that the components and materials are required.

The MPS shows the end items or major components that manufacturing intends to build. These items are made or assembled from components that must be available in the *right quantities and at the right time* to meet the MPS requirements. If any component is missing, the product cannot be built and shipped on time. *Material Requirements Planning* (MRP) is the system used to avoid missing parts. It establishes a schedule (priority plan) showing the components required at each level of the assembly, and based upon lead times, calculates the time when these components will be needed.[54]

There are three (3) inputs to the MRP system in the lubricants supply chain MRP:

- Master Production Schedule (MPS) – Lubricants products per pack size Per Period
- Inventory Records – Available Lubricants Product per Pack Size
- Bills Of Material – Lubricants Product Formulations and Filling Components

What started in the mid-1960s as *Material Requirements Planning* (MRP) quickly grew into closed-loop MRP, with the integration of master scheduling, capacity planning, shop flow control, and purchasing. Together, these strategies provided manufacturing companies with the ability to maintain believable material and capacity plans.[55]

Closed-Loop MRP is commonly known as *Manufacturing Requirements Planning* (MRP II).

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[53] Willcox B, 2008. p3/42

[54] Arnold JRT, Chapman SN, Clive LM, 1998. p77

[55] Goddard WE, 1994.

An understanding of MRP requires discussion of demand and netting, followed by MRP objectives and subsequently the MRP process.

DEMAND

Demand can be either independent or dependant:

- *Independent demand* is not related to the demand for any other product. MPS items are independent demand items which must be *forecast*.
- *Dependent demand* is related to the demand for the products as components or sub-components which can be calculated. MRP is designed to do the calculation.

An item can have both a dependent and independent Demand. A service or replacement part has both.[56]

For the *lubricants supply chain*, the lubricants products are the independent demand (to be forecast) and the raw materials for both blending and filling are the dependant demand.

The *Bill of Materials* (BoM) is the list of component parts that go into a product. The BOM file keeps track of which component parts, and how many of each, goes into a unit of the parent item.[57] The *American Production and Inventory Control Society* (APICS) defines a *bill of material* as a "listing of all the sub-assemblies, intermediates, parts and raw materials that go into making the part assembly showing the quantities of each required to make as assembly.

The *bill of material* shows all the (unique) parts required to make one (1) of the item. Each part or item has only one part number. A specific number is unique to one part and is not assigned to any other part. A part is defined by its form, fit or function. If any of these changes, then it is not the same part and it must have a different part number.[58]

In the case of Lubricants Products, we have two (2) BOM's: blending and filling. The blending BOM lists required quantities of raw materials which will be blended together as a percentage of the overall product formulation. The filling BOM list the filling components for packaged lubricants (container and cap).

[56] Arnold JRT, Chapman SN, Clive LM, 1998. p77-78

[57] Schonberger RJ, Knod EM Jr, 2003. p323

[58] Blackstone JH Jr, 2008. p12

NETTING

The MRP *netting* process is the way calculations are carried out on a level by level basis down through a bill of materials, converting the *master production schedule* of finished products into suggested or planned orders for all subassemblies, components & raw materials.

Netting generates gross requirements for the item by "exploding" the *planned order* quantities of the next higher level assembly, by reference to the bill of material structure file. The gross requirements are amended by the amount of inventory of that item that is expected to be available in each week, i.e., on hand from previous week plus scheduled receipts. This information is obtained from the inventory status file and the amended requirements are called the net requirements. The net requirements are then offset by the relevant lead time for the item to give planned orders for initiating the manufacture or procurement. [59]

The *item master file* holds reference and control data, including on-hand stock balances and planning factors for every component item. The *on-hand balance* is used by the MRP to compute planned orders. Firstly, the system computes gross requirements for a given part. Then it calculates projected stock balances (for a give component) to see if there is a net requirement, which would indicate the need for a *planned order*; that calculation is called *netting*. A net requirement is the same as a negative *projected stock balance*.[60]

The measures for Netting are Previous Stock Balance, Gross Requirements and Planned & Scheduled Receipts and the metric is Projected Stock Balance:

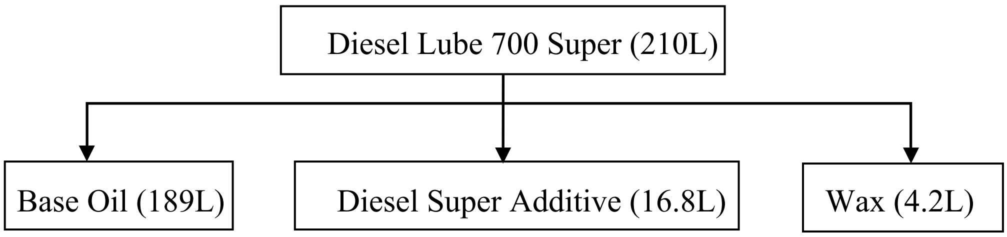
- ⇨ *Previous Stock Balance = Available On-Hold Inventory*
- ⇨ *Gross Requirements = Calculated Components*
- ⇨ *Planned & Scheduled Receipts = Planned Orders Receipt*
- ⇨ *Projected Stock Balance = Previous Stock Balance*
  – Gross Requirements
  + Planned and Scheduled Receipts

[59] Cooper C, 2005.

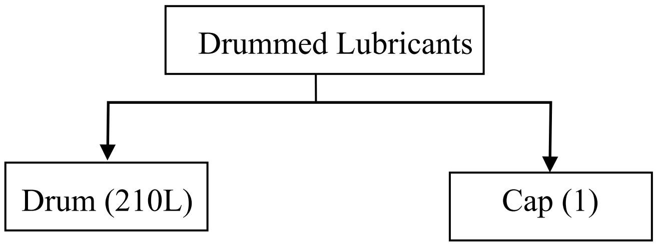
[60] Schonberger RJ, Knod EM Jr, 2003. p321

An example of *Netting* in the *lubricants supply chain* for Diesel Lube 700 Super in a 210L Drum is depicted in Table 3.10 where the lead time for all materials is one (1) week:

Blending BOM:



Filling BOM:



Previous Stock Balance = Available On-Hold Inventory = 250 drums

Gross Requirements (Week1) = (3200 - 250 Drums) x 210 Litres per Drum = 619500 Litres

Components: Base Oil = 90% x 619500 = 557550 Litres

Diesel Lube Additive = 8% x 619500 = 49560 Litres

Wax = 2% x 619500 = 12390 Litres

Drums = 2950 Drums

Caps = 2950 Caps

Gross Requirements (Week2) = 3200 Drums x 210 Litres per Drum = 672000 Litres

Components: Base Oil = 90% x 672000 = 604800 Litres

Diesel Lube Additive = 8% x 672000 = 53760 Litres

Wax = 2% x 672000 = 13440 Litres

Drums = 3200 Drums

Caps = 3200 Caps

Part		Period		
		Week 0	**Week 1**	**Week 2**
Diesel Lube 700 Super Drummed	Gross Requirements		3200	3200
	Projected Available	250	0	0
	Nett Requirements		2950	3200
	Planned Order Receipt		2950	3200
	Planned Order Release	2950	3200	
Base Oil	Gross Requirements		604800	604800
	Projected Available	0	0	0
	Nett Requirements		557550	604800
	Planned Order Receipt		557550	604800
	Planned Order Release	557550	604800	
Diesel Lube Additive	Gross Requirements		53760	53760
	Projected Available	0	0	0
	Nett Requirements		49560	53760
	Planned Order Receipt		49560	53760
	Planned Order Release	49560	53760	
Wax	Gross Requirements		12390	13440
	Projected Available	0	0	0
	Nett Requirements		12390	13440
	Planned Order Receipt		12390	13440
	Planned Order Release	12390	13440	
Drums	Gross Requirements		2950	3200
	Projected Available (1000)	1000	0	0
	Nett Requirements		1950	3200
	Planned Order Receipt		1950	3200
	Planned Order Release	1950	3200	
Caps	Gross Requirements		2950	3200
	Projected Available (1000)	1000	0	0
	Nett Requirements		1950	3200
	Planned Order Receipt		1950	3200
	Planned Order Release	1950	3200	

Table 3.10 – Gross and Net Requirements (Netting)

Source: Researcher

For Netting, the *gross requirements* per package and raw material are grouped per week (codification) and the *projected available, net requirements planned order receipt* and *planned order release* is calculated per week (abstraction). The information is used to determine the *required capacity* (diffusion).

The subset of MRP for handling *independent demand* is called *Time Phased Order Point* (TPOP). TPOP requires that the independent demands be forecast since they cannot be computed; there are no part demands from which to compute. The main difference between MRP and TPOP is this; dependant demands are calculated based on parent-item needs (MRP), while independent demands are forecast (TPOP).[61]

Demand dependency can be horizontal or vertical i.e. the dependency of a component on its parent is *vertical*. However, components also depend upon each other (*horizontal dependency*). If a component is going to be late, then the final assembly is late and the other components are not needed until later.

For Lubricants Products, dependency is vertical as no sub-assemblies exist.

MRP OBJECTIVES

MRP has two (2) major objectives i.e. determine requirements and keep priorities current.

Determine Requirements – The main objective of any *manufacturing planning and control system* is to have the right materials in the right quantities available at the right time to meet the demand for the firm's products. The MRP objective is to determine what components are needed to meet the MPS and based upon lead time, to calculate the periods when the components must be available. The MPS must determine what to order, how much to order, when to order and when to schedule delivery.[62]

For the *lubricants supply chain* the components required are raw materials for Lubricants Blending in accordance with the Blending BOM as well as containers and caps required in accordance with the Filling BOM.

Keep Priorities Current – The demand for, and supply of, components changes daily. Customers enter or change orders. Components get used up, suppliers are late with delivery, scrap occurs, orders are completed, and machines break down. In this ever changing world, a *materials requirements plan* must be able to reorganize priorities to keep plans current. It must be able to add and delete, expedite, delay and change orders.[62]

61 Schonberger RJ, Knod EM Jr, 2003. p328

62 Arnold JRT, Chapman SN, Clive LM, 1998. p78-89

As orders for Lubricants Products change, so too does the demand for components as either blending raw materials or filling containers and caps. Adjustments are made demand for components on a weekly basis as this is the lead time for procurement of components as a result of shortfalls i.e. a negative *project available balance*.

Buffer or safety stock is held as a contingency for stock shortfalls.

For the *lubricants supply chain,* if inventory as buffer/safety stock is required at the end of the manufacturing run, and there is capacity in the manufacturing lines for a particular period, then the net requirements for the product being manufactured can be increased (up to maximum capacity of the manufacturing line).

For an increase of manufacturing to the maximum capacity, the gross and nett requirements for the period will be the same.

MRP PROCESS

Each component shown on the *bill of material* is planned for by the MRP system. Planning and control takes place for each component on the bill.

Raw materials may go through several operations before it is processed and ready for assembly, or there may be several assembly operations between components and parent. These operations are planned and controlled by *production and activity control*, not material requirements planning.

The purpose of material requirements planning is to determine the components needed, quantities, and due dates so items in the MPS are made on time.

The basic MRP techniques are exploding and offsetting, gross and net requirements, releasing orders, capacity requirements planning, low-level coding and netting and multiple bills of material.[63]

Each of these will be discussed with relevance to the lubricants supply chain.

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[63] Arnold JRT, Chapman SN, Clive LM, 1998. p89

Exploding and Offsetting – *Exploding* is the process of multiplying the requirements by the usage quantity and recording the appropriate requirements throughout the product tree. *Offsetting* is the process of placing the exploded requirements in their proper period based upon lead time. Lead Time is the span of time needed to perform a process. In manufacturing it includes time for order preparation, queuing, processing, moving, receiving and inspecting, and any expected delay.

Planned orders are released at the start of the lead time and receipted at the end of the lead time. [64] For the *lubricants supply chain*, planned orders are placed for procurement of lubricants raw materials (if none exists in inventory). Bulk stock is kept of required containers and caps for filling on the respective manufacturing lines and replenished based upon reorder levels.

Gross and Net Requirements – *Gross requirements* are the total components needed for a parent Item, whereas *net requirements* subtracts available Inventory in order to determine what has to be ordered.[64]

The measures for Gross and Nett Requirements are Planned Order Receipt and Planned Order Release and the metric is Net Requirements per Component:

- ⇨ *Planned Order Receipt = Order Required*
- ⇨ *Planned Order Release = Order Released (based upon Lead Time for Receipt)*
- ⇨ *Net Requirements = Gross Requirements – Available Inventory*

An example of *Gross and Nett Requirements* in the *lubricants supply chain* for Diesel Lube 700 Super in a 210L Drum is depicted in Table 3.10 where the lead time for all materials is one week.

Releasing Orders – As requirements change, the materials requirements planning system recalculates the requirements for sub-assemblies and components and re-creates *planned order releases* to meet the shift in demand. Planned order releases are just planned, they have not been released. It is the responsibility of the material planner to release planner orders. Releasing an order means that authorisation is given to Purchasing to buy the necessary material or to manufacturing to make the component.

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[64] Arnold JRT, Chapman SN, Clive LM, 1998. p90-92

Before the manufacturing order is released, component availability must be checked. Component inventory records are checked to be sure enough material is available and, if so, to allocate the necessary quantities to that work *order*. If the material is not available, the planner will be advised of the shortage.

When the authorisation to purchase or manufacture is released, the *planned order receipt* is cancelled, and a *scheduled receipt* is created in its place.

When a manufacturing order is released the required quantities of a parent's components will be allocated to the order and the *projected available quantity* will be reduced.[65]

Scheduled Receipts – Orders placed on manufacturing or on a vendor represent a commitment to make or buy. For an order in a factory, necessary materials are committed and work-centre activity is allocated to that order. For purchased parts, similar commitments are made to the vendor. The *scheduled receipts* show the quantities ordered and when they are expected to be completed and available.[65]

Open Orders – Scheduled receipts on the MRP are open orders on the factory or vendor and are the responsibility of *purchasing* and of *production activity control*. When the goods are received into inventory and available for use, the order is closed out, and the *scheduled receipt* disappears to become part of *on-hand inventory*.[65]

The measure for Releasing Orders is Available Inventory and the metric is Nett Requirements per Component:

⇨ *Scheduled Receipt = Planned Order Receipt*

⇨ *Net Requirements = Gross Requirements – Scheduled Receipts – Available Inventory*

An example of *Releasing Orders* in the *lubricants supply chain* for Diesel Lube 700 Super in a 210L Drum is depicted in Table 3.10 where the lead time for all materials is 1 week.

Capacity Requirements Planning - The MRP *priority plan* must be checked against available capacity, called *capacity requirements planning*. (See 3.2.5 Capacity Management)

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65 Arnold JRT, Chapman SN, Clive LM, 1998. p94-97

Low Level Coding and Netting – A component may reside on more than one level in a *bill of material*. If this is the case, it is necessary to make sure that all *gross requirements* for that component have been recorded before *netting* takes place. The process of collecting the gross requirements and netting can be simplified by using low-level codes.

The *low-level code* is the lowest level on which a part resides, on all bills of material. Every part has only one low-level code. Low-level codes are determined by determined by starting at the lowest level of a bill of material and, working up, recording the level against the part. If a part occurs on a higher level, its existence on the lower level has already been recorded.

Once the low-level Codes are obtained the *net requirements* for each part can be calculated. The low-level codes are used to determine when a part is eligible for netting and exploding. In this way, each part is netted and exploded only once. There is no time-consuming re-netting and re-exploding each time a new requirement is met.[66]

Multiple Bills of Material – Most companies make more than one product and often use the same components in many of their products. The materials requirements planning system gathers the *planned order releases* from all the parents and creates a schedule of *gross requirements* for all components. The same procedure used for a single bill of material can be used when multiple products are manufactured. All bills must be netted and exploded level by level as was done for a single bill.[66]

In the *lubricants supply chain*, base oil is used as a raw material in all lubricants products and most additives are used in multiple products, hence multiple blending BOMs occur. The gross and nett requirements, after *inventory* has been subtracted, will be determined for all raw materials to be used in the blending of lubricants products based upon the blending BOM of the particular product. The filling BOM, however, depends on the container/package used for a particular manufacturing line with no common items used across the manufacturing line. For example, a drum filling line will have steel drums and steel caps which are not used on another manufacturing line, a can filling line only has cans, a bottle filling line will have bottles and screw caps, etc.

[66] Arnold JRT, Chapman SN, Clive LM, 1998. p94-100

3.2.5 Capacity Management

CAPACITY OVERVIEW

Manufacturing develops *priority plans* to satisfy *demand*. However, without the resources to achieve the priority plan, the plan will be unworkable. *Capacity management* is concerned about supplying the necessary resources.

Capacity is the amount of work that can be done in a specified time period.

The APICS dictionary defines *capacity* as 'the capability of a worker, machine, work centre, plant or organisation to produce output per time period'. Capacity is the rate of doing work, not the quantity of work done.[67]

Two kinds of *capacity* are defined viz. capacity available and capacity required.

Capacity available is the capacity of a system or resource to produce a quantity of output in a given time period. Capacity available is the rate at which work can be withdrawn from the system. Capacity required is the capacity of a system or resource needed to produce a desired output in a given time period. The sum of all the required capacities is called the *load* i.e. the amount of released and planned work assigned to a facility for a particular time period. Load is the amount of work in the system.[68]

Capacity management is responsible for determining the capacity needed to achieve the priority plans as well as providing, monitoring and controlling that capacity so that the *priority plan* can be met.

The APICS dictionary defines *capacity management* as 'the function of establishing, measuring, monitoring and adjusting time limits or levels of capacity in order to execute all manufacturing schedules.'[68]

Capacity planning is the process of determining the resources required to meeting the priority plan and the methods needed to make that capacity available. It takes place at each level of the priority planning process. *Capacity control* is the process of monitoring production output, comparing it with capacity plans, and taking corrective action when needed.[68]

[67] Blackstone JH Jr, 2008.

[68] Arnold JRT, Chapman SN, Clive LM, 1998. p126-127

Capacity planning involves calculating the *capacity* needed to achieve the *priority plan* and finding ways of making that capacity available. If the capacity requirement cannot be met, the priority plans have to be changed. *Priority plans* are usually stated in units of product or some standard unit of output. Capacity can sometimes be stated in the same units but if there is no common unit, capacity can be stated as the hours available. The priority plan must then be translated into *hours of work required* and compared to the *hours available*.

The process of *capacity planning* is to determine the *capacity available* at each work centre in each time period, determine the *load* at each work centre in each time period by translating the priority plan into *hours of work required* at each work centre in each time period (sum up the capacities required for each work item on each work centre to determine the *load* on each work centre in each time period) and to resolve differences between *available capacity* and *required capacity*. If possible, adjust available capacity to match the load. Otherwise, the priority plans must be changed to match the available capacity.[69]

The measure is available capacity per work centre and the metric is Load per Work centre:

⇨ *Load per work centre = sum Required Capacity (Work Item) per work centre*

For Load, the *required capacity* is grouped per work item per work centre (codification) and the *load* is calculated per work centre (abstraction). The information is used to determine the *load* for each blend kettle and manufacturing line (diffusion).

For the *lubricants supply chain*, the available capacity per manufacturing line is determined based upon the volume of products per pack size with a direct correlation between the manufacturing line, with finite daily capacity available, and pack size.

Each manufacturing line can fill, cap and seal a number of packs based upon benchmarks per pack size.

For example, for typical lubricants manufacturing lines we can determine the available capacity per manufacturing line as depicted in Table 3.7.

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[69] Arnold JRT, Chapman SN, Clive LM, 1998. p127

Figure 3.2 below depicts the various *planning levels* in the supply chain, with relevance in this section to *capacity*.

