Evaluating the need for developing new customer service safety stock models in a long lead-time chemical supply chain.

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A research project submitted to the Gordon Institute of Business Science, University of Pretoria, in partial fulfilment of the requirements for the degree of Master of Business Administration.

11 November 2009

Abstract

Safety stock models have been developed for traditionally short lead-time supply chains. With globalisation, long lead-time complex supply chains have become the norm for multi-national organisations. Customers have evolved and are expecting better supply reliability at lower costs. The research investigates the need for developing new safety stock models that adapt to the changing global supply chains and customer needs and can optimally absorb supply and demand variability. The new safety stock models should ensure promised customer service levels.

Sasol Solvents, a chemical commodity company, was used as the basis for the research. The organisation has global distribution hubs in four regions with unique location based constraints. The sales and supply chain personnel in these regions participated in the research.

It was found that the current safety stock models exclude applicable variables that are needed to determine the optimal safety stock levels in a long lead-time supply chain. This exclusion causes sub-optimal safety stocks, which result in lower customer service levels. New safety stock models should therefore be developed that contain these variables identified and should be adaptable to the evolving changes in customer preferences and supply chain configurations. The new models should ensure the optimisation of profitability for global organisations.

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Declaration

I declare this research project is my own work. It is submitted in partial fulfilment of the requirements for the degree of Master of Business Administration at the Gordon Institute of Business Science, University of Pretoria. It has not been submitted before for any degree or examination in any other University. I further declare that I have obtained the necessary authorisation and consent to carry out this research.

Louis Snyders **08/11/2009**

Acknowledgements

I would like to acknowledge the following persons and organisations for helping and assisting me in completion of my research:

- Aldrin Beyer for his supervision and guidance.
- Sasol Solvents for the consent of using the organisation as a research platform.
- Liana Joubert, for her never ending support and understanding. Without her, this research would not have been possible.
- My family and friends for their continuing support.

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1 Introduction to the research problem

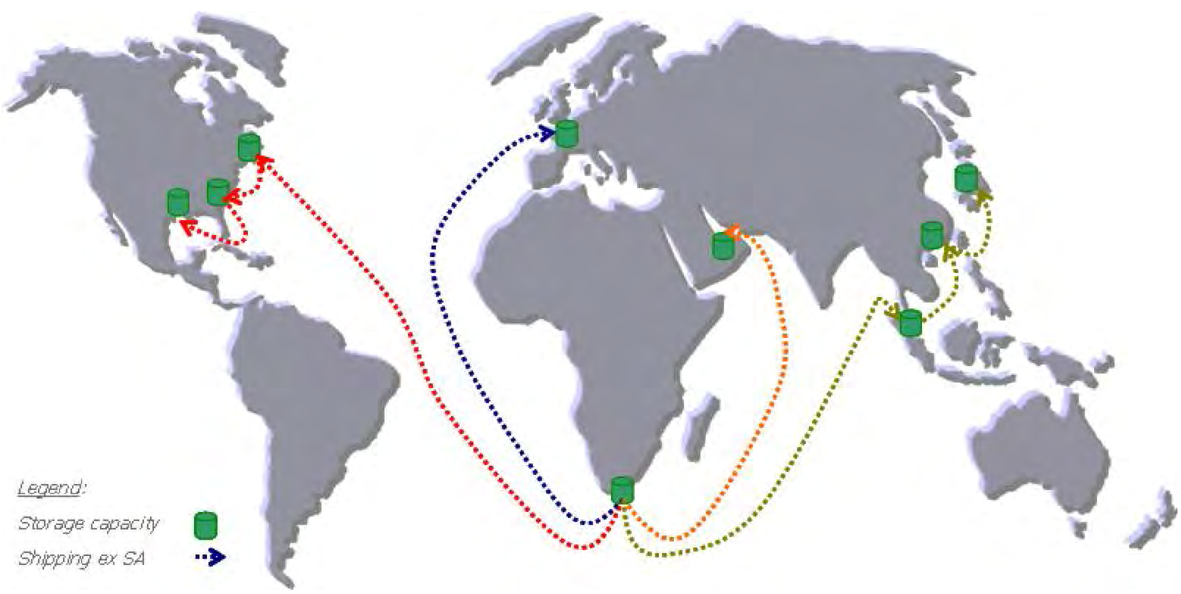
1.1 Research title

Evaluating the need for developing new customer service safety stock models in a long lead-time chemical supply chain.

1.2 Scope of research

The research will be limited to the inventory management of bulk chemical products for a global petrochemical organisation with production plants located in South Africa. The organisation has a local supply chain servicing the South African market as well as a multi-echelon supply chain servicing four global distribution hubs. The distribution hubs are located in Europe, Far East, Middle East and the United States and are illustrated in Figure 1.

Figure 1: Sasol Solvents global distribution



Each storage hub has established storage capacity for a number of products that are targeting that specific market. All regional customer sales are done from these defined storage facilities in the regional hubs. The multi-echelon inventory management in the different regions pose challenges due to the variability of supply from South Africa, which is negatively affecting the customer service delivered.

1.3 The unique problem – Location based

The pattern of supply to the global storage hubs are dependant on the reliability of the monthly supply of deep-sea vessels from owners to call the South African ports. For each supply region, contracts are negotiated with vessel owners where capacity and an evenly distributed inter-arrival time of vessels are committed to. In this case, a vessel inter-arrival time of 30 days is targeted. Each region should therefore ideally receive 12 vessels per *annum*. The assumption of 12 vessel arrivals per *annum* then serve as the basis on which monthly sales and storage capacity is planned and contracted for in each regional storage hub and sales market. The vessels that are used to serve the regional distribution hubs however follow specific shipping trade routes around the world and pending the volume that is loaded at various stages of the journey, variable inter-arrival times are experienced. In Table 1, a summary of the inter-arrival times and standard deviations is shown for the different regional hubs for the last two to four years.