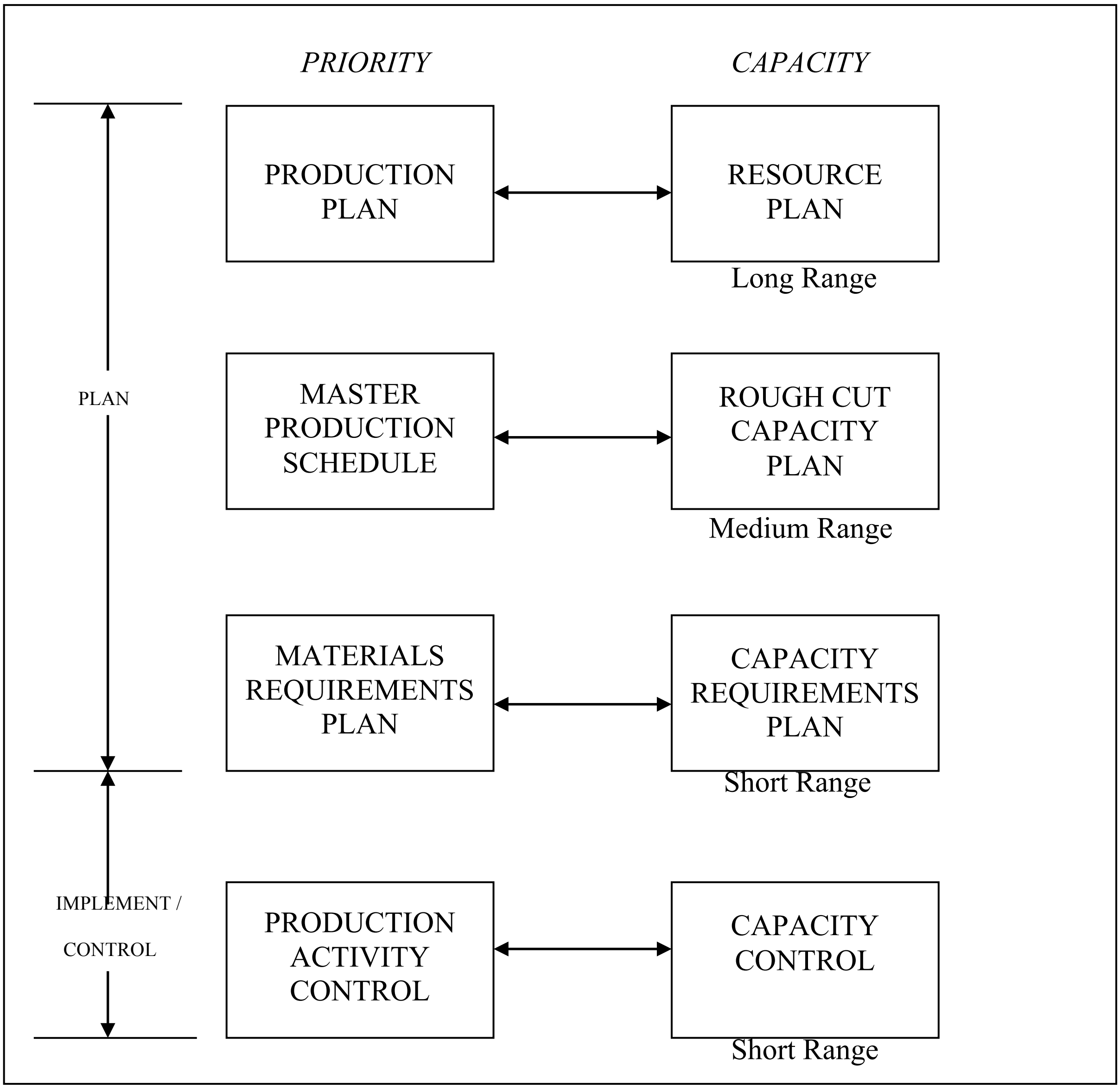

Figure 3.2: Planning Levels

Source: Arnold JRT, Chapman SN, Clive LM, 1998.

The various forms of *capacity planning* as depicted in Figure 3.2 are resource planning, rough-cut capacity planning and capacity requirements planning, each of which will be discussed further.

Resource Planning involves long-range *capacity resource requirements* as it directly linked to production planning. It involves translating the monthly, quarterly or annual production priorities from the *production plan* into some total measure of capacity, such as gross labour hours. Resource planning involves changes in staffing, capital, equipment, product design, or other facilities that take a long time to acquire and eliminate.

If a *resource plan* cannot be devised to meet the *production plan*, the production plan has to be changed. These plans set the limits and levels of production. If they are realistic the Master Production Schedule (MPS) should work. For the *lubricants supply chain*, resource planning occurs on a monthly basis to determine gross staffing requirements, whereas changes requiring Capital Expenditure (CAPEX) viz. blending and manufacturing line equipment, product container design and facilities lead to initiation of projects.

Rough-Cut Capacity Planning takes capacity planning to the next level of detail. The Master Production Schedule (MPS) is the primary information source. The purpose of Rough-Cut Capacity Planning (RCCP) is to check the feasibility of the MPS, provide warnings of any bottlenecks, ensure utilisation of work centres, and advise vendors of capacity requirements. For the *lubricants supply chain*, RCCP is used to determine if any bottlenecks will occur in the lubricants blending, filling, capping and sealing operations based upon the utilisation of the blending tanks and manufacturing lines. Capacity requirements for staffing will be communicated to contract companies which provide contract staff to the overall operations.

Capacity Requirements Planning is directly linked to Materials Requirements Planning (MRP). Since this type of planning focuses on component parts, greater detail is involved than in rough-cut capacity planning. It is concerned with individual orders at individual work centres and calculates work centre loads and labour requirements for each time period for each work centre. For the *lubricants supply chain*, the capacity requirements planning will calculate load for each blend kettle and manufacturing line along with labour requirements.

Planned orders from the MRP and open shop orders (*scheduled receipts*) are converted into demand for time in each work centre in each time period. The process takes into consideration the lead times for operations and offsets the operations at work centres accordingly. The inputs needed for the Capacity Requirements Plan (CRP) are open shop orders, planned order releases, routings, time standards, lead times & work centre capacities.[70]

[70] Arnold JRT, Chapman SN, Clive LM, 1998. p129-130

An open shop order appears as a *scheduled receipt* on the Material Requirements Plan (MRP). It is a released order for a quantity of a part to be manufactured and completed on specific date. It shows all relevant information such as quantities, due dates and operations. The *open order file* is a record of all active shop orders. Open shop orders in the *lubricants supply chain* indicate the various lubricants products to be blended and packed into the various pack sizes as well as the containers, caps and seals required for packaging operations.

Planned order releases are determined by the MRP logic based upon the gross requirements of a particular part. They are inputs to the CRP process in assessing the *total capacity required* in future time periods. Planned order release in the *lubricants supply chain* will be based upon the gross requirements for blending raw materials and filling containers and caps.

A routing is the path that work follows from work centre to work centre as it is completed.

A routing file should exist for every component manufactured and contain the following: information:

⇒ Operations to be performed – Decanting raw materials, blending and filling

⇒ Sequence of Operations – Decanting raw materials, blending and filling

⇒ Work Centres to be used – Blend kettles and manufacturing lines

⇒ Possible Alternate work centres – Alternatives for lubricants are costly

⇒ Tooling needed at each work centre – None required for lubricants supply chain

⇒ Standard Times – Setup times of manufacturing line and run time per package type

A work centre is composed of a number of machines or workers capable of doing the same work. The machinery will normally be similar so there are no differences in the kind of work the machines can do or the capacity of each.

A work centre file contains information on the capacity and move, wait and queuing times associated with the work centre.

The measures for work centre are Queue, Setup, Run, Wait and Move Times and the metric is Lead time per work centre:

The measure is Available Capacity per work centre and the metric is Load per Work Centre:

⇨ *Lead Time = Queue Time + Setup Time + Run Time + Wait Time + Move Time*

In the *lubricants supply chain*, there are two work centres types viz. blend kettle and manufacturing line.

For the blending *work centre* there is no *queue time*, *wait time* or *move time* (as product is remains in the blend kettle until pipe fed to a manufacturing line). The *setup time* is roughly an hour (to fill the product from either a line from a storage tank or drums) and the *run time* based upon historical blending durations is on average 10 hours per blend. Products are blended overnight as required for next day filling in the manufacturing line as they are heated whilst product is blended or stored in them. The cost build-up of products based upon activity based costing takes into account gas heating costs of blend kettles which are relatively high. The blend kettle is thus not defined as a bottleneck step in the process of blending and filling.

For the manufacturing *work centre*, there is no queue time and the setup time is an hour on average and usually takes place from 8AM to 9AM (to connect the blend kettles to the manufacturing line and to fill empty containers at the start of the manufacturing line). The run time is 8 hours for each manufacturing line which coincides with an 8am - 5pm shift. No wait time and move time exists for the filling process as products are shrink-wrapped and moved to a high rise warehouse in the continuous manufacturing process.

The shop calendar shows the number of working days available.

CAPACITY AVAILABLE

Capacity available is the capacity of a system or resource to produce a quantity of output in a given time period. It is affected by product specifications, product mix, plant and equipment as well as work effort[71]. If the product specifications change, the work content i.e. work required to make the product will change thus affecting the number of units produced. Each product has its own work content measured in the time it takes to make the product. If the mix of the products being produced changes, the total work content (time) for the mix will change. Plant and equipment relate to methods used to make the product. If the method is changed e.g. a faster machine is used, the output will change. Similarly, if more machines are added to the work centre, the capacity will change. Work Effort relates to the speed or pace at

[71] Arnold JRT, Chapman SN, Clive LM, 1998. p130-131

which the work is done. If the workforce changes pace, perhaps producing more in a given time, the capacity is altered.

Even though product formulations (specifications) and the inherent bill of material (mix) product for a lubricants product changes very rarely, the blending and packaging processes often change to increase the overall efficiency of the manufacturing process.

During times of excess demand the workforce is required to produce more by increasing the throughput of the manufacturing process, characterised by additional shifts and overtime, as the demand is evidenced by actual customer orders for Lubricants products.

Every product has a buffer/safety stock level to guard against stock-outs.

Capacity available is determined by measurement (Codification) or calculation (Abstraction).

Measurement – Demonstrated capacity is determined from historical data (average).

The measure for Capacity Available is Standard Hours of work and the metric is Demonstrated Capacity:

⇨ *Standard Hours of Work = Standard Hours per period*

⇨ *Demonstrated Capacity = sum Standard Hours of Work for periods / No periods*

Calculation – *Rated capacity* is based upon available time (number of hours a work centre can be used), utilisation and efficiency

The measures for Rated Capacity are Available Time, Utilisation and Efficiency and the metric is Rated Capacity:

⇨ *Available Time =No Machines x Hours per day x No Days*

⇨ *Utilisation = Hours Actually Worked / Available Hours*

⇨ *Efficiency = Actual Rate of Production / Standard Rate of Production*

⇨ *Rated Capacity = Available Time x Utilisation x Efficiency*

For the *lubricants supply chain*, capacity available is determined by measurement i.e. historical data and averages.

For example, if a manufacturing line had 160, 140 and 150 standard hours of work over the past 3 months (codification) the demonstrated capacity for the manufacturing line will be

(160+140+150)/3=150 standard hours (Abstraction). The standard hours of work are tracked each month as part of a capability study along with root cause analysis (Diffusion).

CAPACITY REQUIRED

Capacity requirements are generated by the priority planning systems and involve translating priorities, given in units of product or some common unit, into hours of work required at each work centre in each time period.[72]

Determine the time needed for each order as the sum of the setup time and run time. Run time is equal to the run time per piece multiplied by the number of pieces in the order.

The measure for Capacity required is Setup Time & Run Time and the metric is Time Needed for Each Order:

- ⇨ *Setup Time = time required for setup of work centre*
- ⇨ *Run Time = Run Time per Piece x No Pieces*
- ⇨ *Time Needed For Each Order = Setup Time + Run Time*

For the *lubricants supply chain*, the time needed for each order is determined per manufacturing line based upon setup time + run time (abstraction), with each line having a standard run time per piece (codification).

Sum up the capacity required for individual orders to obtain the load by determining the standard hours of operation time for each planned and released order for each work centre per time period, thereafter add all the standard hours together for each work centre in each period. The result is the total *required capacity* (load) on that work centre for each time period of the plan.

The measures for Load are Released and Planned Orders per work centre and the metric is Load:

- ⇨ *Released Orders per work centre for period = Setup Time + Run Time per work centre*
- ⇨ *Planned Orders per work centre for period = Setup Time + Run Time per work centre*
- ⇨ *Load for period = sum Released Orders + Planned Orders (all work centres)*

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[72] Arnold JRT, Chapman SN, Clive LM, 1998. p132

For the *lubricants supply chain*, the load is the sum of all planned and released Orders for all blending kettles and all manufacturing lines.

The load must be compared against available capacity. The work centre load report shows future capacity requirements for released and planned orders for each time period of the plan.

The measures are Released Load, Planned Load and Rated Capacity and the metric is (Over)/Under Capacity:

⇨ *Released Load per period = sum of Released Orders for period*

⇨ *Planned Load per period = sum of Planned Orders for period*

⇨ *(Over) / Under Capacity per period = Rated Capacity – (Released + Planned Load)*

For (Over)/Under Capacity, the *released orders* and *planned orders* are summed grouped per period (codification) and the *(over)/under capacity* is calculated per period (abstraction). The information is used to determine the excess or required capacity (diffusion).

SCHEDULING ORDERS

As *orders* are processed across a number of *work centres*, it is necessary to calculate when orders must be started and completed on each work centre so the final due date can be met. This process is called *scheduling*. The usual process is to start with the due date and, using the lead times, to work back to find the start date for each operation (back scheduling).

The *scheduling process* calculate the capacity required (time) at each work centre. To *schedule*, we need to know for each order the quantity and due date, sequence of operations and work centres needed, setup and run times for each operation, timings (queue, wait and move times) as well as work centre capacity available (rated or demonstrated). [73]

For each work order, calculate the capacity required (time) at each work centre.

The measures for Scheduling are Released Load, Planned Load and Rated Capacity and the metric are (Over)/Under Capacity:

⇒ *Capacity Required per work centre = Setup Time + Run Time per work centre*

Starting with the due date, schedule back to completion and start dates per operation.

The measures are Arrival Date, End Date, Finish Date, Wait Time (days), Operation (days) and Queue (days) and the metric is Start Date:

⇒ $Arrival\ Date_n = End\ Date$

⇒ $Finish\ Date_n = Arrival\ Date_n - Store\ Move\ Days$

[73] Arnold JRT, Chapman SN, Clive LM, 1998. p138-154

$\Rightarrow$ *Arrival Date* $_{n-x}$ = *Finish Date* $_{n-x+1}$ – *Wait – operation – Queue*
$\Rightarrow$ *Arrival Date* $_0$ = *Start Date*

The *lubricants supply chain,* a continuous manufacturing process, does not utilise scheduling.

MAKING THE PLAN

The next step is to compare *load* to *available capacity* to see if there are imbalances and if so, find possible solutions.

There are two ways of balancing capacity available and load viz. alter the load or change capacity available.[74]

Altering the load means shifting orders ahead or back so the load is levelled. If orders are processed on other work stations the schedule and load on the other work stations have to be changed.

It may also mean that other components should be rescheduled and the master *production schedule* changed.

Changing the load may not be the preferred course of action. In the short run, capacity may be adjusted by scheduling overtime or under-time, adjusting level of the workforce, shifting the workforce or subcontracting work.

The results of *capacity requirements planning* should be a detailed workable plan that meets the priority objectives and provides capacity. Ideally, it will satisfy the material requirements plan and allow for adequate utilisation of the workforce, machinery and equipment.

Materials Requirements Planning (MRP) and Capacity Requirements Planning (CRP) should form a closed loop system that not only includes planning and control functions but also provides feedback so planning can be current (see Figure 3.3).

[74] Arnold JRT, Chapman SN, Clive LM, 1998. p141

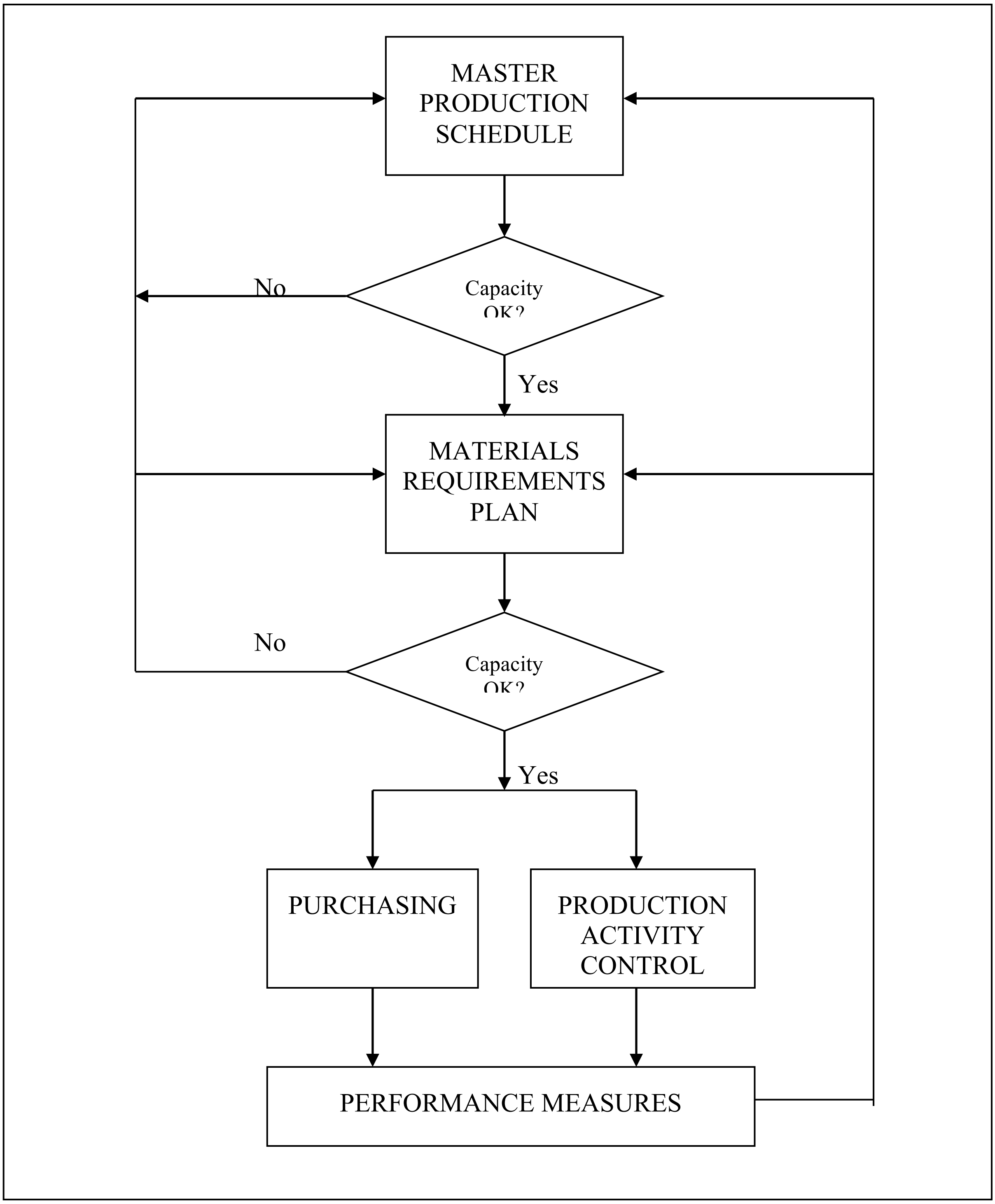

Figure 3.3: MRP and CRP Closed Loop System

Source: Arnold JRT, Chapman SN, Clive LM, 1998.

3.2.6 Production Activity Control

PRODUCTION ACTIVITY CONTROL OVERVIEW

Production Activity Control (PAC) is responsible for executing the Master Production Schedule (MPS) and the Materials Requirements Plan (MRP).

The MRP authorises the PAC to release work orders to the shop for manufacturing, take control of work orders and to make sure they are completed on time, be responsible for the immediate detailed planning of the flow of orders through manufacturing, carrying out the plan and controlling the work as it progresses to completion as well as manage day-to-day activities and provide the necessary support.[75]

The activities of the *production activity control* can be classified into planning, implementation and control functions.[75] (as depicted in Figure 3.4).

Planning – The flow of work through each of the work centres must be planned to meet delivery dates, which means *production activity control* must ensure the required materials, tooling, personnel and information are available to manufacture the components as needed and to schedule start and completion dates for each shop order at each work centre so the scheduled completion date of the order can be met. This will involve the planner in developing a load profile for the work centres.

Implementation – Once the plans are made, *production activity control* must put them into action by advising the shop floor what must be done by gathering information needed to make the product and release orders to the shop floor as authorised by the MRP (dispatching).

Control – Once plans are made and shop orders released, the process must be monitored to learn what is actually happening. The results are compared to the plan to decide whether corrective action is necessary by ranking the shop orders in desired *priority sequence* by work centre and establish a *dispatch list* based upon this information, tracking the actual performance of work orders and compare it to planed schedules (where necessary, *production activity control* must take corrective action by re-planning, re-scheduling or adjusting capacity to meet final delivery requirements), monitor and control work-in-progress, lead times and work centre queues and report work centre efficiency, operation times, order quantities and scrap.

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[75] Arnold JRT, Chapman SN, Clive LM, 1998. p153-159

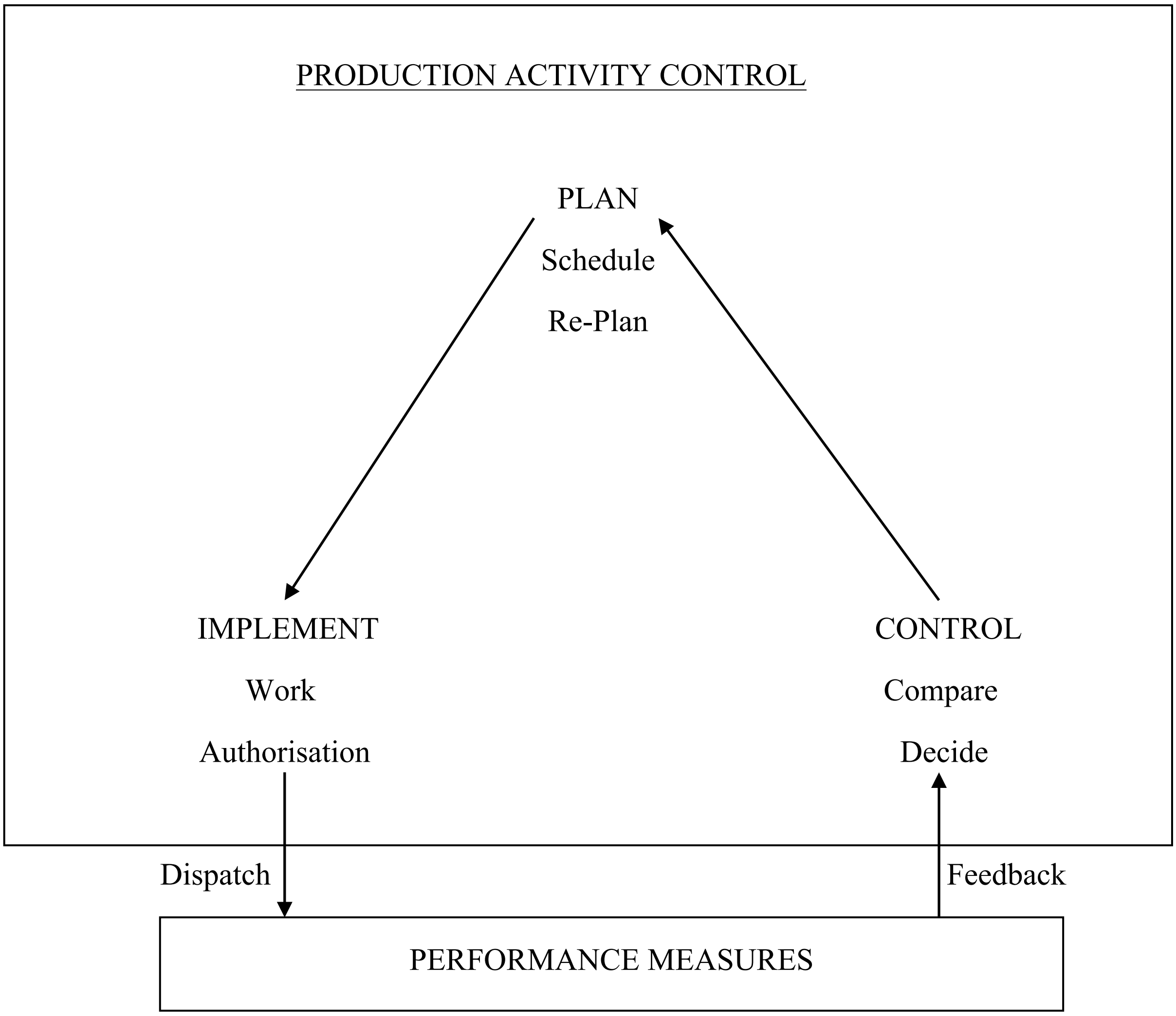

Figure 3.4: Plan, Implement and Control

Source: Arnold JRT, Chapman SN, Clive LM, 1998.

MANUFACTURING SYSTEMS

The particular type of *production control system* used varies from company to company, but all should perform the preceding functions. However, the relative importance of these functions will depend on the type of manufacturing process, which can be conveniently organised into three (3) categories: Flow Manufacturing, Intermittent Manufacturing and Project Manufacturing.[76]

[76] Arnold JRT, Chapman SN, Clive LM, 1998. p155-157

Flow Manufacturing – Flow manufacturing is concerned with the production of high-volume standard products. If the units are discrete (e.g. cars and appliances) the process is usually called repetitive manufacturing. If the goods are made in a continuous flow (e.g. gasoline and in our case lubricants) the process is called *continuous manufacturing*. The characteristics of flow manufacturing are that routings are fixed, and work centres are arranged according to the routing. The time taken to perform work at one work centre is almost the same as any other work centre in the line (e.g. bottle filling, capping and sealing in lubricants manufacture). Work centres are dedicated to producing a limited range of similar products. Machinery and tooling are specifically designed to make the specific products. Material flows from one workstation to another using some form of mechanical transfer. There is little build-up of work-in-progress. Inventory and throughput times are slow. Capacity is fixed in the line. *Production activity control* concentrates on planning the flow of work and making sure the right material is fed to the line as stated in the planned schedule. Since work flows from one workstation to another automatically, implementation and control are relatively simple.

Intermittent Manufacturing – Intermittent Manufacturing is characterised by many variations on product design, process, requirements and order quantities. Flow of work through the shop is varied and depends on the design of a product. As orders are processed, they will take more time at one workstation than at another. The work flow is not balanced. Machinery and workers must be flexible enough to do the variety of work. Machinery and work centres are usually grouped according to the function they perform. Throughput times are generally long. Scheduling work to arrive just when needed is difficult, the time taken by an order at each work centre varies, and work queues before work centres, causing long delays in processing. Work-In-Progress inventory is often large. The Capacity required depends on the particular mix of products built and is difficult to predict.

Production activity control in *intermittent manufacturing* is relatively complex. Because of the number of products made, the variety of routings and scheduling problems, production activity control is a major activity in this type of manufacturing. Planning and control are typically exercised using shop orders for each batch being produced.

Project Manufacturing – Project Manufacturing involves the creation of one or a small number of units. Because the design of a product is often carried out or modified as a product develops, there is close coordination between manufacturing, marketing, purchasing and engineering.

PRODUCTION ACTIVITY CONTROL DATA REQUIREMENTS[77]

To plan the flow of materials through manufacturing, Production Activity Control (PAC) determines what and how much to produce, when parts are needed to the completion date can be met, what operations are required to make the product and how long the operations will take and what the available capacities of the various work centres are.

Production activity control must have a data or information system from which to work. Usually the data needed to answer these questions are organised into databases. The files contained in the databases are two types: Planning and Control.

Planning files include the Item Master File, Product Structure File and Routing File and Work Centre Master File.

Item Master File – There is one record in the item master file for each part number including part number (a unique number assigned to the component), part description, manufacturing lead time (the normal time need to make this part), quantity on hand, quantity available, allocated quantity (quantities assigned to specific work orders but not yet withdraw from inventory), on-order quantities (balance due on all outstanding orders) and lot size quantity, (quantity normally ordered at a time).

Product Structure File (bill of material) – A list of the single-level components and quantities needed to assemble a parent.

Routing File – A record of each part manufactured. The routing consists of a series of operations required to make the item. For each product there is a step-by-step set of instructions describing how the product is made including the *operations* required to make the product and the *sequence* in which those operations are performed, a brief description of each operation, equipment, tools, and accessories needed for each operation, setup times (standard time required for setting up the equipment for each operation), run times (standard time required to process one unit through each operation) and lead times for each operation.

Work Centre Master File – All the relevant data on a Work centre including work centre number, capacity, number of shifts worked per week, number of machine hours per shift, number of labour hours per shift, efficiency, utilisation, queue Time (average time that a job waits at the work centre before work is begun) and alternate work centres.

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[77] Arnold JRT, Chapman SN, Clive LM, 1998. p157-174

Control in *intermittent manufacturing* is exercised through shop orders and control files that contain data on those orders. There are generally two kinds of files viz. Shop Order Master File and a Shop Order Detail File:[78]

Shop Order Master File – Each active manufacturing order has a record in the shop order master file. The purpose is to provide summarised data on each shop order in terms of shop order number (unique number identifying shop order), order quantity, quantity completed, quantity scrapped, quantity of material issues to the order, due date (expected finish date of order), priority (value used to rank the order in relation to others), balance due (quantity not yet completed) and cost information.

Shop Order Detail File – Each shop order has a record for each operation needed to make the item which includes operation number, setup hours (planned and actual), run hours (planned and actual), quantity reported complete at that operation, quantity reported scrapped at that operation and either due date or lead time remaining.

The information contained in the control files are used to report deviations from plan. Root cause analysis will be performed for any deviations to plan and corrective action put in place to prevent further deviation from plan.

MANUFACTURING LEAD TIME

Manufacturing Lead Time (MLT) is the time normally required to produce an item in a typical Lot Quantity. MLT consists of queue time (amount of time the job is waiting at a work centre before operation), setup time (time required to prepare the work centre for operation), run time (time require to run the order through the operation), wait time (amount of time the job is at a work centre before being moved to the next work centre) and move time (transit time between work centres).[78] The Total MLT (abstraction) will be the sum of all Order Preparation and Release plus MLT for operations (codification).

The measures are Order Release Time & MLT per work centre and the metric is Total MLT:

- ⇨ *Order Release Time = Order Released (based upon Lead Time for Receipt)*
- ⇨ *MLT per work centre = Queue Time + Setup Time + (Run Time x No Pieces) + Wait Time + Move Time*
- ⇨ *Total MLT = Order Release Time + sum of MLT for all work centres*

[78] Arnold JRT, Chapman SN, Clive LM, 1998. p158-159

The largest of the elements is queue time. Production Activity Control (PAC) is responsible for managing the queue by regulating the flow of work into and out of work centres. [79]

The flow manufacturing in the *lubricants supply chain* only use setup time + (run time per container type x no. containers).

CONTROL

Once work orders have been issued to manufacturing, their progress has to be controlled. Manufacturing Lead Time (MLT) is the time normally required to produce an item in a typical *lot* quantity. To control progress, performance must be measured and compared to what is planned. If what is actually happening (measured) varies significantly from what is planned, either the plans have to be changed or corrective action must be taken to bring performance back to plan.[79]

To meet delivery dates, a company must control the progress of orders on shop floor, which means controlling the lead time for orders. As the largest component of lead time is queue, delivery dates can be met if the queue is controlled.

Queue exists because of erratic input and output. In *intermittent manufacturing*, many different products and quantities have many different routings, each requiring different capacities. In this environment, it is almost impossible to balance load over all the work stations. Queue exists because of this erratic input and output. To control queue and meet delivery commitments, *production activity control* must control the work going into and coming out of each work centre (input output control) as well as set the correct priority of orders to run at each work centre.

Input Output Control – Production Activity Control must balance the flow of work to and from different work centres. This is to ensure Queue, Work-In-Progress and Lead Times are controlled. The Input Output Control system is a method of managing Queues and Work-In-Progress Lead Times by monitoring and controlling the input to and output from a facility. It is designed to balance the Input Rate in Hours to the Output Rate so these will be controlled. The Input Rate is controlled by the Release of Orders to the Shop Floor. If the rate of input is increased, the Queue, Work-In-Progress and Lead Times are increased. The Output Rate is controlled by increasing or decreasing the Capacity of a work centre.

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[79] Arnold JRT, Chapman SN, Clive LM, 1998. p174

To control input and output, a plan must be devised, along with a method of comparing what actually occurs against what was planned. Cumulative variance is the difference between the total planned for a given period and the actual total for that period.

The measures are Actual Input, Planned Input, Actual Output, Planned Output, and the metrics are Cumulative Variance Input, Cumulative Variance Output, Planned Backlog and Actual Backlog:

- ⇨ *Cumulative Variance Input $_{1}$ = Actual Input – Planned Input*
- ⇨ *Cumulative Variance Input $_{2+}$ = Previous Cumulative Variance Input + Actual Input – Planned Input*
- ⇨ *Cumulative Variance Output $_{1}$ = Actual Input – Planned Output*
- ⇨ *Cumulative Variance Output $_{2+}$ = Previous Cumulative Variance Output + Actual Output – Planned Output*
- ⇨ *Planned Backlog = Previous Planned Backlog + Planned Input – Planned Output*
- ⇨ *Actual Backlog = Previous Actual Backlog + Actual Input – Actual Output*

Operation Sequencing – The APICS dictionary defines Operation Sequencing as "a technique for short-term planning of actual jobs to be run in each work centre based upon capacity (i.e. existing workforce and machine availability) and priorities."[80]

Priority in this case is the sequence in which jobs at a work centre should be worked on, exercise through dispatching.

Dispatching is the function of selecting and sequencing available jobs to be run at individual work centres. The *dispatch list* is the instrument of priority control. It is a listing by operation of all the jobs available to be run at a work centre with the job listed in priority sequence. It includes information related to plant, department, work centre, part no, shop order no, operation no, description of jobs at the work centre, standard hours, priority, jobs coming to the work centre; and is updated and published at least daily.[81]

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[80] Blackstone JH Jr, 2008.

[81] Arnold JRT, Chapman SN, Clive LM, 1998. p177

Dispatch Rules – The ranking of jobs for the *dispatch list* is created through the application of priority rules. There are many rules, some attempting to reduce work-in-progress inventory, others attempting to minimise the number of late orders or maximise the output of the work centre. Some common rules are:

- First Come First Served (FCFS) – Jobs are performed in the sequence in which they are received. This rule ignores due dates and processing time.
- Earliest Job Due Date (EDD) – Jobs are performed according to their due dates. Due dates are considered, but processing time is not.
- Earliest Operation Due Date (EDD) – Jobs are performed according to their operation due dates. Dues dates and processing time are taken into account. The operation due date is easily understood on the shop floor.
- Shortest Process Time (SPT) – Jobs are sequenced according to their process time. This rule ignores due dates, but it maximises the number of jobs processed. Orders with long process times tend to be delayed.
- Critical Ratio (CR) – An index of the relative Priority of an order to other orders at a work centre. It is based on a ratio of rime remaining to work remaining.[82]

  The measures are Actual Time Remaining and Lead Time Remaining and the metric is Critical Ratio:

  ⇨ *Actual Time Remaining = Due Date – Present Date*

  ⇨ *Critical Ratio = Actual Time Remaining / Lead Time Remaining*

  If the Actual Time Remaining is greater than the lead time remaining, the job is ahead of schedule. Critical Ratio can be interpreted as follows:

  - *CR < 1* - *Actual Time less than Lead Time* *Order Behind Schedule*
  - *CR = 1* - *Actual Time equal to Lead Time* *Order On Schedule*
  - *CR > 1* - *Actual Time greater than Lead Time* *Order Ahead Of Schedule*
  - *CR < 0* - *Today's Date greater than Due Date* *Order Already Late*

For the *lubricants supply chain*, jobs are despatched using the *first come first served* rule and the *critical ratio* is used to determine the status of a job. If a job is behind schedule then overtime will be scheduled.

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[82] Arnold JRT, Chapman SN, Clive LM, 1998. p177-179

INVENTORY

Inventories are materials and supplies that a business or institution carries either for sale or to provide inputs or suppliers to the production process. As inventories are used, their value is converted into cash, which improves cash flow and Return on Investment (ROI). There is a cost for carrying inventories, which increases operating costs and decreases profits.

Inventory management is responsible for planning and controlling inventory from the raw materials stage to the customer. Inventory must be considered at each of the planning levels, and is thus part of production planning, Master Production Scheduling and Materials Requirements Planning. Production planning is concerned with overall inventory, master planning with end items and Materials Requirements Planning with components parts and raw material.[83]

FLOW OF MATERIAL

Inventory can be classified by the flow of material into and out of a manufacturing organisation as follows:

- Raw Materials – Purchased items received that have not entered the production process.
- Work-In-Progress (WIP) – Raw material that have entered the manufacturing process and are being worked on or waiting to be worked on.
- Finished Goods – Finished products of the production process that are ready to be sold as completed items. They may be held at a factory or central warehouse or at various points in the distribution system.
- Distribution Inventories – Finished goods located in the distribution system.
- Maintenance, Repair and Operational Supplies (MRO's) – Items used in production that do not become part of a product.[83]

For the *lubricants supply chain*, raw materials (base oil, additives and wax) are used in blending of products as well as filling, sealing and capping (containers, seals and caps), with no WIP. Finished products are produced as either bulk or packaged Lubricants which are despatched to various *distribution centres* in the major cities of South Africa (including Durban, Johannesburg, Cape Town and Port Elizabeth). Minimal MRO's are used for the raw materials and finished product tankage and associated manufacturing lines.