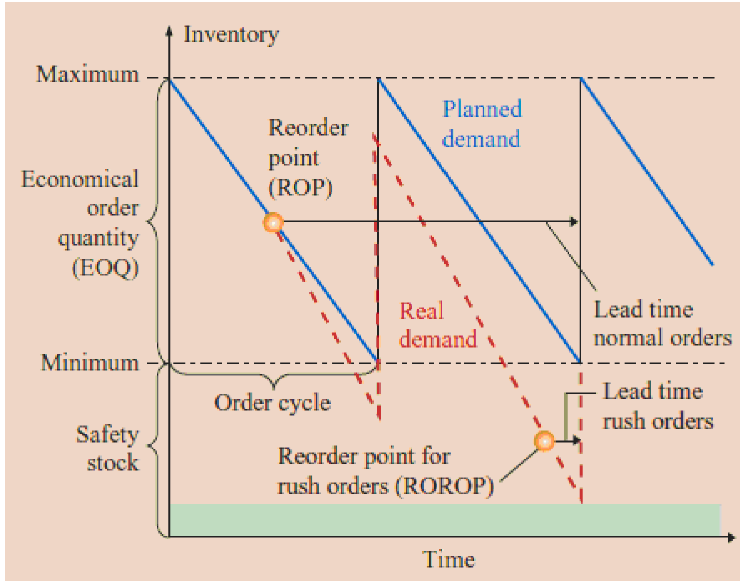
Table 1: Vessel inter-arrival analysis

Measured in days

Region	Average inter-arrival times	Standard deviation	N
Europe	32.7	10.3	37.0
Far East	29.5	9.2	25.0
Middle East	33.8	9.6	22.0
United States	28.2	11.5	52.0

The variability illustrated in Table 1, places severe pressure on inventory management and subsequent customer service offering. This pattern of arrivals is due to the limited availability of vessels sailing the specific route via the southern tip of Africa. Inventory replenishment to the global distribution hubs are therefore not dependant on pre-determined inventory re-order points but rather the availability, and inherent variability, of the deep-sea vessel arrivals. This is in contrast to the generic inventory management model (EOQ), as illustrated in Figure 2, where the model is dependent on the ability to re-order product at certain pre-determined points (Boedi, Korevaar & Schimpel, 2007).

Figure 2: Traditional inventory management model (Boedi *et al*, 2007)



In addition to the variable supply of vessels for regional inventory replenishment, the process is further complicated by the booking procedure that is required for the vessels. A typical booking time-line for a region is illustrated in Figure 3.

Figure 3: Typical vessel booking timeline

The booking of a regional vessel has four definitive time-stamps, which require some specific action to be completed at each point (as is illustrated in Figure 3). The total process from nomination until vessel arrival typically spans 45 days. A short description of each of these time-stamps now follows:

1. ***Nomination*** – At this time-stamp, a specific vessel is nominated by the vessel owners for calling South Africa. Information about the estimated time of arrival at the port of loading in South Africa as well as the estimated time of arrival at the ports of discharge in the region is provided. The vessel capacity is also stated which indicates the available volume for stowage in South Africa. This then guides the inventory planning locally and in the regional storage hub.

2. ***Provisional booking*** – At 37 days before the estimated arrival of the vessel, a provisional booking is required by the vessel owners. This booking indicates the provisional volumes that is planned to be shipped to each port on the nominated vessel route. This enables the vessel owners to initiate the stowage of the ship for the booking.

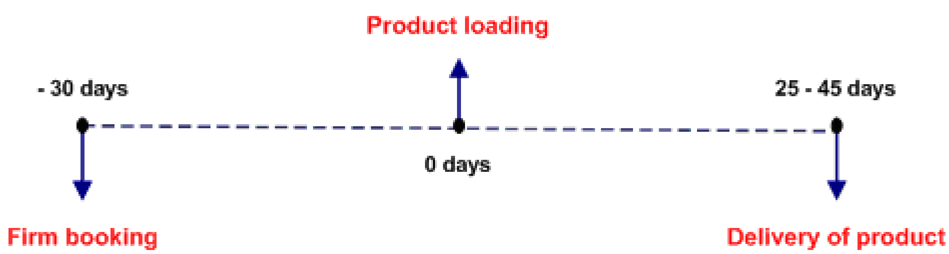
3. ***Firm Booking*** – At this time-stamp, a firm commitment for volume is made to the vessel owners. From this point forward, the total firm booked volume can only change by ± 5%. If volume increases of more than 5% are required, the additional volume will most likely not be able to be stowed. If less than the firm booked volume is shipped, the shortage is penalised by dead-freight. The dead-freight is calculated as the contracted freight rate multiplied by the decrease in volume below the – 5% mark. To make changes after firm booking is very costly and typically refrained from unless required due to some crisis.

4. ***Start of documentation*** – Between the firm booking date and start of documentation, changes to the cargoes can still be made while remaining

inside the ± 5% volume bracket (pending stowage). At fourteen days before the estimated sailing date, completion of the final documentation will start. From this point forward, no changes to the cargoes can be made.

This process is rigorous and requires firm commitment far in advance of the actual product delivery date. The total time-line for product delivery to a region is illustrated in Figure 4.

Figure 4: Time-lines from product booking until actual delivery



This results in a total time of between 55 and 75 days (long lead-time) since a firm commitment is made until the actual delivery of the products that were committed to. This has the effect that in certain regions, a previous vessel has not yet arrived at the destination before a next firm booking a required. In a system where variability is definite, accurate inventory planning is nearly impossible and maintaining customer service levels remain a challenge. When supplying commodities, if the promised customer service cannot be provided, customers easily shift to other suppliers resulting in lost sales opportunities (Clarke-Hill, Clarkson & Robinson, 2002).

The specific booking dates, as illustrated in Figure 3, are required by vessel owners due to the unique location of the production plants in South Africa. At the firm booking date, a vessel owner will typically arrive at the last port of cargo loading before heading for South Africa. With the aim of maximizing the capacity utilisation on a vessel, the vessel owner needs to determine what cargo can still be loaded in e.g. Singapore before leaving for South Africa with an ultimate end destination of the United States. Ensuring that the volume to be loaded in South Africa is known 30 days prior to arrival, owners are able to commit to spot volumes in the last port of loading to optimise their capacity utilisation.

The result of this rigorous process is severe inventory fluctuations in the regional storage hubs. Bookings need to be done so far in advance that stock-outs are inevitable. Due to this unique and complex global supply chain, characterised by stochastic demand and long lead-times, safety stock plays a particularly important role in maintaining customer service levels.

1.4 Research problem

According to Christopher and Lee (2004), managing supply chains today are increasingly challenging due to greater uncertainties in supply and demand as well as the globalisation of the market. Globalisation has influenced the reliability of vessels as owners are calling more ports more frequently than before. Pursuing economies of scale have resulted in the decrease of shipping efficiency due to delays incurred by shipments (Rodrigue, 1999).

Christopher and Lee (2004) stresses that mismanaged supply chains, which lead to excessive or mismatched inventory, poses huge financial risks. Due to the uncertainties and differences between product demands, the result of generic strategies, particularly safety stock, is either inflating costs due to increased levels of inventory or resulting in lost sales opportunities due to the inability to serve customers (Baek, Jun, Kim, Kim & Smith, 2005). Traditional inventory literatures, which make simplifying assumptions that are invalid in complex environments, are one of the main contributors to these phenomena (Butler, Jeffery & Malone, 2008). Butler et al (2008) argues that service level goals used in literature often do not result in the ideal trade-off between inventory and customer service and does not take into account the complexities of supply patterns.

Globalised supply chains are becoming more complex and challenging due to the decrease in shipping efficiencies and the increase in distribution costs. The mismanagement of inventory therefore poses huge risks but in contrast, customers are expecting more reliable short lead-time supply. Safety stocks are introduced into long lead-time supply chains and try to balance the increased supply and demand variability with the increase in customer expectations. The challenge however is to implement the correct safety stock models to achieve these objectives.

1.5 Research purpose

The purpose of the research would be to determine if the generic customer service safety stock models used to determine safety stock targets are accomplishing their goals of minimizing cost while maximizing customer satisfaction and therefore increasing profitability (Mattsson, 2007), for a unique and complex long lead-time bulk chemical supply chain. The research investigates the need of developing new customised safety stock solutions, which can potentially replace generic approaches by identifying critical parameters needed to ensure customer service levels in a globalised economy. This research will aim to answer/confirm some literature gaps (or parts thereof) in terms of the following aspects that were identified:

- Benyoucef and Jain (2008) concluded that supply chain models used in literature are confined in their capability and applicability to analyse real long supply chains.
- Mattsson (2007) concluded that inventory control measures used in industry fail to achieve the desired service levels that the methods are designed to attain.
- Love, Stone, Taylor and Weaver (2008) concluded that insufficient research has been conducted to examine the inventory needs in support of global supply problems and what is of particular concern is the determination of required safety stock levels to support the desired customer service levels.

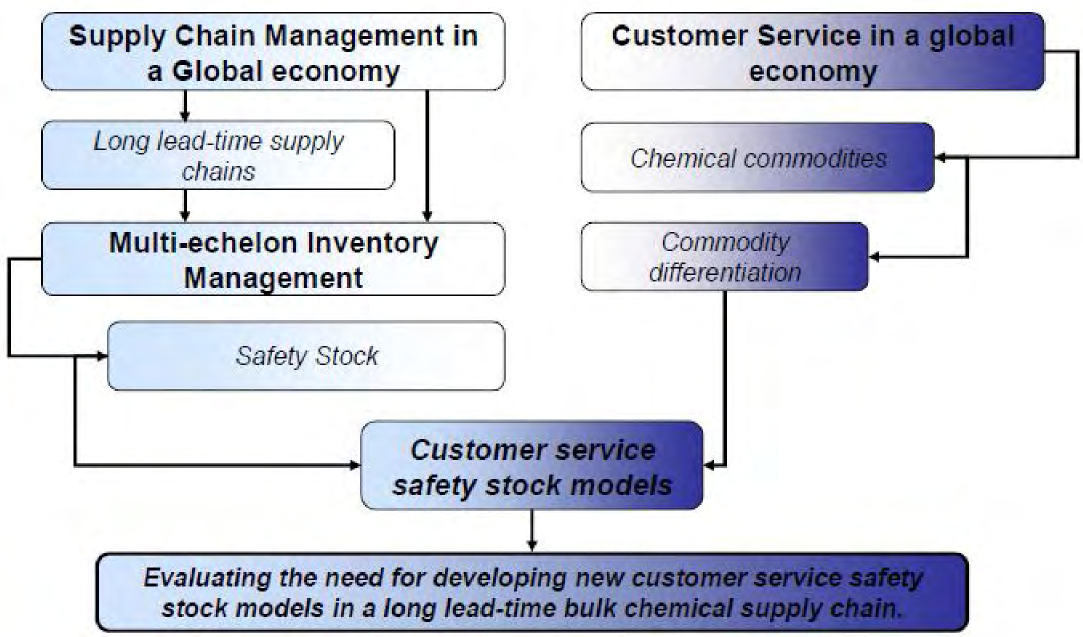
The research focus is very specific and directly relates to the safety stock requirements in a complex bulk supply chain that is dependent on transport mode reliability to effectively supply regional storage hubs (via a push strategy) and therefore ensuring their targeted customer service levels.

2 Literature review

2.1 Summary of literature headings

A number of literature topics were found that related to the research on hand. In Figure 5, a summary of the literature headings, and flow of the discussion that was covered in this Chapter is illustrated.