[83] Arnold JRT, Chapman SN, Clive LM, 1998. p254-279

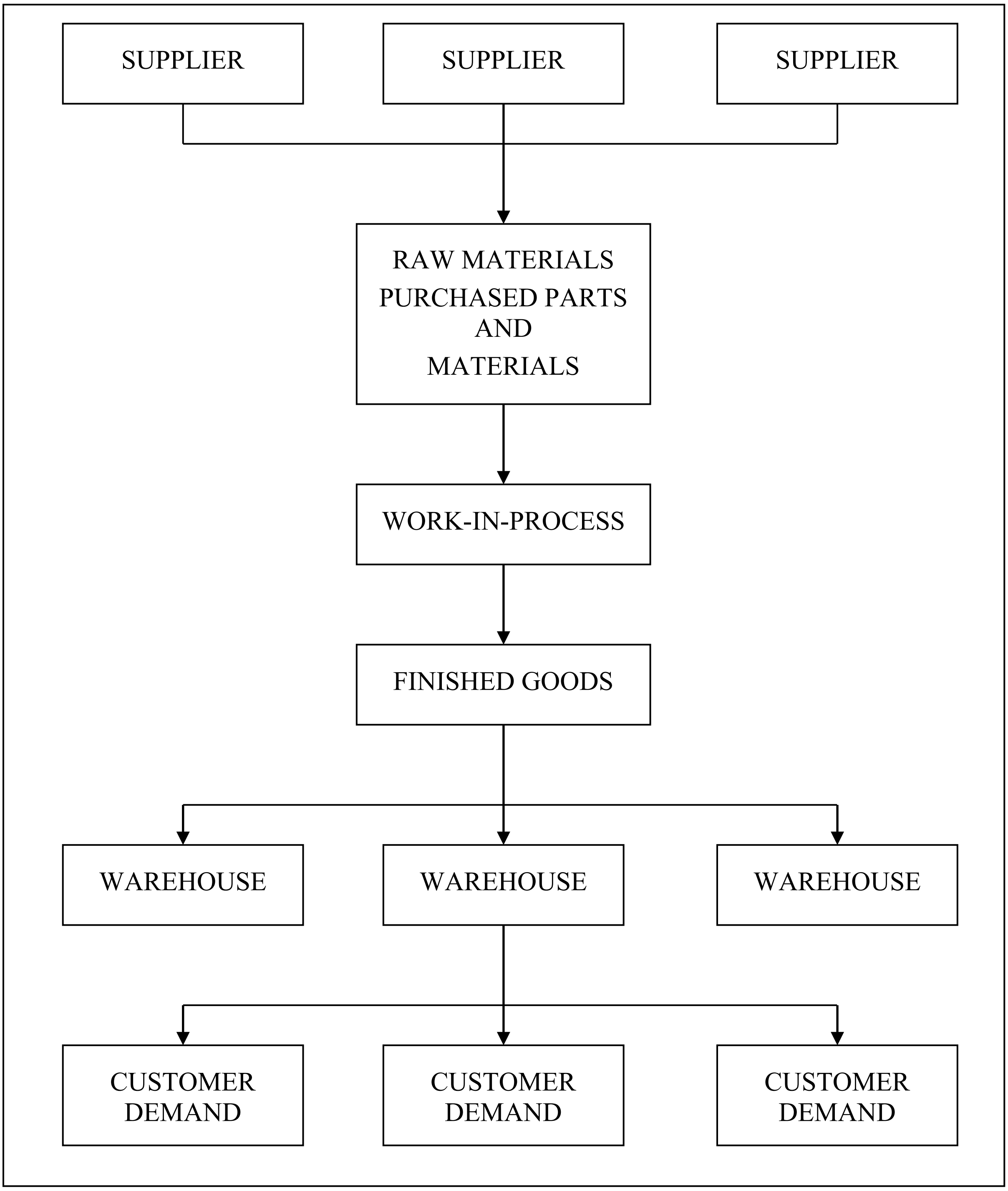

Figure 3.5: Inventories and the Flow of Materials

Source: Arnold JRT, Chapman SN, Clive LM, 1998.

The flow of materials in the supply chain is depicted in Figure 3.5.

FUNCTIONS OF INVENTORIES [84]

In *batch manufacturing*, the basic purpose of inventories is to decouple supply and demand. Inventories serve as a buffer between supply and demand, customer demand and finished goods, requirements for an operation and the output for the preceding operation and parts and materials to begin production and the supplies of materials.

Inventories can be classified according to the operation they perform:

- Application Inventory – Built up in anticipation of future demand. They are built up to help level production and to reduce the costs of changing production rates.
- Fluctuation Inventory (safety stock) – Cover random unpredictable fluctuations in supply and demand or lead Time, called buffer or reserve stock. If demand or lead time is less than forecast, a stock-out occurs. Safety stock is held to protect against this possibility. Its purpose is preventing disruptions in manufacturing or customer deliveries.
- Lot-Size Inventory – Items purchased or manufactured in quantities greater than needed immediately create lot-size inventory (cycle stock). It is the portion of inventory that depletes gradually with customer orders and replenished cyclically with suppliers' orders.
- Transportation Inventory – Exists because of time needed to move goods between locations (e.g. plant to DC), sometimes called pipeline or movement Inventory.

  The measures are Transit Time in Days (t) and Annual Demand (A) and the metric is Average Annual Inventory in Transit (I):

  ⇨ $I = t \times A / 365$

  An example of *average inventory* for Diesel Lube 700 Super in the *lubricants supply chain* is:

  Transit Time: 3 days (2 days from plant to depot and 1 day from depot to customer)

  Annual Demand: 12500 Drums

  Average Annual Inventory in Transit: (3 x 12500) / 365 = 102.74 Drums
- Hedge Inventory – Products such as minerals and commodities which are traded on the world market which are hedged against price fluctuations with respect to and in accordance with world supply and demand.
- Maintenance, Repair and Operational Supplies (MRO's) – Items used to support general operations and maintenance but that do not become directly part of a product, including maintenance supplies, spare parts and consumables.

[84] Arnold JRT, Chapman SN, Clive LM, 1998. p257–259

The real challenge for inventory in the lubricants supply chain revolves around the cost of keeping excess inventory as safety (buffer) stock. The mismatch occurs during periods when the manufacturing plant is not able to produce finished products as required by customers i.e. either the stock has not been forecast by sales or the manufacturing plant does not have the respective capacity and/or raw materials to produce stock for customer orders.

The management of slow moving, dead and obsolete stock becomes crucial to minimise the cost of keeping safety stock at depots and/or distribution centres.

It is even more crucial to align the management of stock with *forecast accuracy* in order to manage expectations of future sales forecast for products. If the forecast accuracy for a particular finished product is low i.e. less than 50%, then less safety stock should be kept.

A feedback loop should be put in place to revise sales forecasts for finished products based upon the historical forecast accuracy of a particular finished product, alternatively for groups of products as required for the development and maintenance of the production plan.

INVENTORY COSTS

The costs used for inventory management decisions are item cost, carrying cost and ordering cost, stock-out costs and capacity associated costs.[85]

Item Cost is the price paid for a purchased item, which consists of the cost of the item and any other direct costs associated in getting the item into the plant (e.g. transportation, custom duties and insurance). The inclusive cost is called the landed price. For an item manufactured in-house, the costs include direct material, direct labour and factory overhead.

Carrying Costs include all expenses incurred by the firm because of the volume of *inventory* carried. As inventory increases, so do these costs. They can be broken down into capital costs (money invested in inventory is not available for other uses and as such represents a lost opportunity cost) and storage costs (cost of space, workers and equipment). As inventory increases so do these costs. Risk costs entails the risks of carrying inventory are obsolescence (loss of product value resulting from a model or style change or technological development), damage (inventory damaged while being held or moved), pilferage (goods lost, strayed or stolen) or deterioration (inventory that rots or dissipates in storage or whose shelf life is limited).

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[85] Arnold JRT, Chapman SN, Clive LM, 1998. p261-264

The measures for Carrying Costs are Capital Costs%, Storage Costs% and Risk Costs% (Codification) with metrics Total Cost of Carrying Inventory% and Annual Cost of Carrying Inventory (Abstraction):

⇨ *Total Cost of Carrying Inventory% = Capital Costs% + Storage Costs% + Risk Costs%*
⇨ *Annual Cost of Carrying Inventory = Total Cost of Carrying Inventory% x Avg. Inventory*

For example, if the Total Cost of Carrying Inventory % based on estimates of *Capital Costs* (12%), *Storage Costs* (8%) and Risk Costs (5%) for South Africa is 25% then the Annual Cost of Carrying Inventory based upon an Average Annual Inventory of R20M will be R5M.

Ordering Costs are costs associated with placing an order either with the factory or a supplier. The cost of placing an order does not depend upon the quantity ordered. Ordering costs in a factory include the following costs:

Production Control Costs are the annual cost an effort expended in production control depends on the number of orders placed, not on the quantity ordered. The fewer orders per year, the less cost. The costs incurred are those of issuing and closing orders, scheduling, loading, dispatching and expediting including:

- Setup and Teardown Costs – Every time and order is issued, work centres have to be set up to run the order and tear down the setup at the end of the run. These costs do not depend on the quantity ordered but on the number of orders placed per year.
- Lost Capacity Cost – Every time an order is placed at a work centre, the time taken to set up is lost as productive output time. This represents a loss of capacity and is directly related to the number of orders placed.
- Purchase Order Cost – Every time a purchase order is placed, costs are incurred to place the order. These costs include order preparation, follow-up, expediting, receiving, authorising payment and the accounting costs of receiving and paying the invoice.

  The measures for Ordering Costs are Fixed Costs, Variable Costs and No Orders (Codification) and the metric is Average Cost per Annum (Abstraction):

  ⇨ *Average Cost = (Fixed Costs / No Orders) + Variable Costs*

  For example, the Average Cost of placing an order based upon estimates will be:

  Production Control Salaries = R2M
  Supplies & Operating Expenses for Production Control Department = R500K
  Fixed Costs (per annum) = R2M + R500K = R2.5M

  Variable Cost = Cost of setting up work centres for an order = R5K

  No Orders (per annum) = 2000

  Average Cost = (Fixed Costs/No Orders)+Variable Cost = (R2.5M/2000)+R5K = R6, 250

Stock-out Costs relate to when demand during the lead time exceeds forecast, we can expect a stock-out. A stock-out can potentially be expensive because of back-order costs, lost sales and possibly lost customers. Stock-outs can be reduced by carrying extra inventory to protect against those times when the demand during the lead time is greater than the forecast.

Capacity Associated Costs are incurred when output levels must be changed, there may be costs for overtime, hiring, training, extra shifts and layoffs. These costs can be avoided by levelling production i.e. producing items in slack periods for sale in peak periods.

The measures for Capacity Associated Costs are Forecast Demand, Production, Ending Inventory and Inventory Carrying Costs (Codification) and the metrics are Average Inventory and Inventory Cost per period (Abstraction):

⇨ *Production per Period = sum of Forecast Demand / No Periods*

⇨ *Ending Inventory per Period = Previous Period Ending Inventory + Forecast Demand – Production*

⇨ *Average Inventory per Period = (Previous Period Ending Inventory + Ending Inventory)/2*

⇨ *Inventory Cost per Period = Average Inventory per Period x Carrying Costs*

An example of *Capacity Associated Costs* in the *lubricants supply chain* for Diesel Lube 700 Super based upon an estimated *Inventory Carrying Costs* of R30 per unit is depicted in Table 3.11 below:

Period		**Quarter 1**	**Quarter 2**	**Quarter 3**	**Quarter 4**	**Total**
Forecast		20000	30000	30000	40000	120000
Production		30000	30000	30000	30000	120000
Ending Inventory	50000	60000	60000	60000	50000	
Average Inventory		55000	60000	60000	55000	
Inventory Cost (R)		1.65M	1.8M	1,8M	1.65M	6.9M

Table 3.11 – Inventory Carrying Costs

Source: compiled by researcher

For Inventory Carrying Costs, *forecasts* and *production* are grouped per quarter (codification) and the *ending inventory, average inventory* and *inventory cost* are calculated per quarter.

FINANCIAL INVENTORY PERFORMANCE MEASURES[86]

From a financial point of view, inventory is an *asset* and represents money that is tied up and cannot be used for other purposes. As inventory has a carrying cost, finance wants as little inventory as possible and needs some measure of the level of inventory. Total inventory investment is one measure, but in itself does not relate to sales.

Measures that relate to sales are Inventory Turns and Days of Supply:

Inventory Turns is a convenient measure of how effectively Inventories are being used.

The measures for Inventory Turns are Annual Costs of Goods Sold and Average Inventory Cost (Codification) and the metric is Inventory Turns (Abstraction):

⇨ *Inventory Turns = Annual Costs of Goods Sold / Average Inventory Cost*

Inventory Turns will be evaluated to determine how to increase *inventory turns* in order to reduce inventory, alternatively to reduce the cost of carrying inventory to obtain a saving in the inventory carrying costs.

An example of *Inventory Turns* for Diesel Lube 700 Super in the *lubricants supply chain* based upon an estimated *Annual Costs of Goods Sold* and *Average Inventory Cost*:

Annual Costs of Goods Sold = R48M

Average Inventory Cost = R6M

Inventory Turns = Annual Costs of Goods Sold/Average Inventory Cost = R48M/R6M = 8

If the *Inventory Turns* were increased to 12 times per year the *Average Inventory Cost* will be reduced from 6M to 4M:

Average Inventory Cost = Annual Costs of Goods Sold / Inventory Turns
= R48M / 12
= R4M

If the cost of carrying inventory is 25% then the savings in inventory carrying costs will be 25% of R4M = R1M.

86 Arnold JRT, Chapman SN, Clive LM, 1998. p268-269

Days of Supply measure of the equivalent number of days of inventory on hand, based on usage.

The measures for Days of Supply are Inventory On Hand and Average Daily Usage (Codification) and the metric is Days of Supply (Abstraction):

⇨ *Days of Supply = Inventory On Hand / Average Daily Usage*

Days of Supply will be evaluated by monitored by *inventory on hand* to check if it is sufficient to cater for required levels of safety stock.

An example of *Days of Supply* for Diesel Lube 700 Super in the *lubricants supply chain is as* follows*:*

Units On Hand = 500 units

Average Annual Usage = 120,000 units

Working Days per Year = 240

Average Daily Savings = 120,000 / 240 = 500 units

Days of Supply = Inventory on Hand / Average Daily Usage
= 5000 / 500
= 10 days

INVENTORY EVALUATION

There are four methods accounting uses to cost the inventory.[87] Each has its implications for the value placed on inventory. If there is little change in the price of an item, any one of the four will produce about the same results.

However, in rising and falling prices, there can be a pronounced difference. There is no relationship with the actual physical movement of actual items in any of the methods.

Whatever method is used is only to account for usage:

[87] Arnold JRT, Chapman SN, Clive LM, 1998. p270

- First In First Out (FIFO) – This method assumes that the oldest (first) item in Stock is sold first. In rising prices, replacement is at a higher price than the assumed cost. This method does not reflect current prices. The reverse is true in a falling price market.
- Last In First Out (LIFO) – This method assumes that the newest (last) item in stock is sold first. In rising prices, replacement is at the current price. In a falling price market existing inventory is overvalued. However, the company is left with an inventory that may be grossly understated in value.
- Average Cost – This method assumes an average of all prices paid for the article. The problem with this method in changing prices (rising or falling) is that the cost used is not related to the actual cost.
- Standard Cost – The method uses cost determined before production begins. The cost includes direct material, direct labour and overhead. Any difference between the standard cost and actual cost is stated as a variance.

In the *lubricants supply chain*, the average price mechanism is used to evaluate inventory, often referred to as the Moving Average Price (MAP) as prices of raw materials used in the blending of finished products i.e. base oils, additives and wax, are based upon their 'import parity price'[88].

[88] Import Parity Price - A price charged for a domestically produced good that is set equal to the domestic price of an equivalent imported good, thus the world price plus transport cost plus tariff. (www.encyclo.co.uk)

ABC INVENTORY CONTROL[89]

Control of inventory is exercised by controlling individual Items, which is called Stock Keeping Units (SKU's).

In controlling inventory, the following questions must be answered:

- What is the importance of the inventory item?
- How are they to be controlled?
- How much should be ordered at one time?
- When should an order be placed?

The ABC classification system answers the first two questions by determining the importance of items and thus allowing different levels of control based upon relative importance of items.

The ABC principle is based on the observation that a small number of items often dominate the results achieved in a situation (Pareto law). As applied to inventories, it is usually found that the relationship between the percentage of items and the percentage of annual spend usage follows a pattern in which three (3) groups can be defined:

- Group A (high priority) – About 20% of the items account for about 80% of the spend usage
- Group B (medium priority) – About 30% of the items account for about 15% of the spend usage
- Group C (low priority) – About 50% of the items account for about 5% of the spend usage

The steps in defining an ABC classification are:

- Establish the item characteristics that influence the results of inventory management. This is usually spend usage, but may be other criteria e.g. scarcity of material
- Classify items into groups based upon established criteria
- Apply a degree of control in proportion to the importance of the group

[89] Arnold JRT, Chapman SN, Clive LM, 1998. p270-271

Procedure – The procedure for classifying by annual spent usage is as follows:

- Determine the annual usage of each item
- Multiply the annual usage of each item by its cost to get its total annual spend usage
- List the items in according to their annual spend usage
- Calculate the cumulative annual spend usage and the cumulative percentages of items
- Examine the annual usage distribution and group the items into A, B and C groups based on percentage of annual usage.

Rules – Using the ABC approach, there are two general rules to follow:[90]

- Have Plenty of Low-Value items – "C" Items represent about 50% of the items but account for only about 5% of the total inventory value. Carrying extra "C" items adds little to the total value of the Inventory. "C" items are only really important if there is a shortage of one of them, so a supply should always be on hand.
- Use the Money and Control Effort Saved (to reduce the inventory of high-value items) – "A" items represent 20% of the items and account for about 80% of the value. They are extremely important and deserve the tightest control and most frequent review.

Controls – Different controls used with different classifications might be the following:[90]

- "A" Items (high priority) – Tight control including complete accurate records, regular and frequent Review by management, frequent review of demand forecasts and close follow-up and expediting to reduce lead time.
- "B" Items (medium priority) – Normal control with good records, regular attention and normal processing.
- "C" Items (low priority) – Simplest possible controls, simple or no records (use of a two-bin system or periodic review system). Order large quantities and carry safety stock.

In the *lubricants supply chain*, weekly stock management meetings are held to review the levels of stock in terms of sales forecasts and adherence to controls for "A" items, with similar monthly meetings for "B" items. Minimal controls and large runs with safety stock are evident for "C" items.

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[90] Arnold JRT, Chapman SN, Clive LM, 1998. p273-274

3.2.7 Distribution

Physical distribution is the movement of materials from the producer to the consumer.

The physical distribution system involves the transportation of goods through the various modes, the inventory that exist in-transit and in distribution centres, the physical handling of goods and the need for protective packaging.[91]

CHANNELS OF DISTRIBUTION

A *channel of distribution* is one or more companies or individuals (intermediaries) who participate in the flow of goods and/or services from the producer to the final user or consumer. Intermediaries include wholesalers, agents, transporters and warehousers.

There are two related channels:

- Transaction Channel – Transfer of ownership with the function to negotiate, sell and contract
- Distribution Channel – Transfer of delivery of the goods or services[91]

Whereas manufacturing adds form value to a product by taking the raw materials and creating something more useful, distribution adds place value and time value by placing goods in markets where they are available to the consumer at the time the consumer wants them.

The specific way in which materials move depends upon many factors:

- Channels of Distribution – Producer to wholesaler to retailer to consumer
- Types of Markets Served – Market characteristics such as the geographic dispersion of the market, the number of customers and the size of orders
- Characteristics of the Product – Weight, density, fragility and perish ability
- Type of Transportation Available – Trains, ships, planes and trucks.[91]

[91] Arnold JRT, Chapman SN, Clive LM, 1998. p360-362

PHYSICAL DISTRIBUTION SYSTEM

Physical distribution is responsible for delivering to the customer what is wanted on time and at minimum cost. The objective of distribution management is to design and operate and distribution system that attains the required level of customer service and does so at least total cost which includes:

- Transportation – Transportation involves the various methods of moving goods outside the firm's buildings. For most firms, transportation is the single highest cost in distribution (30-60%).
- Distribution Inventory – Distribution inventory includes all finished goods inventory at any point in the distribution system. In costs terms, it is the 2nd most important item in distribution (25-30%).
- Warehouses (Distribution Centres) – Warehouses are used to store inventory. The management of warehouses makes decisions on site selection, no of distribution centres, layout, and methods of receiving, storing and retrieving goods.
- Materials Handling – Materials handling is the movement and storage of goods inside the distribution centre. The type of materials handling equipment used affects the efficiency and cost of operating the distribution centre.
- Protective Packaging – Goods moving in a distribution system must be contained, protected and identified. In addition, goods are moved and stored in packages and must fit the dimension of the storage spaces and the transportation vehicles.
- Order Processing and Communication – Order processing includes all activities needed to fill customer orders. Order processing represents a time element in delivery and is an important part of customer service. Many intermediaries are involved in the movement of goods, and good communication is essential to a successful distribution system. [92]

In the *lubricants supply chain* the effectiveness of the physical distribution system is measured by the number of deliveries which are delivered to customers within a Service Level Agreement (SLA), typically 48 hours from order placement (where most companies have a cut-off time for order placement when the SLA starts).

[92] Arnold JRT, Chapman SN, Clive LM, 1998. p364–365

The SLA is measured against a target per customer tier e.g. 95% for tier 1, 90% for tier 2 and 80% for tier 3 based upon the success of the delivery On Time In Full (OTIF) in terms of customer expectations.

A delivery failure occurs (i.e. delivery takes place after the deemed SLA or the quantity delivered is less than the customer order) as a result of a stock shortage, an order change after the order has been scheduled for delivery, motor vehicle incident or product return.

The measures for Physical Distribution are Customer Order Fulfilment (COF) and Customer Delivery Reliability (Codification) and the metrics are On Time In Full OTIF, On Time In Short OTIS, Late Delivery and Total Deliveries per period (Abstraction):

⇒ *OTIF = Delivery On Time In Full per period*

⇒ *OTIS = Delivery On Time In Short per period*

⇒ *Late Delivery = Delivery after SLA*

⇒ *Total Deliveries = Total Deliveries per period*

⇒ *COF = OTIF / Total Deliveries*

⇒ *Delivery Failures = OTIS + Late Deliveries*

⇒ *CDRM = 100 – (Delivery Failures / 1000)*

An example of *COF and CDRM* follows:

Total Deliveries = 1250 deliveries

OTIF = 1200 deliveries

OTIS = 20 deliveries

Late Deliveries = 30 deliveries

Delivery Failures = OTIS + Late Deliveries
= 20 + 30
= 50 deliveries

COF = OTIF / Total Deliveries
= 1200 / 1250
= 96%

CDRM = 100 – (Delivery Failures / 1000)
= 100 – (50 / 1000)
= 95%

TRANSPORTATION

To provide a transportation service, the carrier must have certain basic elements:[93]

- Ways – Paths over which the carrier operates. They include the right-of-way (land area being used) plus any roadbed, tracks or other physical facilities needed on the right-of-way.
- Terminals – Places where the various carriers load and unload goods to and from Vehicles and make connections between local pickup and delivery service and line-haul service. Other functions performed at terminals are weighing, connecting with other routes and carriers, vehicle routing, dispatching and maintenance, as well as administration and paperwork.
- Vehicles – Serve as carrying and power units to move the goods over the ways.

Modes of Transport – The carriers of transportation can be divided into five basic modes viz. Rail, Road, Air, Water and Pipeline.[93]

Each mode has different *Cost and Service characteristics* which determine which method is appropriate for the types of goods to be moved. Cost trade-offs thus has to be considered against service levels.

Transportation Cost Elements – Goods move either directly from the shipper to the consignee or through a terminal, where they are picked up in some vehicle suitable for the short-haul local travel. They are then delivered to a terminal where they are sorted according to destination and loaded onto highway vehicles for travel to a destination terminal. There, they are again sorted, loaded on local delivery trucks and taken to the consignee.[93]

For the *lubricants supply chain* in South Africa, manufacturing facilities for oil majors are situated in Port of Durban where raw materials are either imported via ship or sourced from local refineries via pipeline (inbound logistics). From the manufacturing facilities, finished products are sent to the respective distribution centres (primary distribution) in the major cities mainly via road as they are more reliable than rail. Rail is used only for specialised railroad oils used by Transnet for their rail cars. Limited pipeline usage is considered for bulk lubricants as some of the finished products have to be heated and South Africa has limited heated pipeline infrastructure with excessive tariffs as they are costly to operate.

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[93] Arnold JRT, Chapman SN, Clive LM, 1998. p369-373

From the DC's, the finished products are sent to customers (secondary distribution) via road as the most reliable and cost effective mechanism. See Figure 3.6 below.

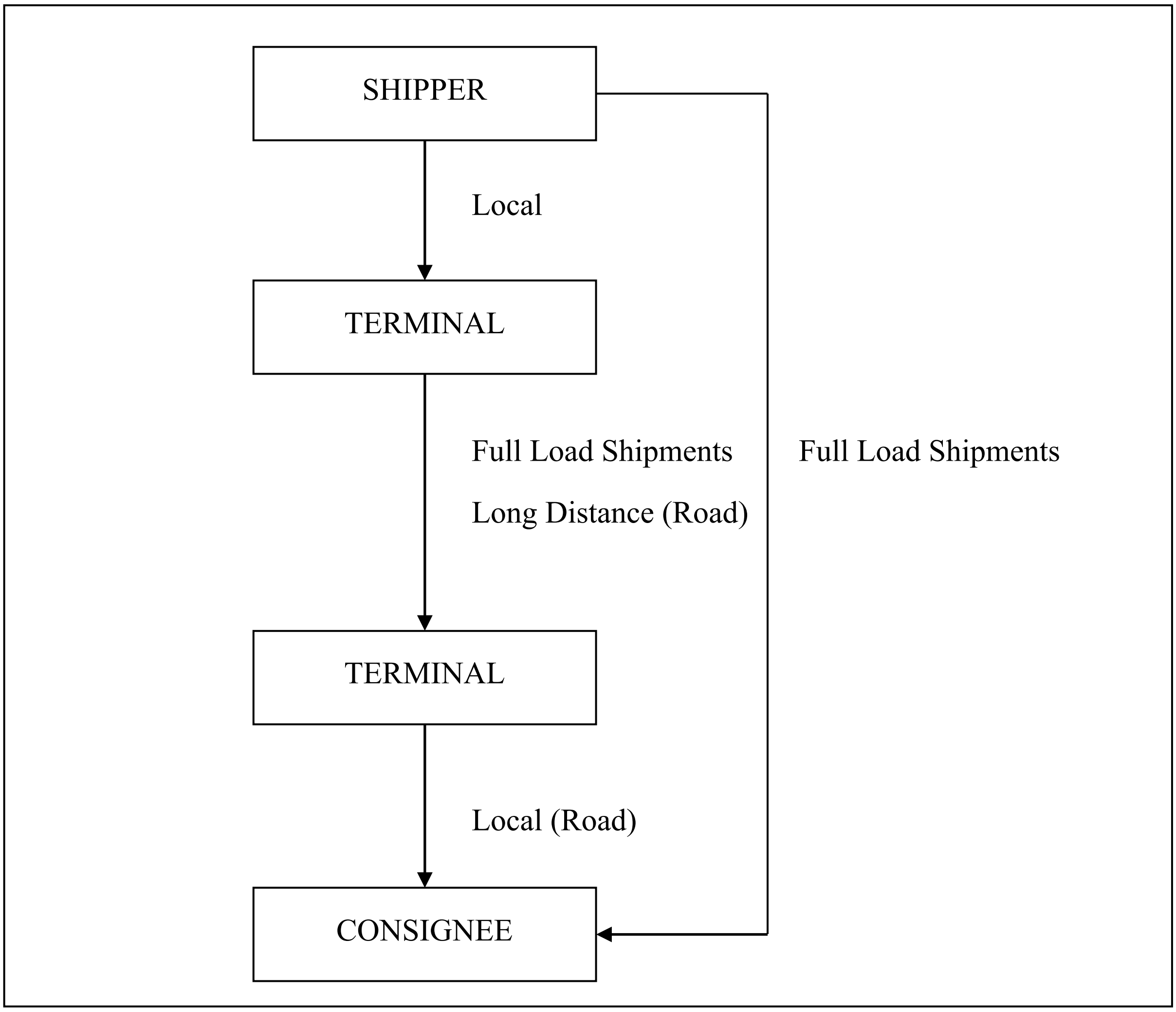

Figure 3.6: Shipping Patterns

Source: Arnold JRT, Chapman SN, Clive LM, 1998.

There are four basic cost elements in transportation:[94]

- Line Haul – When goods are shipped, they are sent in a moving container with a weight & volume capacity. The carrier has basic costs to move the container (which exist whether the container is full or not). For trucks, these include the driver's wages and depreciation for usage. The costs vary with distance travelled, not weight carried.

  The measures for Line Haul are Line Haul Cost per km, Distance in km and Volume (Codification) *and the metric is Line Haul Cost per Hundredweight* (Abstraction)*:*

  $\Rightarrow$ *LHC/cwt = (Line Haul Cost x Distance) / Volume*

[94] Arnold JRT, Chapman SN, Clive LM, 1998. p372-376

- Pickup and Delivery – Similar to line-haul costs, except that the cost depends more on the time spent than on the distance travelled. The carrier will charge for each pickup and the weight picked up. If the shipper is making several shipments, it will be less expensive if they are consolidated and picked up in one trip.
- Terminal Handling – Costs depend on the number of times a shipment must be loaded, handled and unloaded. If full truckloads are shipped, the goods need not be handled in the terminal but can go directly to the Consignee. If part loads are shipped, they must be taken to the terminal, unloaded, sorted and loaded onto a highway (*long haul*) vehicle. At the destination, the goods must be unloaded, sorted and loaded onto a local delivery vehicle (*short haul*). Each individual parcel must be handled. A shipper who has many customers, each ordering small quantities, will expect the terminal handling costs to be high because there is a terminal handling cost for each package.
- Billing and Collection – Every time a shipment is made, paperwork must be done and an invoice made out billing and collection costs can be reduced by consolidating shipments and reducing the pickup frequency.

WAREHOUSING

Warehouses include plant warehouses, regional warehouses and local warehouses. From a physical distribution perspective, warehouses serve three important roles viz. Transportation Consolidation, Product Mixing and Service.[95]

Transportation Consolidation – Transportation can be reduced by using warehouses. This is accomplished by consolidating small Less On-Truckload (LTL) shipments into large Truck Load (TL) shipments. Consolidation can occur in both the supply and distribution systems. In physical supply, LTL shipments from several suppliers can be consolidated at a warehouse before being shipped at TL to the factory. In physical distribution, TL Shipments can be made to a distant warehouse and LTL shipments made to local users (break bulk).

Product Mixing – Although transportation consolidation concerns reducing transportation costs, product mixing deals with grouping of different items into an order and the economies warehouses can provide in doing this. When customers place orders, they often want a mix of products that are produced in different locations. Without distribution centres, customers would have to order from each source and pay from LTL transport from each source. Using a distribution centre, orders can be placed and delivered from a central location.

[95] Arnold JRT, Chapman SN, Clive LM, 1998. p376 – 379

Service – Distribution centres improve customer service by providing place utility. Goods are positioned close to markets so the markets can be served more quickly.

The measures for Warehousing are Plant-To-Customer LTL Costs per cwt, Plant to Distribution Centre TL Costs per cwt, Inventory Carrying Cost of DC per cwt, Distribution Centre to Customer LTL Costs per cwt and Volume (Codification) and the metrics are Direct Delivery Costs, DC Delivery Costs and Saving (Abstraction):

⇨ *Saving = Direct Delivery Costs – DC Delivery Costs*

= (Plant to Customer LTL Costs per cwt x Volume) –

(Plant To Distribution Centre TL Costs per cwt +

Inventory Carrying Cost of DC per cwt +

Distribution Centre to Customer LTL Costs per cwt) x Volume)

Market Boundaries – Laid-Down Cost (LDC) is the delivered cost of a product to a particular geographic point. The delivered cost includes all cost of moving the goods from A to B. [96]

The measures for Laid-Down Cost are Product Costs per cwt (P), Transportation Costs per km (T) and Distance in km (X) and the metric is Laid Down Cost per cwt (LDC):

$\Rightarrow$ $LDC = P + TX$

The *market boundary* is the line between two or more supply sources where the laid down cost is the same.

The measures for Market Boundary are Product Costs per cwt (PA and PB), Transportation Costs per km (TA and TB) and Distance in km (Y) (Codification) and the metric is Market Boundaryin km(X) (Abstraction):

$\Rightarrow$ $LDC_A = LDC_B$

$\Rightarrow$ $PA + TA \times X = PB + TB \times (Y - X)$

$\Rightarrow$ $(TA \times X) = PB - PA + (TB \times Y) - (TB \times X)$

$\Rightarrow$ $(TA \times X) + (TB \times X) = PB - PA + (TB \times Y)$

$\Rightarrow$ $(TA + TB) \times X = PB - PA + (TB \times Y)$

$\Rightarrow$ $X = (PB - PA + (TB \times Y)) / (TA + TB)$

96 Arnold JRT, Chapman SN, Clive LM, 1998. p380-381

For the *lubricants supply chain* in South Africa, the market boundary concept is not used as the various Lubricants Distribution Centres (DC's) of the oil majors viz. BP/Castrol, Shell, Petronas/Engen, Chevron/Caltex and Total, are situated in the major cities in South Africa (including Durban, Johannesburg, Cape Town and Port Elizabeth).

Most Oil & Gas companies use a scheduling and transportation system viz. Aspen-One or OR-Tech, which incorporate linear algebra techniques for management of finite resource and constraints. These systems are used to plan and schedule the optimal distribution of finished products to customers from their distribution centres and depots. Priority customers are given preference for orders of finished products during times of scarcity or stock-outs.

In summary, Chapter 3 listed the various supply chain processes and associated *measures and metrics* evident in the *supply chain,* with specific reference to their usage in the *lubricants supply chain*.

Chapter 4 will provide an overview of the *lubricants supply chain* in terms of the value chain and lower level business processes for the analysis of the codification and abstraction of knowledge assets. It will provide a lubricants supply chain framework as a benchmark for the planning and implementation of new lubricants supply chains, alternatively for the review of an existing lubricants supply chain.

Chapter 4
The Lubricants Supply Chain

4 Lubricants Supply Chain Processes

4.1 Introduction & Overview

The purpose of the chapter on the *lubricants supply chain* is to define the overall *value chain* and inherent lower level processes in order to determine how codification (perceptual) and abstraction (conceptual) takes place for information processing and transmission.

As extracted from Boisot [97] it can be deducted that co*dification* is a process of giving form to phenomenon or to experience, whereas *abstraction* is the process of discerning the structures that underlie the forms. They often work in tandem to reduce the data processing load imposed on an agent as well as facilitate communication processes and hence the *diffusion* of information. If *knowledge assets* allow us to economise on consumption of physical resources per unit of effort, then codification and abstraction, in turn, allows us to economize on data-processing and communication efforts required either to create or exploit knowledge. In short, codification and abstraction lowers the cost of converting potentially useful knowledge into knowledge assets.

So what is a Knowledge Asset in the context of data, information and knowledge?

In accordance to Boisot [97], the following definitions will suffice:

- Data – A discernable difference between alternative states of a system, made up of low level energy that *acts informational* rather than mechanically upon an observer.
- Information – Data that *modifies expectations of the conditional readiness* of an observer. The more those expectations are modified, the more informative the data is said to be.
- Knowledge – Set of expectations that an observer holds with respect to an event. It is a *disposition to act in a particular way* that is *inferred from behaviour* rather than observed.
- Knowledge Assets – That subset of dispositions to act that is *embedded* in individuals, groups or artefacts that have *value-adding* potential.

[97] Boisot, MH. 1995

The outcome of the research will be to understand the types of knowledge assets that exist in supply chains, and ultimately how decision making is affected in the context of differentiation and creation of core competencies in the broader lubricants industry in South Africa.

At a high level, raw materials (base oil, additives, wax, containers, caps and seals) are supplied via procurement into the manufacturing facility (*inbound logistics*) and stored in tanks prior to the blending and filling operations during the *manufacturing* (blending and packaging of the various lubricants finished products).

The manufactured volumes are based upon sales forecasts and related customer orders, and subsequently sold and distributed via distribution centres to either 3rd parties (retailers, franchises or distributors) for sale / distribution or customers for use during *primary distribution* and *order delivery*, respectively. At Customer sites, the lubricants finished products are used in either new machinery or ongoing maintenance of existing machinery.

For retailers and franchises, the lubricants finished products are sold to their respective customers for use. Customers in the automotive, mining, agriculture, mills, cement, industrial, marine, aviation, retail and power sectors utilise the bulk and/or packaged lubricants for lubrication of vehicles and moving equipment and/or parts, either for their first fill (i.e. before commissioning) or the ongoing maintenance of the respective equipment in order to reduce friction of the parts and subsequently wear and tear.

For distributors, the lubricants finished products (mainly packaged lubricants) are either delivered to or collected by customers for use.

The flow of raw materials and lubricants products is depicted in Figure 4.1 below which will be analysed further in terms of their lower level processes as part of the broader lubricants value chain.

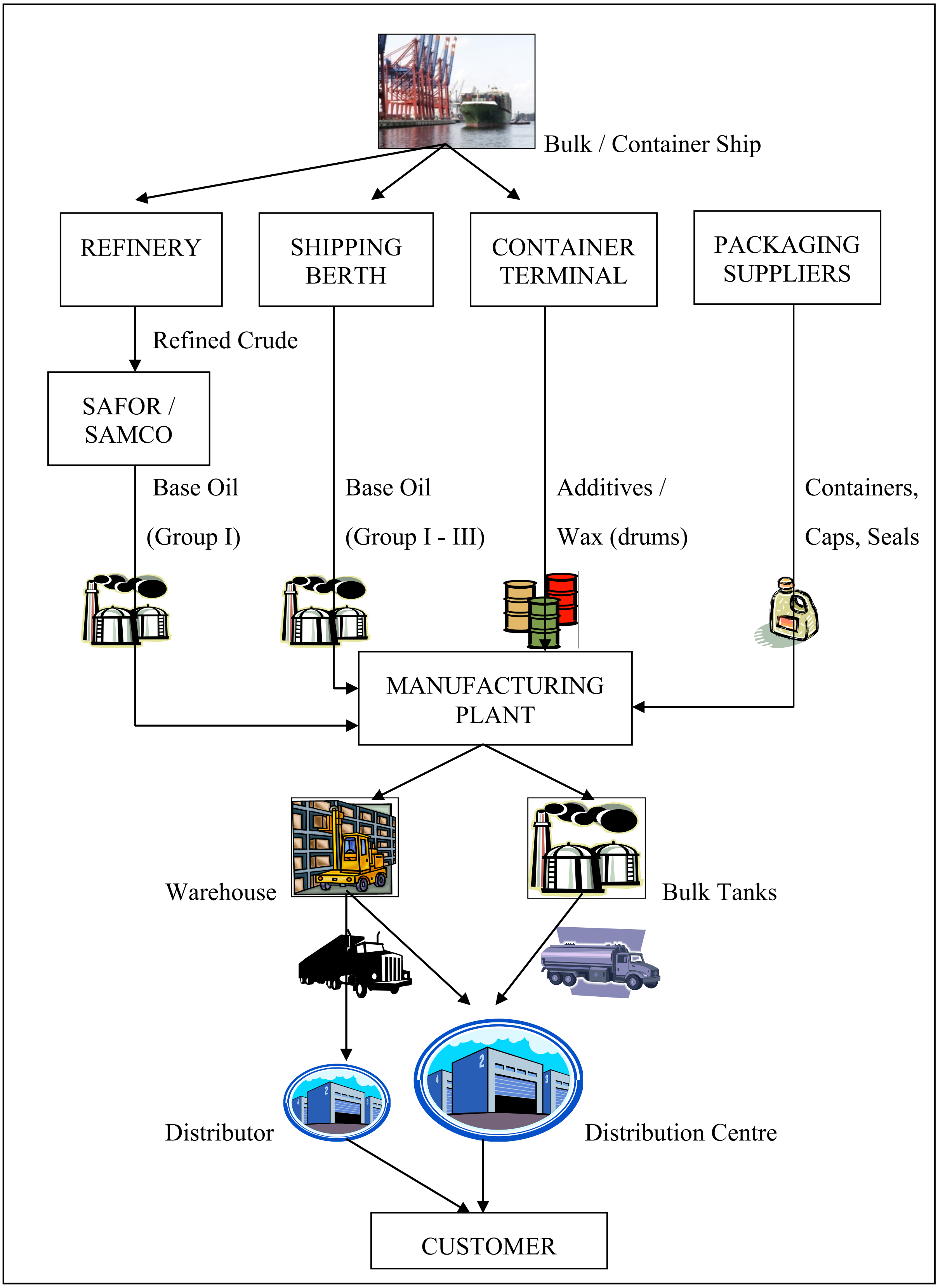

Figure 4.1: Lubricant Raw Material and Products Flows

Source: developed by researcher

4.2 The Lubricants Value Chain

The *lubricants value chain* consists of business processes and associated procedures for Procurement and Supply (Inbound Logistics), Manufacturing and Distribution (Primary Distribution). This occurs in parallel to the sales and marketing processes of Product Life-Cycle Management, Marketing and Sales, Order Management, Order Delivery (Secondary Distribution / Outbound Logistics), Third Party Management and Sales (Franchises and Distributors), Billing and Payment and After Sales Service.