Figure 5: Literature headings



The literature consists of two separate knowledge areas, namely supply chain management and customer service. These two sections are discussed in detail and then related back to the topic at hand. Analysis of the literature related to these topics will now be addressed.

2.2 Supply Chain Management in a Global economy

Every new day sees the economies of the world more intricately networked. Increasing levels of market uncertainty challenge the traditional segmented and hierarchical assumptions that firms employed to design their inter-firm networks and interactions with partners (Klein, Mathiassen, Rai, Straub & Wareham, 2005). According to Roder and Tibken (2006), competition was no longer one company against other companies but rather one enterprise network or supply chain against other networks and supply chains.

Competing in today's environment is to compete between supply chains (Chen, Long & Yan, 2004). Fu and Piplani (2005) suggested that concurrent with the globalisation of business, competition has been transformed from inter-company to inter-supply chain. The supply chain was recently more practically defined as a connected network with organisations, resources and activities that create and deliver various forms of value (Chen, Long & Yan, 2004). Supply Chain Management (SCM) is defined as an integrative approach for planning and control of materials and information flows with suppliers and customers as well as between different functions within a company (Minner, 2003). The goal of any supply chain is to offer the final customer the right product at the right time in the right location. This is done by managing the balance between the different supply chain member's needs while keeping in mind the best interest of all (Bloodgood, Katz & Pagell, 2003). SCM is encompassed into the strategic, tactical and operational activities of a firm (Badell, Espuna, Guillen & Puigjaner, 2006). Badell *et al.* (2006)

and Gamberini, Gebennini and Manzini (2009) described the following hierarchical integration of SCM activities in the firm:

1. ***Strategic level*** – This level referred to a long-term planning horizon and addressed the problem of designing and configuring a generic supply chain. Decisions included the number of facilities, locations, capacity and allocation aspects.
2. ***Tactical level*** – This level referred to both long and short-term horizons and dealt with the determination of the best operating policies and material flows in a multi-echelon inventory system.
3. ***Operational level*** – This level referred to the day-to-day operations such as scheduling.

The integration of these complexities across different decision levels posed challenging in terms of optimal supply chain integration (Badell *et al.* 2006).

Experts maintained that global supply chains are more difficult to manage than domestic supply chains due to the substantial geographical distances and difficult decisions required in terms of the inventory trade-offs due to increased lead-times (Gargeya & Meixell, 2005). Globalisation has forced companies to move away from traditional SCM, which were designed in times of modest competition, and slow response times (Benyoucef & Jain, 2008). Benyoucef and Jain (2008) suggested that the focus of SCM has moved from production efficiency to customer-driven approaches. The increase in international competition and the shift of SCM focus have resulted in companies pursuing a number of supply chain strategies to become more competitive and customer focused (Bloodgood, Katz & Pagell, 2003). These new supply chain strategy initiatives was supported by the increasing levels of market uncertainty that challenged the traditional segmented and hierarchical assumptions of supply chain design (Klein, Mathiassen, Rai, Straub & Wareham, 2005). An integrated global supply chain is very difficult to duplicate and therefore plays an important role in the competitive strategy for any global organisation (Gargeya & Meixell, 2005).

According to Er and MacCarthy (2006), more and more companies are involved in international supply chains, which are posing greater challenges in terms of potentially longer and more uncertain delivery times.

2.2.1 Long lead-time supply chains

Delivery lead-time affects the inventory levels and order decisions of a supply chain (So & Zheng, 2003). The uncertainty about lead-times in a supply chain causes an increase in inventory levels and risk in terms of the unavailability of inventory and the risk for additional sourcing costs (Chandra & Grabis, 2006). According to Chandra and Grabis (2006), a reduction in lead-time reduced inventory cost due to more accurate demand information and lower safety stock requirements. Leng and Parlar (2009) supported this notion and continued to state that a reduction in lead-times result in more accurate forecasts, lower safety stocks and smaller order-sizes which then lead to a reduction in inventory, a reduction in the bullwhip effect and therefore a reduction in costs. Globalisation has however made inventory management more difficult due to the association between international supply chains and long and variable lead-times (Er and MacCarthy, 2006, Hilletofth, 2009). Benyoucef and Jain (2008) concluded that supply chain models used in literature are confined in their capability and applicability to analyse real long supply chains.

2.2.2 Multi-echelon inventory management

According to Wen (2005), there are two basic theories that explained the role of inventories: the production-smoothing theory and the stockout-avoidance theory. According to the production-smoothing theory, organisations keep inventory to smooth the path of production. According to stockout-avoidance theory, firms hold inventories to avoid losses of prospective sales when production is incapable of supplying the sudden demand (Wen, 2005).

Multi-echelon inventory systems are formed when an item moves through more than one stage before reaching a final customer. These inventory systems were employed to distribute products to customers through an extensive geographical area (Gumus & Guneri, 2007). Multi-echelon supply chains have on average higher lead times as well as higher lead time variability, which results in higher levels of inventory (So & Zheng, 2003). Such inventory systems should satisfy customer needs at specified levels at the lowest possible cost (Romeijn, Shu & Teo, 2006).

According to Billington and Lee (1992), efficient and effective management of inventory throughout the supply chain have significantly improved the service delivered to the final customer. However, due to unpredictable customer needs and economic situations, customer demand fluctuates (Baek *et al*, 2005). When formulating inventory policies, the two main objectives are to (1) maintain a specified service level to the customers and (2) reduce inventory levels to minimise the investment in inventory (Kodali & Routroy, 2004).

Safety stocks were introduced into supply chains to hedge against uncertainty and ensured that customers received the promised service levels (Blau *et al*, 2008). Higher safety stock levels guaranteed higher service levels but also increased supply chain operating cost (Blau *et al*, 2008). Koumanakos (2008) concluded that firms with higher levels of inventory are associated with lower rates of return. These levels therefore had to be suitably optimised (Blau *et al*, 2008).