These High Level processes are depicted in Figure 4.2 below:

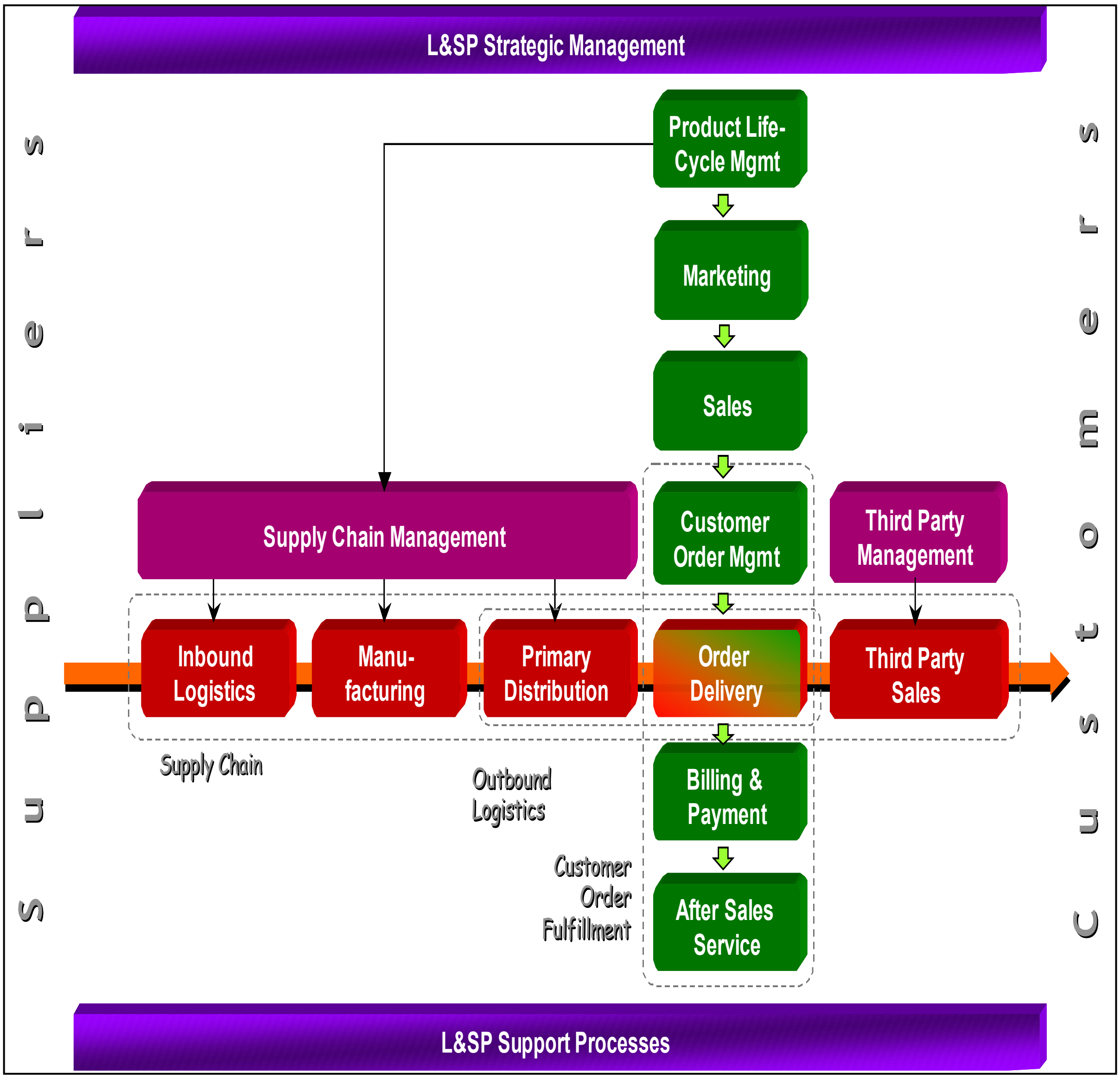

Figure 4.2: Lubricants Value Chain

Source: compiled from observation of research material

The focus will be on the lower level processes inherent in the Inbound Logistics (Supply), Manufacturing and Primary Distribution processes as these are unique to particular organisations in the *lubricants supply chain. They* can thus be used for differentiation against the dimensions of Cost, Quality, Flexibility, Reliability, Service and Innovation, which are common in the strategies of companies in the oil & gas industry; as well as the creation of *core competencies* in order to gain *competitive advantage*.

Differentiators will be identified in terms of the inherent characteristics of "Products, People and Performance"[98] across the different organisations in order to identify what makes them unique and not easy to replicate by competitors.

The Inbound Logistics (Supply), Manufacturing and Primary Distribution processes are encapsulated in the Materials Management (MM) module in an Enterprise Resource Planning (ERP) system viz. SAP, JDE and Oracle; used by Oil & Gas companies in the *lubricants supply chain* to automate their supply chain processes. Knowledge about the unique characteristics of an organisation is embedded in the business rules and procedures as automated by these best practice ERP systems, which have been customised to suit the particular business processes of an organisation and makes them difficult to easily replicate by competitors.

4.2.1 Inbound Logistics (Supply)

The aim of Inbound Logistics is to source the right raw materials and finished products (for stock) at the optimal cost in the correct quantity just-in-time to meet agreed customer requirements. It consists of the Place Order on Supplier, Receive and Store Stock, Assume Product Quality, Pay Supplier processes for further analysis.

Codification and abstraction in the inbound logistics process takes place with the identification of suppliers of raw materials for the lubricants blending and packaging operations (codification) and their subsequent categorisation based upon the type of raw material (abstraction i.e. utilisation based upon processed information).

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[98] Garratt B, 2003. p152

Negotiations take place in setting various terms and conditions, pricing and escalations, delivery turnaround times / SLA, target volumes as well as incentives and penalties which are stipulated in a supply contract.

Further identification of inbound tankage for storage of bulk base oils takes place in order to accommodate expected volumes of required as well as buffer / safety stock to last for at least a month (which is the turnaround time for placement of orders and their receipt from suppliers in South Africa or via Imports).

The creation of drum storage for additives and wax is also required based upon expected volumes a well as buffer / safety stock to last for at least a month.

The *place order on supplier* process starts with the procurement of raw materials for the lubricants blending and packaging operations. For lubricants blending, the raw materials are base oil, additives and wax. For lubricants packaging they are containers (viz. 500 ml tins, 1L or 5L plastic bottles, 20L pails and 210L drums), labels, caps and seals.

The categorisation of suppliers into groups takes place depending on the type of raw material i.e. base oil, additives, wax, tins, plastic bottles, bottle caps, bottle seals, drums, drums seals and labels (bottles and drums). They are further abstracted into their categorisation of suppliers of containers and labels as these are distinct operations.

Suppliers of bulk base oils to the lubricants industry in South Africa are further segmented into local (SAFOR and SAMCO[99]) as well as import suppliers for group I base oils (used in non-synthetic product formulations) and group III base oils (used in synthetic product formulations). For the purchase of group I base oils, SAFOR and SAMCO are the preferred suppliers as the cost is much lower than those imported viz. Jurong via ship from Singapore.

Suppliers of additives to the to the lubricants industry in South Africa include Protea Speciality Chemicals, Lubrizol, Aktol Chemicals, Octel and Chevron (Oronite). Additives are supplied in 210L drums to the respective manufacturing plant for use in blending operations. The major supplier of wax in South Africa is Sasol with limited supply imported.

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[99] SAFOR and SAMCO – Consortiums of oil majors in South Africa who provide group I base oil to the local industry in South Africa. SAFOR is operated by Engen Petroleum Limited, Chevron and Total (downstream to the Engen refinery ENREF) with output of 145,000 Tonnes per annum and SAMCO by BP and Shell (downstream to the SAPREF Refinery) with output of 155,000 Tonnes per annum.

Suppliers of lubricants containers to the lubricants industry in South Africa include Pack 2000 (Astrapak) who supply blow-moulded thermoformed and can packaging with labelling. Labels for 210L drums and 20L pails are outsourced to suppliers (e.g. FerroPrint).

The major differentiators in the place order on supplier process are *cost* (affecting finished product costs), *quality* and *reliability* (availability and security of supply for blending requirements).

The *receive and store stock* process pertains to raw materials, were base oil is received via pipeline in bulk and stored in tanks within the blending facility whereas the additives and wax are received in 210L drums and stored in a pre-blending facility.

Empty containers are received by truck in shrink-wrapped pallets, along with boxed caps and seals, and stored in a pre-filling facility. Labels are received as a plastic wrapped package and stored in a pre-filling facility.

Buffer (safety) stock for a month is usually kept in order to accommodate shortages of supply, based upon procurement lead times.

The major differentiator in the receive-and-store stock process is *cost* (bulk storage and handling affecting facility fixed costs and ultimately finished product costs) with *reliability* (timeous storage and disbursement of raw materials for blending) considered secondary.

The *assume product quality* process entails the laboratory testing of raw materials for blending i.e. base oil, additives and wax.

The differentiator in the assume product quality process is *quality* (timeous testing of product quality and issuance of certificate of acceptance).

The *pay supplier* process is a standard payment for receipt of raw materials based upon an invoice received from the particular supplier. For imports, sometimes forward cover is negotiated based upon agreed exchange rates.

The differentiator in the pay supplier process is *cost* (usually as a supply contract negotiated with the supplier along with target incentives and penalties).

Knowledge assets for suppliers are embedded in the costs of raw materials, their quality and the reliability of suppliers:

- ✓ Cost – Historical costs for raw material costs from the different supplier groups (e.g. base oil, additive and wax suppliers) in conjunction with exchange rates and international crude oil prices are mapped over time to determine where the most supplier value has been obtained. This adds value to decisions about future purchases and is regarded as a knowledge asset as well as core competency as competitors cannot easily replicate the knowledge gained.

  Historical costs for raw material storage costs in tanks (base oil) and drums (additives and wax) are determined by the fixed and operational costs per annum divided by the number of tanks turns to be used as a benchmark for the subsequent year(s), another knowledge asset which adds value to decision making using past and potentially future costs.

  Historical costs for supplier payments along with incentives/penalties are recorded in the financial systems for future reference in supplier contract negotiations as knowledge asset.

- ✓ Quality – Raw materials are tested prior to a batch being used for a blend where off-specification raw materials are identified and a claim instituted against the supplier, although this happens rarely making trend analysis difficult. A record of off-specification raw materials per supplier is kept and if the frequency increases analysis may be useful. For each batch of raw materials purchased a sample is taken prior to use in blending of finished products and laboratory tests of viscosity and density performed. Records of results are stored in a Laboratory management system for future reference.

  These knowledge assets add value as they are required for decision making related to selection of suppliers of quality raw materials.

- ✓ Reliability – When an order is placed for raw materials from a particular supplier, the order may arrive late against a contractual SLA with the supplier, alternatively the full volume ordered my not be received. No record is kept of such late deliveries or part orders which should be tracked over time to determine supplier reliability. Any delays in making raw materials available for blending into finished products in the manufacturing plant will happen infrequently but will nevertheless be recorded and the impact on stock shortages highlighted as required to add value once again to as a knowledge asset to aid selection of suppliers of raw materials who deliver as promised in terms of an SLA.

4.2.2 Manufacturing

The aim of Manufacturing is to produce the right products in the right quantity and quality to meet agreed customer requirements, just in time, at an optimal cost to the supply chain. It consists of the Conduct Plant Level Planning, Blend Product, QA Product, Package Product, Store Product processes for further analysis.

Codification and abstraction in the manufacturing process takes place with the creation of manufacturing lines (codification) in conjunction with the various package types based upon customer requirements (abstraction), as well as warehousing for finished products (codification) to cater for storage and picking of segmented bulk and packaged finished products (abstraction).

The conduct plant level planning process determines which products to blend in the available blending kettles and to package on the manufacturing lines in the continuous manufacturing operations. These are based upon a *strategic business plan* which specifies annual volume targets for the families of products, associated sales forecasts as well as emergency sales requirements to fulfil priority customer orders and back orders.

A **Production Plan** is created for the monthly blends of the lubricants family of products e.g. Automatic Transmission Fluid (ATF), irrespective of the packaging requirements along with the *resource plan* indicating staffing requirements for blending operations.

For the production plan, the *production per month* is determined with no ending inventory as all blends will be packaged on the manufacturing lines in the filling, capping and sealing steps and the blending kettles used for subsequent blends.

⇨ *Production per Month =Production / 12*

The **Master Production Schedule (MPS)** is created for the finished products per pack size e.g. ATF in 5L and 1L Packs, as required on a monthly basis for the usage of the respective manufacturing lines for container filling, capping and sealing**.** For the MPS, the *production per period* is determined based upon ending inventory and opening inventory whereas the ending inventory is determined based on opening inventory, production and demand.

⇨ *Production per Month = (Total Production + Opening Inventory – Ending Inventory) / 12*

⇨ *Ending Inventory per Period = Opening Inventory + Production – Demand*

The **Preliminary MPS** is created for finished products per pack size required on a monthly basis (for the usage of the respective manufacturing lines for container filling, capping and sealing) along with the *rough-cut capacity plan*.

For the preliminary MPS, the *projected available per period* is determined based upon the inventory of the prior period and forecast demand, whereas the MPS per period is determined based upon manufacturing lot where projected available is negative.

⇨ *Projected Available per Period = (Inventory of prior Period – Forecast Demand)*

⇨ *MPS per period = Manufacturing Lot where Projected Available is negative*

For the **Rough-Cut Capacity Plan**, the *assembly time per product model* is determined based upon the number of product models (finished product) x build time of product model and the *resource bill* is the sum of assembly time per product model for each of the lubricants manufacturing lines.

⇨ *Assembly Time per Product Model = (No. x Build Time of Product Model)*

⇨ *Resource Bill = sum (Assembly Times per Product Model)*

As the lubricants supply chain is both a make-to-stock and make-to-order environment, demand is satisfied from inventory as well as production capacity.

For **ATP**, in the starting period the *inventory on hand* is the available inventory and the ATP is determined by inventory on hand, MPS (production) and monthly orders. After period 1, ATP is determined by MPS receipts and monthly orders.

⇨ *Inventory On Hand = Available Inventory in Period 1*

⇨ *ATP (Period 1) = Inventory On Hand + MPS – Orders before next MPS*

⇨ *ATP = MPS Receipts – Orders before next MPS*

Projected Available Balance (PAB) is based upon forecast demand. We have to consider customer orders which can sometimes be greater than forecast demand and sometimes less. PAB is calculated based upon whichever is greater and depending upon whether the period is before or after the demand time fence viz. the number of periods, starting with period 1, in which changes are not accepted due to excessive cost caused by schedule disruption.[100]

[100] Arnold JRT, Chapman SN, Clive LM, 1998. p63-64

The lubricants supply chain does not have a demand time fence as schedule changes are accommodated (due to excess capacity being available in the manufacturing line operations as well as capacity being available in shifts).

For PAB, in the starting period the *inventory on hand* is the available inventory and the PAB is determined by inventory on hand, MPS (production) and monthly orders. After period 1, PAB is determined by MPS, monthly orders and/or forecast).

⇨ *Inventory On Hand = Available Inventory in Period 1*

⇨ *PAB (Period 1) = Inventory On Hand + MPS – Orders*

⇨ *PAB = Prior Period PAB + MPS – (greater of Orders or Forecast)*

The differentiators in the plant level planning process are *cost* (CPL of finished products), *quality* (formulations and container fittings), *flexibility* (ability to run priority and emergency customer orders timeously) and *reliability* (ATP and Available Inventory).

The blend product process requires the Materials Requirements Plan (MRP) to determine the exact number of raw materials and containers, caps and seals required in order to satisfy the low-level component requirements of the MPS.

MRP netting is the way MRP carries out calculations on a level by level basis down through a bill of materials which converts the MPS of finished products into suggested or planned orders for the required raw materials (blending BoM).

For MRP netting in blending, the *inventory on hand* is the available on-hold inventory, *gross requirements* the calculated components, *planned and scheduled receipts* the planned orders receipt and the *projected stock balance* is determined by the previous stock balance, gross requirements as well as planned and scheduled receipts.

⇨ *Previous Stock Balance = Available On-Hold Inventory*

⇨ *Gross Requirements = Calculated Components*

⇨ *Planned and Scheduled Receipts = Planned Orders Receipt*

⇨ *Projected Stock Balance = Previous Stock Balance – Gross Requirements + Planned and Scheduled Receipts*

Capacity Requirements Planning (CRP) checks the MRP priority plan against available capacity of the blending kettles. Work centres for the blending operations are the blending kettles (for blending products). The *capacity* of the blending kettle is determined by the volume the blending kettle can accommodate, whereas the *lead time* is determined by setup (decanting), run (blending) and move (piping to manufacturing lines) associated with the blending kettle.

⇨ *Lead Time = Setup Time + Run Time + Move Time*

Capacity available for blending is determined by measurement i.e. historical data and averages, whereas capacity required (load) is obtained from *time needed for each order* to be determined by setup and run times of the blend kettle.

⇨ *Setup Time = time required for setup of Blend Kettle*

⇨ *Run Time = Run Time per Blend Batch*

⇨ *Time Needed For Each Order = Setup Time + Run Time*

The monthly *load* is the sum of the capacity required for individual orders which is determined by the sum of the standard hours of operation time for each planned and released order for each blending kettle per Month.

⇨ *Released Orders per work centre for Month = Setup Time + Run Time per work centre*

⇨ *Planned Orders per work centre for Month = Setup Time + Run Time per work centre*

⇨ *Load for Month = sum Released Orders + Planned Orders (all work centres)*

The orders are categorised into the particular blend kettles to be used based upon blending volume and available blending capacity.

The differentiators in the *blend product* process are *cost* (CPL of finished products), *quality* (product formulations), *flexibility* (ability to blend priority customer orders timeously) and *reliability* (product consistency).

Once a product has been blended, samples are taken from the blend kettle and tested in a laboratory as part of the *QA product* process.

If a blend is acceptable in terms of product formulation and density quality requirements, the blend is passed for packaging in terms of the MPS requirements. If not, then the composition of raw materials is adjusted and re-blended in order to achieve desired Quality requirements.

The differentiator in the *QA product* process is *quality* (product formulations) and *reliability* (consistency).

The *package product* process requires the Materials Requirements Plan (MRP) to determine the exact number of containers, caps and seals required in order to satisfy the low-level component requirements of the MPS.

MRP netting is the way MRP carries out calculations on a level by level basis down through a bill of materials which converts the MPS of finished products into suggested or planned orders for the required containers, caps and seals (filling Bill of Materials).

For MRP netting for packaging, the *inventory on hand* is the available on-hold inventory, *gross requirements* the calculated components, *planned and scheduled receipts the* planned orders receipt and the *projected stock balance* is determined by previous stock balance, gross requirements as well as planned and scheduled receipts.

⇨ *Previous Stock Balance = Available On-Hold Inventory*

⇨ *Gross Requirements = Calculated Components*

⇨ *Planned and Scheduled Receipts = Planned Orders Receipt*

⇨ *Projected Stock Balance = Previous Stock Balance – Gross Requirements + Planned and Scheduled Receipts*

Capacity Requirements Planning checks the MRP priority plan against available capacity of the manufacturing lines. Work centres for the packaging operations are the manufacturing lines (to fill, cap and seal the containers). The capacity of the manufacturing line is determined by the no. of containers to be filled, capped and sealed per hour, whereas the *lead time* is determined by setup (piping from blending kettle), run (fill, cap and seal), queue (shrink wrapping & palletising) and move (warehousing).

⇨ *Lead Time = Setup Time + Run Time + Queue Time + Move Time*

Capacity available for packaging is determined by measurement i.e. historical data and averages, whereas capacity required (load) is obtained from *Time Needed For Each Order* to be determined by setup and run times of the manufacturing line.

⇨ *Setup Time = time required for setup of Manufacturing Line*

⇨ *Run Time = Run Time per Piece x No Pieces*

⇨ *Time Needed For Each Order = Setup Time + Run Time*

The monthly *load* is the sum of the capacity required for individual orders which is determined by the sum of the standard hours of operation time for each planned and released order for each manufacturing line per month.

⇨ *Released Orders per work centre for Month = Setup Time + Run Time per work centre*

⇨ *Planned Orders per work centre for Month = Setup Time + Run Time per work centre*

⇨ *Load for Month = sum Released Orders + Planned Orders (all work centres)*

Small Volume Blends are combined and sequenced for packaging across manufacturing lines. The differentiators in the package product process are *cost* (CPL of finished products), *quality* (non-leaking containers) and *reliability* (expected product volumes).

Once the finished products are packaged in the store product process, they are stored in a warehouse (for subsequent order picking). The tins and plastic containers are shrink-wrapped and stored on pallets in a load rack.

The differentiator in the store product process is *flexibility* (storage and handling of finished products in a warehouse).

Knowledge assets for manufacturing are embedded in the costs of raw materials and their quality, as well as the reliability of suppliers:

✓ Cost – Historical costs for finished products are based upon the costs of raw material costs as well as the batch sizes of blends and resulting economies of scale of manufacturing i.e. blending and filling) which are measured against the capacity of the particular manufacturing line.

  The benchmarks are recorded and at the end of the year the capacity of the manufacturing line are adjusted accordingly as the benchmark for the coming year.

  These costs and associated benchmarks are regarded as knowledge assets as well as a core competency which competitors will find difficult to match as they add value to decision making about adjustments to manufacturing lines to cater for expected future capacity in the coming year as well as aid cost reduction to customers as a result of better economies of scale of manufacturing lines.

- ✓ Quality – A sample of the finished product after a blend is sent to a laboratory for testing of product quality and the sample kept for future reference of customer claims, which happens rarely making trend analysis difficult. A record of the laboratory results per blend is kept and if the frequency increases analysis may be useful.

  As with the selection of supplier of raw materials, these knowledge assets add value as they are required for decision making related to selection of suppliers of quality raw materials.

- ✓ Flexibility – The flexibility of manufacturing depends upon the availability of raw materials and blended finish products as well as the spare capacity, if any, of the manufacturing lines at any given point in time. When an emergency order is placed on manufacturing, the Production Plan, Master Production Schedule (MPS), Materials Requirements Plan (MRP) and Capacity Requirements Plan (CRP), along with all other measures and metrics (ATP, PAB, safety stock, gross requirements, planned and scheduled receipts, projected stock balance etc.) needs to be adjusted to cater for the new requirements which were not planned for. If the raw materials are available, a blend has to be scheduled if the finished product is not available in intermediate tankage (which feeds the manufacturing line with blended products). Fortunately emergency orders are on exception and as a matter of priority.

  The various pans and associated measures and metrics are regarded as knowledge assets as they add value to decision making about whether new customer orders can be accommodated. They are also regarded as a core competency as flexibility to accommodate customer orders ensures security of supply to customers' thereby entrenching customer trust and ultimately loyalty.

- ✓ Reliability – When an order is placed for a finished product a SLA is initiated and measured against when a delivery confirmation is recorded. At the end of each month a Customer Order Fulfilment (COF) measure is calculated based upon the percentage of deliveries On Time in Full (OTIF) divided by the number of deliveries, as well as *forecast accuracy* per finished product. The COF and OTIF measures along with forecast accuracy are reported to management each month for tracking purposes as well as to highlight any significant deviations below expected targets. Forecast accuracy as a knowledge asset is considered in decision making of future sales forecasts for the same finished product.

4.2.3 Primary Distribution

The aim of Primary Distribution is to make available the right products at the right place (plant to plant) and the right time in the required quantity and quality at optimal cost as per Distribution Requirements Plan (DRP). It consists of the Place Order on Supply Plant, Move Product, Receive / Store Stock processes for further analysis.

Codification and abstraction in the Primary Distribution process relates to the creation of the Distribution Centre (DC) network throughput South Africa in order to accommodate faster turnaround of customer orders as well as a fleet of long distance trucks to deliver both bulk and packaged lubricants to the DC's in South Africa (codification), directly to customers from the manufacturing plant, or packaged lubricants via distributors to customers (abstraction).

The *place order on supply plant* process initiates the request for finished products at either distribution centre or distributor (for forecasts or actual priority customer orders).

The differentiators in the place order on supply plant process are *flexibility* (product and transport availability), *service* (customer and distributor orders) and *innovation* (extranet to place orders online and consignment stock system).

The move product process moves the physical lubricants from the manufacturing warehouse to a DC or directly to the customer (bulk and packaged) or to the distributor (packaged only) for delivery to customers. The finished products are moved using long haul trucks.

The differentiator in the move product process is *reliability* (delivery turnaround time / SLA).

The *receive and store stock* process relates to the receipt and storage of the finished products at the DC, customer or distributor along with the required signature of the delivery note.

The differentiator in the receive-and-store stock process is *reliability* (right product and quantity, on time in full / OTIF order).

Knowledge assets for primary distribution are embedded in product availability for customer and distributor orders, service of orders, technology to process orders and delivery reliability:

- ✓ Flexibility – The flexibility of primary distribution is similar to manufacturing based upon the availability of finish products in storage at the manufacturing plant (made to stock as safety stock) for distribution to depots, directly to customers or distributors. The other major factor is the knowledge about the availability of long haul trucks, regarded as knowledge assets, to distribute finished products to the DC's and/or customers from the manufacturing plant.

  Besides emergency orders, truck capacity and their storage configurations are captured in a scheduling system as knowledge assets which play role in decision making about allocating available trucks to either plant-to-plant transfers (i.e. manufacturing plant to DC) or direct deliveries to customers.

  When an emergency order has to be initiated the scheduling system is updated with the new truck request (and a truck allocated) as well as the impact on other orders which have to be rescheduled. The scheduling system is regarded as a core competency which ensures the efficiency and effectiveness of product deliveries.

  On return leg of the truck to the manufacturing plant the slow moving, dead and obselete stock are returned to the manufacturing plant when the truck returns from a trip to the DCs. A request to return these finished products to the manufacturing plant will be recorded and aligned to the scheduling system as a knowledge asset for future decision making about product availability.

- ✓ Reliability – The delivery SLA is measured against the OTIF metric and any deviation i.e. OTIS or late delivery, is recorded and a COF measure created to determine general service to customers by customer tier. Any COF measure below targets set per tier (i.e. 95% for tier 1 and 90% for tier 2) are documented as knowledge assets and analysed by the supply chain and root-cause analysis performed to determine if any interventions are required to improve the COF measure.

  The interventions are recorded in a Health Safety Environment and Quality (HSEQ) system for future reference as knowledge assets for future decision making.

The impact of truck incidents on the road and product returns of incorrect finished products delivered, which leads to an order not being fulfilled, is fed back into the scheduling system as knowledge assets to be used for decision making about plans for impending future deliveries.

- ✓ Service – The primary distribution of finished products to customers and distributors are governed by SLA's which generates a customer delivery window within which time the delivery has to take place. These SLA's as knowledge assets are measured against the COF measures.

  If the SLAs and associated customer expectations of orders and deliveries are consistently met they can be used as a core competency which competitors may find difficult to match.

- ✓ Innovation – An extranet to place orders online as well as track them shortens the order-to-billing process for customers and distributors and ultimately allows for improvements in service delivery. A system to manage consignment stock allows for better stock management as well as audit trails of stock consumption and payments for reconciliation. These are regarded as core competencies if competitors do not offer similar services.

4.2.4 Process Analysis

An understanding of the *processes* and related *differentiators* and *knowledge assets* of the *lubricants supply chain* as listed above not only allows for improved decision making based upon the management of the inherent measures and metrics, but also provides deeper insight into various initiatives along with related interventions and controls that can be used to improve effectiveness and efficiency of the overall supply chain.

The *lubricants supply chain* requires raw materials for both blending and packaging, whose costs affects the costs of the various finished lubricants product range in an extremely competitive environment in South Africa.

Costs of products affect the ability to sell them to customers, whom are extremely price sensitive. Another important factor is the quality and ultimately the reliability of the lubricants products to fulfil and sometimes exceed the lubrication requirements of customers in order to ensure repeat purchases. If a particular product can be shown to be superior to a competitor offering, customer loyalty is significantly enhanced. Likewise, the barrier to entry of a competitor of a similar product is fairly high and difficult to breach.

For the receiving of stock purchases, the cost of storage and handling of base oil, additives and wax in tanks and drum carriers once again affects the costs of the finished lubricants product range. For bulk storage and blending, these include storage, intermediate and blending tanks. Their timeous storage and disbursement for blending and subsequently packaging is crucial for the manufacture of finished products in alignment with customer orders as well as depot replenishment based upon forecasts. Here the forecast accuracy of both make-to-order (customer) and make-to-stock (depot) is measured for continuous improvement in stock availability for customers, resulting in greater forecast accuracy.

For blending and packaging, the costs and quality of the lubricants finished products and containers are crucial to minimize product returns from customers. The ability of the blending kettles and manufacturing lines to blend and package, respectively, using long production runs minimises line changeovers. The processing of priority customer orders timeously requires flexible manufacturing line configurations. Their ability to meet ATP and available inventory is crucial to meet COF requirements.

All products are required to have samples taken and tested in a laboratory for formulation consistency and density, resulting in a certificate of acceptance prior to their distribution to either customers or depots. At the depots, products have a shelf life and when these are exceeded they are returned to the manufacturing facilities for either re-blending into new products requiring lower viscosity levels (e.g. chain saw oil) or discarded. Suppliers are paid based on supply contracts which have incentives and penalties to reinforce supply guarantees.

The finished products which are subsequently stored in a warehouse prior to primary distribution directly to customers or depots required effective storage and handling of finished products in warehouses. Here a Warehouse Management System (WMS) is extremely useful in managing effectiveness of storage slots and efficient sorting and picking.

When depots and distributors place orders on the supply plant, product availability is key to ensure COF measures and related SLA's are met. Product moves to the depots and distributors have to ensure product quality and delivery within acceptable turnaround times based upon SLA's. The visibility of dead stock i.e. stock which are required for customer orders but are available at depots where they are stored but not being sold, allows for trans-shipping between depots and distributors. When stock is received at the depot or distributor the right product and quantity is required to satisfy the depot/distributor order and later the customer order based upon the On-Time In-Full (OTIF) requirement.

4.3 Lubricants Supply Chain Framework

The analysis of the lubricants supply chain highlights a requirement to create a framework for the planning, implementation and review the *lubricants supply chain;* to be used as a benchmark for the creation of a new supply chain or review of an existing supply chain.

4.3.1 Planning

For the planning of a *lubricants supply chain* an understanding is required of *customer segments* which list the customer requirements by class of business grouped into sectors viz. automotive, mining, agriculture, mills, cement, industrial, marine, aviation, retail and power. Once *lubrication needs* are defined for each sector by product a *product portfolio is* required; to be imported from international suppliers or blended locally. *Raw materials supply* for each product formulation is required for negotiation with suppliers and for establishment of supply contracts.

The next steps are to plan the *receiving operations* environment and staffing requirements for the receipt of supplied raw materials and packaging, *blending and manufacturing design* of blending kettle, manufacturing lines and facilities including operations and staffing requirements as well as EIA requirements. Next the *tankage and drum storage design* is required for bulk raw materials as well as tankage to store and pipe the required volumes to the lubricants blending facilities and later the manufacturing facilities.

Subsequently, *warehousing design* of storage racks, storage cages and picking facility for finished goods storage prior to distribution is planned, along with the operations environment and staffing for the warehouse. Thereafter the *DC Network* and forecast of product volumes in the broader DC network is defined with the operations environment and staffing per DC.

Distributors and supply contracts are planned for where the viability of a DC is low and requires appointed distributors to store and distribute lubricants packaged products. *Long distance truck* requirements are defined for purchased, leased or outsourced trucks with selected, appointed and trained long distance truck drivers.

Sales forecasting of sales requirements for families of lubricants products are planned and a production plan compiled.

The planning activities are listed in Figure 4.3 below.

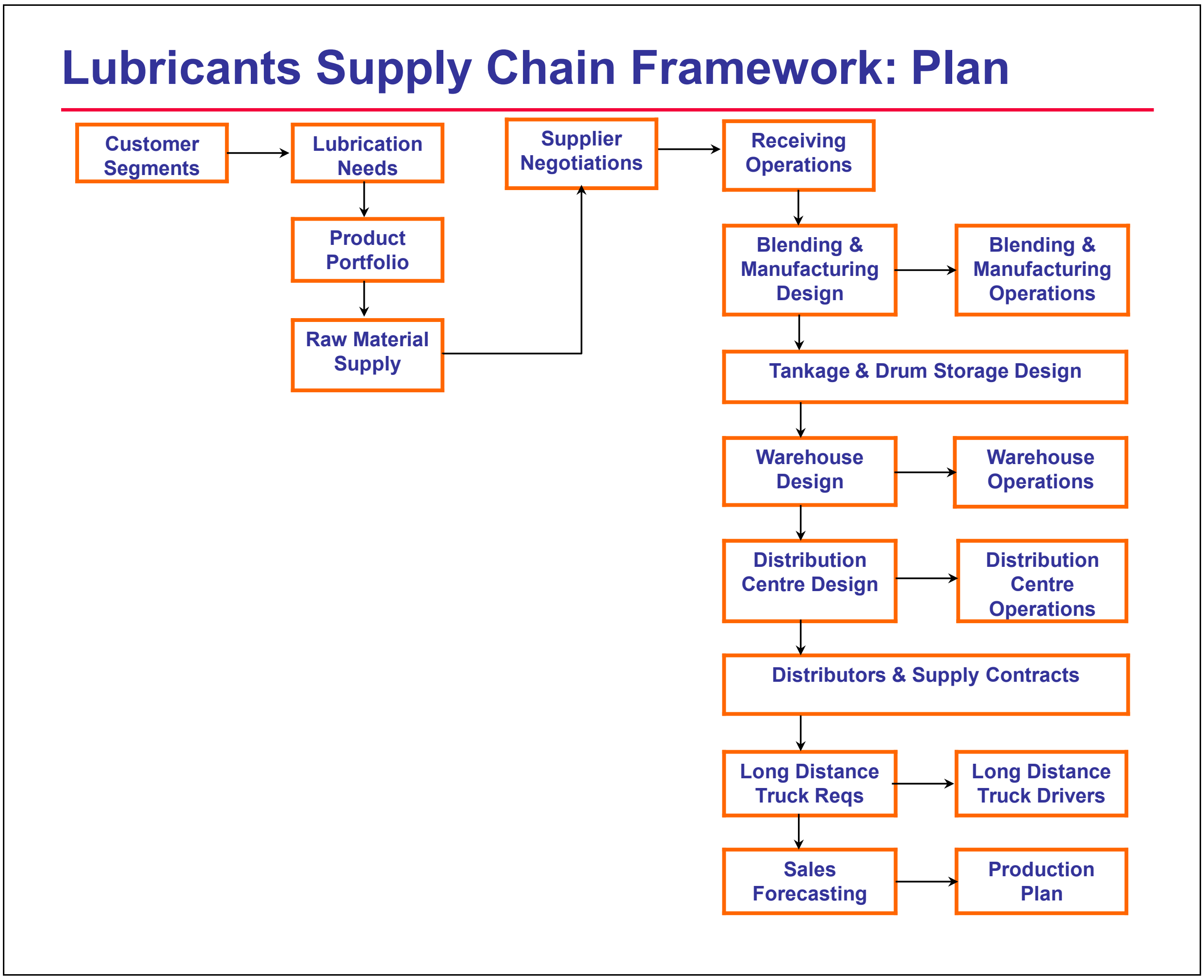

Figure 4.3: Lubricants Supply Chain Framework Planning

Source: developed by researcher

4.3.2 Implementation

For the implementation of a *lubricants supply chain* a build is required of the *tankage and drum storage, blending kettles* and piping to manufacturing lines as well as the *manufacturing lines* with segmented work centres for filling, capping, sealing, shrink wrapping and palletising of lubricants finished products.

Once the *manufacturing staff* are hired and trained ito machine handling, the Master Production Schedule (MPS) is compiled as a preliminary MPS by computing projected available per period (prior period inventory - forecast demand) where MPS per period is manufacturing lot where the projected available is negative. Next is the Rough Cut Capacity Plan (RCCP) where the build time per product model is determined and multiplied by the number to obtain the assembly time per product model, after which the resource bill is computed as the sum of all assembly times of the product models.

Availability To Promise (ATP) is determined for period 1 by subtracting the orders before the next MPS from the MPS (no inventory on hand), after which the ATP per period is the MPS receipts minus the orders before the next MPS. Calculate the *Projected Available Balance (PAB)* per period by adding the prior period PAB and MPS and then subtracting the greater of orders or forecast.

For the *Materials Requirements Plan (MRP)* projected stock balance per period is computed by subtracting the gross requirements of raw materials as well as containers, caps and seals from the previous stock balance (none in period 1), where after planned and scheduled receipts are added.