2.2.3 Safety stocks

When faced with stochastic demand and/or stochastic lead times, safety stocks are required to protect against stock outs (Aghezzaf, Dullaert, Raa & Vernimmen, 2007). When considering a link between a supplier and a receiver, real-life situations will be characterised by some form of uncertainty. This can be due to demand aspects (stochastic fluctuations in consumption of inventory) or supply (unreliability in the lead-times of transport) (Dullaert, Vernimmen, Willeme & Witlox, 2008). In such circumstances, the receiver invested in a certain amount of safety stock to protect against stock-outs (Dullaert *et al*, 2008). Safety stock is held in addition to cycle stock and the three most common analytical approaches for determining safety stocks are the 'time-supply approach', the 'order costing approach' and the 'service-level approach' (Aghezzaf *et al* 2007; Mattsson, 2007).

- ***Time-supply-approach*** – In this approach, the safety stock was set equal to a certain time period that is required to supply a particular item (Aghezzaf *et al* 2007).
- ***Order costing approach*** – This approach involved minimizing the sum of shortage costs and inventory carrying costs. Theoretically, this approach is the most correct one but was limited by the ability to estimate shortage cost as a time dependent variable (Mattsson, 2007).
- ***Service-level approach*** – This approach was chraracterised by choosing a service level that is, from a management perspective, competitive and in line with customer expectations (Mattsson, 2007).

In Table 2, a comparison of the objectives of the different safety stock approaches are illustrated.

Table 2: Comparison of models used for determining safety stock

	Time Supply (TS)	Order Costing (B)	Service-Level (S)
Objective	To set safety stock equal to a certain time of inventory supply	To minimise the total of ordering cost and carrying cost	To minimise carrying cost subject to satisfying a certain pre-specified percentage of customer demand
Outcome	Fixed supply patterns	Minimizing total cost	Optimal customer service versus cost

(Aghezzaf et al, 2007; Mattsson, 2007)

According to Aghezzaf *et al* (2007), the order costing (B) and service level (S) approaches have been more popular among researchers. The time supply (TS) models were rarely used in literature (Dullaert *et al*, 2008). Aghezzaf *et al* (2007) continued to argue that S-models were more practical to use in determining safety stock as B-models have a constraint in its ability to express inventory shortages in monetary terms. According to Aghezzaf *et al* (2007) B-models could be used in three different ways depending on how exactly the shortage cost is defined. The different B-models can be defined as follows:

B1 – Specified fixed cost per stockout occasion

B2 – A specified fractional charge per unit short

B3 – A specified fixed cost per unit short per unit time

Aghezzaf *et al* (2007) suggested that S-models could also be used in three different ways depending on how service levels are defined. These were classified as:

S1 – Satisfying a specified probability of no stockout per replenishment cycle

S2 – A specified fraction of demand to be satisfied by inventory on hand

S3 – A fraction of time with positive stock on hand

These models had the aim of determining accurate re-order points and safety stocks based on the required service levels that was defined by management (Mattsson, 2007). According to Aghezzaf *et al* (2007), there was a striking discrepancy between the service levels proposed in literature and the service levels used in practice. As far as literature was concerned, focus has shifted from S1 to S2 measures. Aghezzaf *et al* (2007) concluded that S2 service measures explicitly took into account order quantities and could be considered more 'fair' than S1 or S3 models which favours small carrying capacity transporters. The main variables used in determining S2 safety stock targets, and other outputs, can be seen in Table 3.

Table 3: Variables used to determine relevant outputs

Variables in determining S2	Outputs from model
1. Mean demand during lead-time 2. Standard deviation of demand during lead-time 3. Transportation costs 4. Costs of cycle stock 5. Costs of inventory in-transit 6. Costs of safety stock 7. Pre-specified fraction of demand to be satisfied from stock on hand 8. Shipment quantity 9. Transportation lead times 10. Transportation lead-time variability	1. Safety stock level 2. Re-order point 3. Safety stock costs per ton

(Aghezzaf et al, 2007; Mattsson, 2007)

According to Mattsson (2007), the simplifying assumptions made in the models for calculating re-order points and safety stocks have an increasingly negative impact on the validity of the models and on the extent to which they represent the actual planning environments in which they are applied. To try to mitigate the complexity of stochastic variable demand and variable lead-times, more accurate safety stock models needs to be developed (Cetin, Gardner & Talluri, 2004). In Figure 6, a generic safety stock model that took into account the two dimensions of demand and lead-time variability, as proposed by Chopra and Meindl (2000) is shown.

Figure 6: Safety stock formulations by quadrant

		Lead-Time: Constant	Lead-Time: Variable
Demand	Constant	No Safety Stock	$R_L = RL$ $\sigma_L = \sqrt{R^2 s_L^2}$ $SS = F_s^{-1}(CSL)\sigma_L$
Demand	Variable	$R_L = RL$ $\sigma_L = \sqrt{\sigma_R^2 L}$ $SS = F_s^{-1}(CSL)\sigma_L$	$R_L = RL$ $\sigma_L = \sqrt{\sigma_R^2 L + R^2 s_L^2}$ $SS = F_s^{-1}(CSL)\sigma_L$

Where:

R = the average demand per period

L = average lead-time for replenishment

R_L = the demand per lead-time of replenishment

σ_R = standard deviation of demand per period

s_L = standard deviation of lead-time

σ_L = standard deviation of demand during lead-time

CSL = cycle service level

F_s^{-1} = represents the inverse normal (Cetin *et al*, 2004)

SS = Safety Stock

Cetin *et al* (2004) claims that the value of the model presented in Figure 6, was captured in its ability to account for both supply and demand variability in setting safety stock targets. The majority of safety stock models were based on the assumption of normal probability distributions and it was a reasonable assumption especially under the condition of rather long lead-times (Mattsson, 2007). This view was in contrast to Dullaert *et al* (2008) who found that the assumption of normal probability distributions is often invalid for real-life situations and can have significant impacts on the safety stocks and service levels. The model presented was dependant on re-order points that are controlled by the supply chain department (Mattsson, 2007). Mattsson (2007) concluded that inventory control measures used in industry fail to achieve the desired service levels that the methods are designed to attain.