For the Capacity Requirements Plan (CRP) the lead time per manufacturing line is computed by adding the setup time, run time (run time per piece x no pieces), queue time and move time per manufacturing line, where after the load is computed as the sum of all released orders and planned orders for all work centres.

Next is the purchasing of raw materials as well as containers, caps and seals to be available as required for manufacturing as well as for buffer / safety stock requirements. For the manufacturing line operations, select, appoint and train staff for respective manufacturing lines and further work centres (i.e. filling, capping and sealing).

Build warehouse with required storage racks, forklifts, cages and distribution facilities and select, appoint and train staff for warehousing operations (receiving, storage, forklift operations, picking and distribution). Build DC's based upon tankage, warehousing and distribution requirements and select, appoint and train staff for DC operations. Thereafter, implement DC supply and distribution requirements.

For *distributors,* select, appoint and train distributors along with supply contracts and implement supply and distribution requirements for each distributor.

Lastly, implement requirements for product returns from DC's and distributors.

The implementation activities are listed in Figure 4.4 below.

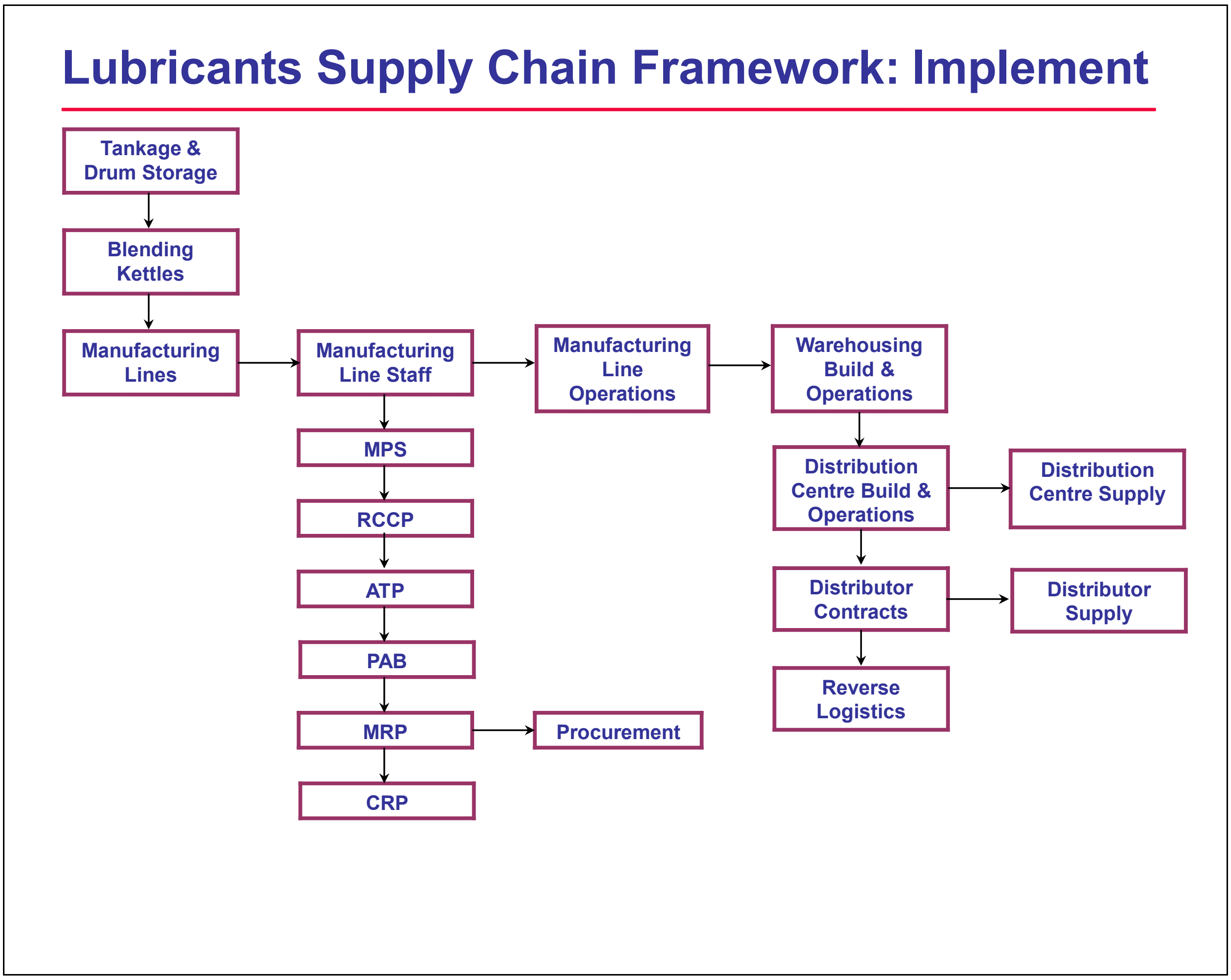

Figure 4.4: Lubricants Supply Chain Framework Implementation

Source: developed by researcher

4.3.3 Review

For the review of a *lubricants supply chain* Production Activity Control (PAC) compares planned backlog (previous planned backlog + planned input – planned output) to the actual backlog (previous actual backlog + actual input – planned output) per period along with steps taken as corrective action.

For *capacity control*, monitor production output and compare it with capacity plans and corrective action taken as required.

Monitor the ABC inventory classification and store buffer / safety stock at depots for slowing moving "C" items.

Determine optimal *stock picking* and distribution patterns e.g. overnight cage packing & depot pickup scheduling to avoid truck congestion and full vs. part pallets for depots.

Dead stock management is used to manage the dead stock at depots and move them to depots where stock can potentially be sold (e.g. marine lubricants may be dead stock in Johannesburg but not in Cape Town).

For *product returns*, categorise and evaluate the reasons for product returns per market sector and implement controls in order to minimise them e.g. for the product reseller market delivery windows are used for receiving of stock at reseller warehouses and/or distribution centres and if missed often leads to product returns.

A review of *market boundaries* and placement of depots is required to determine their effectiveness in effectively reaching large numbers of customers, where sometimes depots which are ineffective should be closed and distributors appointed as part of a broader Sales Network Planning (SNP) exercise conducted on a bi-annual basis.

The review activities are listed in Figure 4.5 below.

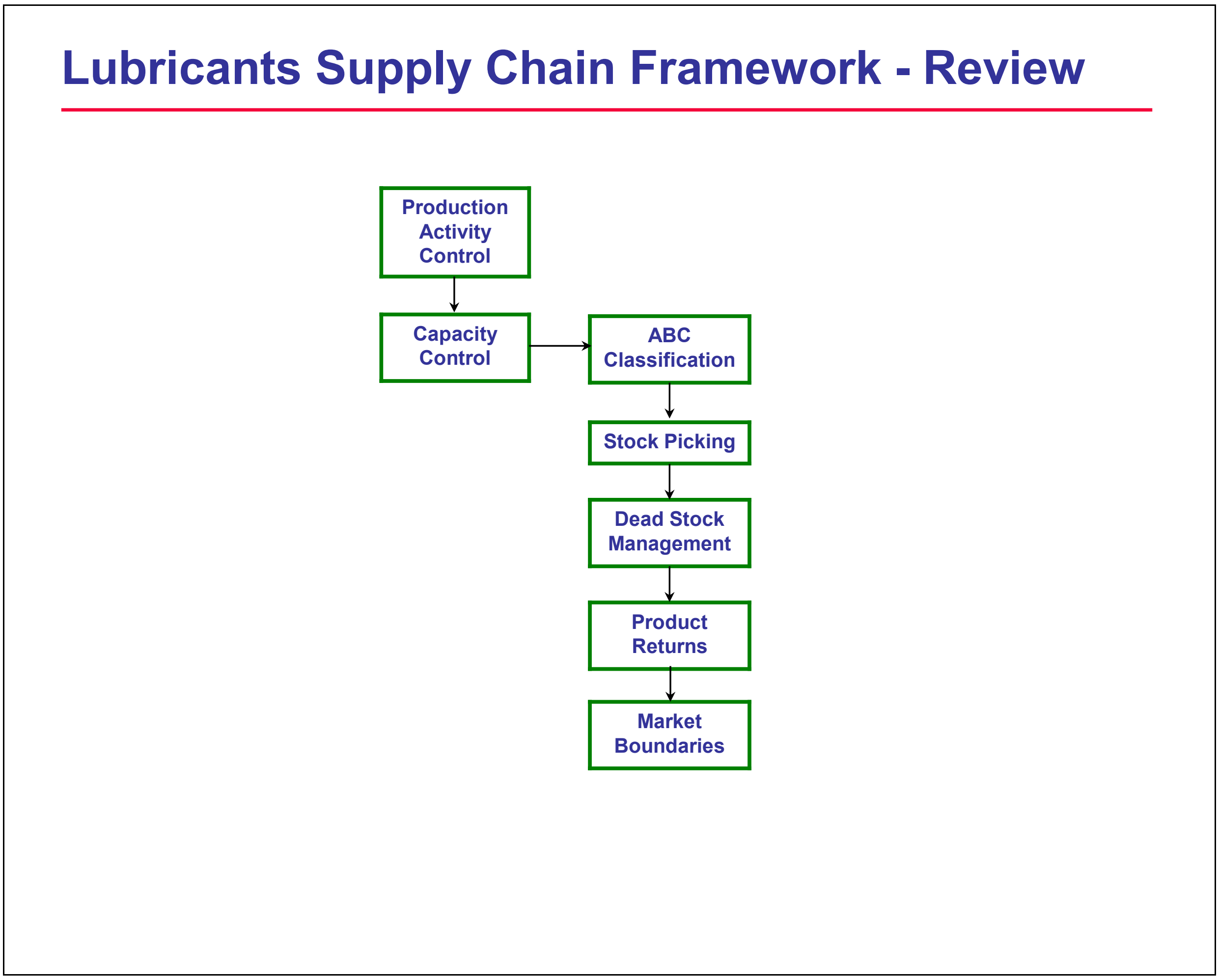

Figure 4.5: Lubricants Supply Chain Framework Review

Source: developed by researcher

4.4 Lubricants Supply Chain Analysis

The analysis of the lubricants supply chain shows how an understanding of the business processes with their embedded measures and metrics allows for the further identification of differentiators as well as core competencies which can be used to uniquely position the lubricants supply against competitors.

These inevitably lead to the creation and utilisation of knowledge assets which can be exploited for competitive advantage as they are extremely difficult to replicate without a significant investment. It fosters a mindset of an integrated supply chain which can be measured against defined performance standards e.g. COF timelines, economic blending batch volumes, manufacturing / packaging items per hour, ABC inventory holding, warehouse picking turnaround times, distribution timelines, etc.

The framework allows one to compare the various planning, implementation and review activities in order to determine where gaps exist in a lubricants supply chain by benchmarking the supply chain against best practice. The gap analysis lead to the initiation of either projects or business improvement opportunities which apply the concepts of business process reengineering, quality control and improvement, elimination or reduction of process variations, task orientation and wastage in order to attain an improved future state.

The gap analysis that takes place will most certainly activate and facilitate the scanning and problem solving activities in the Boisot information space which leads to further codification and abstraction, thereafter diffusion for usage of the knowledge assets for more enhanced decision making and further entrenchment of core competencies (making it even more difficult to counter competitive advantage and by further raising barriers to entry by potential competitors).

Where gaps are difficult to manage consideration should be given to achieve vertical integration in the lubricants supply chain by M&A activity to either purchase or discard/outsource business entities either upstream or downstream of the lubricants supply chain; including base oil, additive and wax manufacture, tankage outsourcing, distribution outsourcing, etc.

Chapter 4 provided an overview of the *lubricants supply chain* in terms of the value chain and lower level business processes for the analysis of the codification and abstraction of knowledge assets. It provided a lubricants supply chain framework as a benchmark for the planning and implementation of new lubricants supply chains, alternatively for the review of an existing lubricants supply chain.

Chapter 5 will provide a summary of findings, conclusion, recommendations and future research.

Chapter 5
Conclusion

5 Findings

5.1 Summary

Even though a host of *measures* and *metrics* exist in supply chains for reporting and management purposes (including back order reporting, balanced scorecard, benchmarking, cycle time, defects per million opportunities, fill rate, inventory accuracy, inventory ABC classification, inventory finance, inventory turns, on time shipping / delivery, perfect order measure and performance to promise), the objective of the thesis is to illustrate how these *knowledge assets* are formed at the operational level and how they can be used for decision making at the tactical level as well as strategic level of supply chain organisations.

Firstly, the embedded *processes* inherent in the *generic supply chain* were mapped along with the identification and formulation of their generic measures and metrics for the identification of knowledge assets, after which they were applied to the lubricants supply chain within the oil and gas industry in South Africa. This ultimately allows for a greater understanding of the distinct processes where further concepts of business process reengineering, quality control and improvement, elimination or reduction of process variations, task orientation and wastage can be applied.

The identification of *differentiators* and subsequently *core competencies* for each of the lubricants business processes was used to identify unique areas within the lubricants supply chain for exploitation (based upon their categorisation in terms of cost, quality, flexibility, reliability, service and innovation). When the *differentiators* and *core competencies* become effectively entrenched in the organisation, it leads to competitive advantage.

Lastly, a *generic lubricants supply chain* framework was formulated in order to detail the processes required to plan, implement and review the supply chain as a business entity of the oil and gas industry in South Africa for benchmarking.

5.2 Conclusion

The objectives of the research conducted by the thesis shows how a generic understanding of supply chains can be used to identify the embedded measures and metrics within supply chains and how they can be adapted for the *lubricants supply chain* in order to identify and manage knowledge assets.

The identification of these embedded *knowledge assets* in the processes has a direct correlation to the Boisot information space where codification, abstraction, diffusion, scanning and problem solving takes place.

The codification and abstraction of the measures and metrics in the *lubricants supply chain* leads to their diffusion (used for decision making at the operational and tactical levels of the supply chain organisation) and they eventually become embedded in the supply chain as knowledge assets. This subsequently leads to improvement initiatives as a result of the scanning and problem activities.

It is during the problem solving phase that projects and various business improvement opportunities are initiated within the broader strategic objectives of the oil and gas organisation for continuous improvement of the supply chain operations.

The application of business process reengineering, quality control and improvement, elimination or reduction of process variations, task orientation and wastage are applied in order to ultimately meet the demands for a more effective and more efficient supply chain, eventually leading to lower costs of lubricants finished products and as a resulting higher profit margins for finished lubricants products and the overall profitability of the lubricants organisation.

It is this never ending cycle which fosters a culture of continuous improvement and the journey to become a learning organisation.

5.3 Recommendations

The major recommendation from the research relates to the creation of a generic roadmap (see Figure 5.1 below) for each lubricants supply chain which will allow for the codification and abstraction of embedded measures and metrics in the road to the creation and utilisation of knowledge assets.

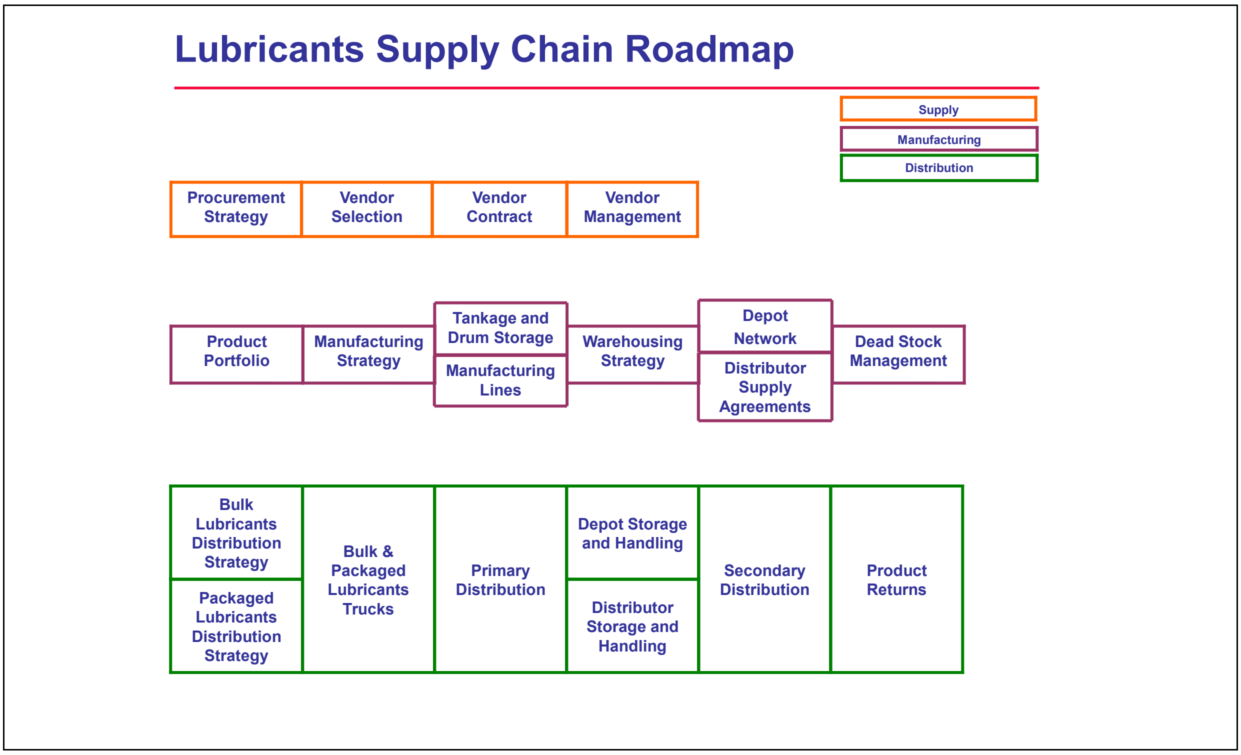

Figure 5.1: Lubricants Supply Chain Roadmap

Source: developed by researcher

The secondary recommendation is to measure the particular lubricants supply chain against the developed framework and perform a gap analysis in order to identify gaps between the current and future (desired) states within the lubricants supply chain. Subsequently, to initiate multiple parallel projects to improve the overall supply chain as a holistic business entity.

The measurement of the lubricants supply chain against a marketing plan which highlights product, place, price and promotion can be used to assess the effectiveness in not only the current but also the future customer lubricants needs.

The integration of customer and company ordering systems will allow for trends to be identified and orders predicted within the areas of Automatic Stock Replenishment (ASR) in a Business-To-Business (B2B) environment where stock and order management becomes the responsibility of the lubricants organisation.

The attainment of the ultimate goal of having an integrated lubricants supply chain which is agile in meeting distinct customer expectations is first prize.

The ongoing monitoring of stock availability, ABC classifications, dead stock management and product returns allows for the implementation of controls in order to minimise customer stock-outs which is detrimental to COF measures and generally customer satisfaction and ultimately loyalty. These issues are generally the items for discussion at the Sales & Operations Planning (S&OP) meetings which should be held at a minimum on a monthly basis.

5.4 Future Research

The thesis only extrapolated the codification and abstraction phases of the *Boisot information space.*

The further phases i.e. diffusion (dissemination and utilisation of information and knowledge assets), as well as scanning and problem solving (using the concepts defined as applicable to supply chains i.e. business process reengineering, quality control and improvement, elimination or reduction of process variations, task orientation and wastage) is available for further research in the lubricants supply chain.

The basis of the research can also be applied to other business areas both within the oil and gas as well as in other supply chain industries e.g. upstream oil exploration and in the Fast Moving Consumer Goods industry.

Even industries unrelated to the oil and gas may be explored e.g. government procurement processes and tender management where the application of the Boisot information space can be extremely beneficial to the identification and creation of knowledge assets, as well as an understanding of areas for differentiation and creation of core competencies.

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