2.3 Customer service in a global economy

The customer service level that an organisation provides is one of the most important factors of an organisations success. In today's competitive market, organisations are pressured to achieve higher customer service levels with fewer resources (Butler *et al*, 2008). Customers have more information, access to more choices, are more sophisticated and as a result have higher expectations than ever before (McQuiston, 2004). Additionally, dynamic factors such as forecast accuracy, demand variability and order lead-time compound the uncertainty surrounding the inventory and service level relationship (Butler *et al*, 2008). Customer service or satisfaction is the measure of how an organisation's total product performs in relation to a set of customer expectations (Konstantopoulos, Tomaras & Zondiros, 2007). According to Wouters (2004), customer service was primarily the optimal supply process for the customer and is divided into logistical and marketing elements, and therefore requires a dynamic approach. Closs, Keller & Mollenkopf (2005) suggested that deeper knowledge of customer requirements and value contribution is required in today's global economy.

In addition to understanding markets and customers, building relationships are becoming critical to ensure sustainable competitive advantage. An emphasis on customer loyalty and the achievement of supply chain excellence have emerged in the industry today (Clarke-Hill *et al*, 2002). To remain competitive, firms have to be able to optimally supply customers (Benyoucef & Jain, 2008) by reducing the insecurity of supply in a dynamic industry (Wouters, 2004).

Wouters (2004) indicated that researchers had distinguished between two basic components of customer service in recent times. The one component was labelled "responsiveness" and concerns an organisations communication skills and commercial flexibility. The second component was labelled "bottom line reliability service" and concerns the basic logistics performance regarding availability, delivery reliability and quality of the deliveries (Wouters, 2004). While designing cost-effective supply chains in a global environment, companies should be aware of changes that will need to be made to operating policies to ensure that customers are served timely (Love *et al*, 2008).

2.3.1 Chemical commodities – Aspects of differentiation

Commodity products are those products that are perceived in the market by both buyers and suppliers as being homogenous or undifferentiated (Clarke-Hill *et al*, 2002). It should however be kept in mind that chemical commodities were not nearly as commoditized as true commodities such as copper or crude oil and therefore still offered much more opportunity for product differentiation (Budde & Hofmann, 2006). Due to the highly competitive global environment, marketers were going through a lot of effort for product differentitiation in an attempt to avoid their products being viewed as commodities (McQuiston, 2004). Very often, the focus of differentiation was shifted from physical to immaterial components. As their influence gradually increased, the commodity itself assumed an accessory nature and what was being offered is a service (D'Amico, 2004). Vandenbempt and Matthyssens (2008) proposed three main value propositions that could lead to competitive differentitiation:

1. ***Product leadership*** **–** Differentiation based on product innovation and superior product qualities.
2. ***Cost leadership*** **–** Differentitiation based on operational excellence and fair value solutions.
3. ***Customer linking*** **–** Differentiation based on service innovation and customer bonding.

According to Closs *et al* (2005), an increasing number of chemical companies were focused on supply chain management to cut costs while improving business processes and customer service. Research suggested that the chemical industry lagged other industries in terms of service capability. It was critical that customer requirements were integrated into chemical logistics capabilities (Closs *et al*, 2005).

2.3.2 Commodity differentiation – The link with supply chain

Clarke-Hill *et al* (2002) investigated the service attributes that enabled the differentitiation of chemical commodity products that would allow companies to break free from the commodity trap. From thirty-four options that were listed as possible differentiating attributes, the top eight were identified as:

1. Regular contact with customers
2. Order handling procedures
3. Emergency response to accident and prevention
4. Technical information
5. Delivery on time
6. Credit terms
7. Technical service and assistance
8. Just-in-time (JIT) delivery procedures (Clarke-Hill *et al*, 2002)

Three out of the eight identified attributes related to the logistics function and was labelled as follows:

- ***Category B*** – Relationship logistics focused, consisting of; order handling procedures, delivery on time, JIT delivery procedures (Clarke-Hill *et al*, 2002).

When considering the importance of Category B as identified by Clarke-Hill *et al* (2002), changes were required in terms of operating philosophies of supply chains and what was of particular concern is the determination of the required safety stock levels to support the desired customer service levels (Love *et al*, 2008). Love *et al* (2008) also concluded that insufficient research has been conducted to examine the inventory needs in support of global supply problems.

2.4 Conclusion of literature review

From the literature review, its apparent that supply chains are becoming more global and that lead-times for delivery is increasing. This phenomena result in higher inventory levels and more supply variability. In addition to the globalisation of supply chains, customers are becoming more complex and require more attention especially in a commodity market where differentitiation is based on the service levels provided. Customer service safety stock models are implemented with the intention to absorb the variability in terms of stochastic demand and supply and to ensure a constant service level to the customer. The current approaches and models however use generic assumptions and parameters, which result in lower than expected customer service levels.

The intention of this research is to establish if the current generic approaches to determining safety stocks are still relevant and if new models need to be developed with newly defined parameters that address a unique long lead-time bulk supply chain.

3 Research questions

When considering the context of the research and the literature review from Chapter 2, the following research questions will be addressed to enable conclusions concerning the research topic.

Research question 1: Are complex long lead-time supply chains prone to deliver low customer service levels?

This question will determine if longer lead-times for product delivery has an impact on the service levels delivered to the customer. The aspect of a variable stock re-order point will also be explored in terms of the impact on customer service. This question will establish the importance and difficulty of achieving higher levels of customer service in the context of the long lead-time supply chain under investigation.

Research question 2: Are safety stock models successful in absorbing variability of supply and demand?

This question will establish the current state of safety stocks in the supply chain under investigation and enquire regarding the inventory levels maintained at the different distribution hubs.

Research question 3: Are safety stock models optimizing the inventory investment and lost sales opportunities relationship?

In this question, the importance of safety stock in terms of cost optimisation *versus* customer service maximisation will be tested against each other. This will establish what is viewed as more important in the chemical commodity business, the cost of higher inventories or the potential of lost sales resulting in lower customer service levels.

Research question 4: Are the parameters used in customer service safety stock models applicable to a long lead-time supply chain?

In this question, the parameters that are considered to be of most importance in determining safety stock levels for customer service models will be determined and compared to what is currently used in literature. This result will then enable conclusions about the validity of the models in use.

When considering the outputs and results from al four questions, the research question in itself can be answered and recommendations can be made for future research within this field of literature.

4 Proposed Methodology

4.1 Research Design

The type of research to be done will be descriptive and the research design will be of a quantitative nature. In quantitative research, there are fundamentally two approaches to answering questions: descriptive and experimental (Botti & Endacott, 2008). According to Zikmund (2003), descriptive research seeks answers to who, what, where and how questions and it is based on some previous understanding of a research problem. Zikmund (2003) further states that descriptive research is frequently used to attempt to determine the extent of differences in the needs, perceptions and characteristics of sub-groups, as would be the case in this identified research. The aim is to evaluate if there is a requirement to develop new safety stock models in a globalised customer service environment characterised by long lead-time deliveries. Thus, seeking answers for questions that has surfaced due to a possible misalignment between safety stock models that are generically proposed and a unique supply chain environment.

4.2 Unit of analysis

The proposed unit of analysis would be cross-regional team responses from the identified sample.

4.3 Population and sampling frame

The population will be defined as all sales and supply chain personnel in organisations that are characterised by:

- Bulk chemical sales of > 1,000,000 tons per *annum*.
- Dependence on long lead-time supply chains for delivery of final product to distribution hubs where customers are then serviced from.
- Dependence on the availability of shipments for exports. The availability of vessels determines the stock re-order points and is thus in contrast to traditional theory where inventory levels determine the re-order points.
- A multi-echelon supply chain with fixed distribution hubs.
- A multiple product grade supply chain.

According to Zikmund (2003), a sampling frame is a list of elements from which a sample can be drawn. The sampling frame in the research will consist of employees from Sasol Solvents globally. The employees will include all sales and supply chain personnel stationed at one of the four chemical distribution hubs. The sampling frame will also include the global planning team situated in South Africa. The distribution hubs (and populations) are defined as:

- Johannesburg – Sasol Solvents South Africa
- Singapore/Xiao Hu Dao/Yokohama/Shanghai – Sasol Chemical Pacific
- Houston/Wilmington/Carteret – Sasol Chemicals North America

- Antwerp/Rotterdam/Moers – Sasol Chemicals Europe
- Dubai – Sasol Middle East

4.4 Sampling method

Non-probability sampling, where not every element in the identified sample has an equal probability of selection, will be the chosen sampling method (Zikmund, 2003). Although random sampling is the preferred sampling method, it can be very difficult due to time, cost and geographic considerations (Botti & Endacott, 2007). Convenience sampling, where the most readily available individuals are surveyed will be used (Botti & Endacott, 2007). This method is used when only estimates of a particular element are required (Botti & Endacott, 2007). In addition, when cost, time and geography places constraints on the sampling time-lines, convenience sampling provides the easiest solution.

4.5 Sample size

The larger the sample size, the higher the likelihood that the findings will accurately reflect the population because larger samples have lower sampling errors (Botti & Endacott, 2007). The sample size that will be targeted in this research will be forty-two respondents. The geographical detail of the sample can be seen in Table 4.

Table 4: Expected sample size and geographical distribution

Region	Size of sample
Sasol Chemical Pacific	23
Sasol Chemicals North America	5
Sasol Chemicals Germany	7
Sasol Middle East	3
Sasol Solvents South Africa	6
Other (please specify)	2
Total	**46**

4.6 Questionnaire design

The questionnaire can be defined as an instrument consisting of a series of questions and/or attitude opinion statements designed to elicit responses, which can be converted into measures of the variable under investigation (Murray, 1999). The questionnaire was constructed using a number of references from literature and will consist of five questions targeted at establishing if there is a need to develop new customer service safety stock models. For a detailed analysis and example of the questionnaire, please refer to Appendices 1. The questionnaire was not tested for clarity of design due to the small sample used for the research.

4.7 Data gathering process

Surveys in the form of self-administered electronic questionnaires will be used to generate primary data (Zikmund, 2003). The questionnaires will be distributed via e-mail due to the geographic location of the sampling frame. Zikmund (2003) proposed that internal surveys lend themselves to be distributed via e-mail and that the quick response time is a major advantage.

4.8 Analysis approach

According to Zikmund (2003), analysis is the application of reasoning to understand and interpret data that has been gathered. When referring to Table 5, the different approaches that will enable interpretation of the primary data to be collected are illustrated. The primary aim would be to determine if there are substantial differences between supply chains with long lead-times and variable re-order points and traditional supply chains used in literature to determine safety stock models. This will enable conclusions concerning the need for new safety stock models.

Table 5: Analysis approaches

Reference	Analysis approach	Motivation for approach
Question i (from questionnaire)	Frequency analysis (nominal) to categorize data if required.	To determine the proportion of the different regions. This will allow the segmentation of the data into sets for analysis as required.
Question 1	Interval analysis (Mean, standard deviation) on a Likert scale.	To determine the extent of the impact of long lead-time and variable re-order points on the customer service level.
Question 2	Frequency analysis (nominal) as well as interval analysis (Mean, standard deviation) on a Likert scale.	To determine if safety stock models are achieving the intended purpose of balancing supply and demand variability and if certain strategies are resulting in their expected outcomes.
Question 3	Interval analysis (Mean, standard deviation) on a Likert scale as well as some frequency analysis.	To determine the importance of safety stock in terms of balancing the cost between increased inventory and lost sales.
Question 4	Frequency analysis from a fixed checklist.	To establish if the correct parameters are being used in determining safety stock in comparison to the models in use.

The analysis approaches will allow the necessary conclusions to be made when addressing the research problem identified. A confidence level of 0.95 will be used throughout the analysis. Traditionally, researchers use a 0.95 confidence level. The 0.95 number allows for acceptable levels of random sampling error in this type of research where only estimates are required (Zikmund, 2003).

4.9 Research Limitations

The following aspects will limit the research on hand:

- The current regional distribution hubs are fixed and cannot be changed.
- It will be assumed that the coastal storage sites in South Africa will have sufficient capacity to supply product to the regions as required. The focus will therefore only be on the safety stocks in the defined global distribution hubs.
- The information collected will only be applicable to the context as defined briefly in the research scope and population.
- The current methods used in determining safety stocks are aligned to the customer service safety stock models and therefore assumed consistent across the regions.
- The customer service safety stock model was identified as the most applicable model for the defined scope and will be used for the basis of analysis

- Responses will only come from one global chemical company. This will limit the ability of generalising the research findings.
- The current booking procedure is fixed and only increases the complexity of the problem in terms of longer lead-times.
- The sample is too small to test the questionnaire for clarity and fit for purpose design to fully meet objectives of the research.

5 Results of research questionnaires

In total, 46 questionnaires were sent out and 39 were received back. This relates to an 84.4% response rate. The distribution of responses is illustrated in Table 6.

Table 6: Response rate distribution

i.i *Region*	*Size of sample*	*%*	*Responses received*	*%*
Sasol Chemical Pacific	23	*50%*	20	*51%*
Sasol Chemicals North America	5	*11%*	4	*10%*
Sasol Chemicals Germany	7	*15%*	7	*18%*
Sasol Middle East	3	*7%*	2	*5%*
Sasol Solvents South Africa	6	*13%*	5	*13%*
Other (please specify)	2	*4%*	1	*3%*
Total	**46**	*100%*	39	*100%*
Response rate			**84.8%**	

The questionnaire was sent to the supply chain and sales departments of the different regions as well as the general managers (captured under 'other') for the specific regions. The distribution of the departmental feedback is illustrated in Table 7.

Table 7: Summary of departmental feedback

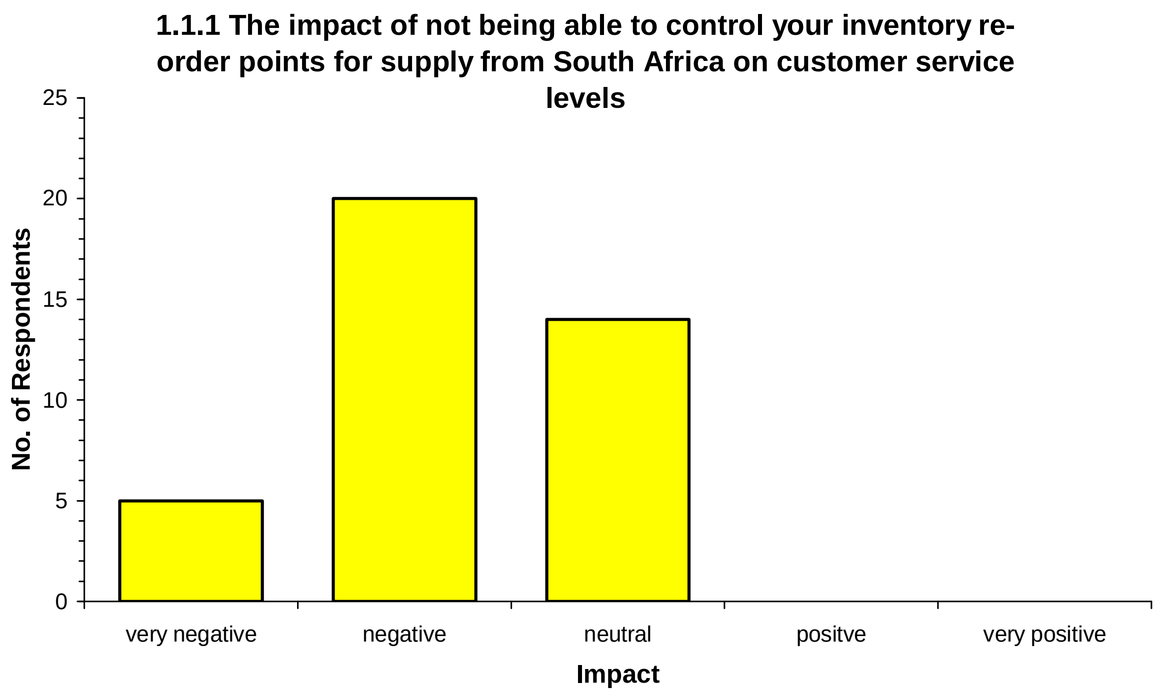
i.ii **Department**	**Respondents**	%
Supply Chain	21	*54%*
Sales	11	*28%*
Other	7	*18%*
Total	39	100%

Respondents that fulfilled a role in both the supply chain and sales departments were captured under 'other'. The questionnaire results were coded to enable descriptive analysis. The detail concerning the coding can be seen in Appendices 2. The results of each section will now be discussed.

5.1 Question 1 – Long lead-time supply chains

For the first part of Question 1, respondents were asked to comment on the impact of two aspects on their customer service levels on a Likert scale of 1 to 5 where one indicated very negative and five very positive impacts with three as neutral (please refer to Appendices 1 for a detailed description of the questionnaire). The two aspects measured in terms of impact on customer service levels were the inability to control the re-order points of stock replenishment and secondly the variable supply lead-time from South Africa. The results and summary statistics for the first part, impact of re-order points on customer service, can be seen in Figure 7.

Figure 7: Summary of the impact of re-order points on customer service levels



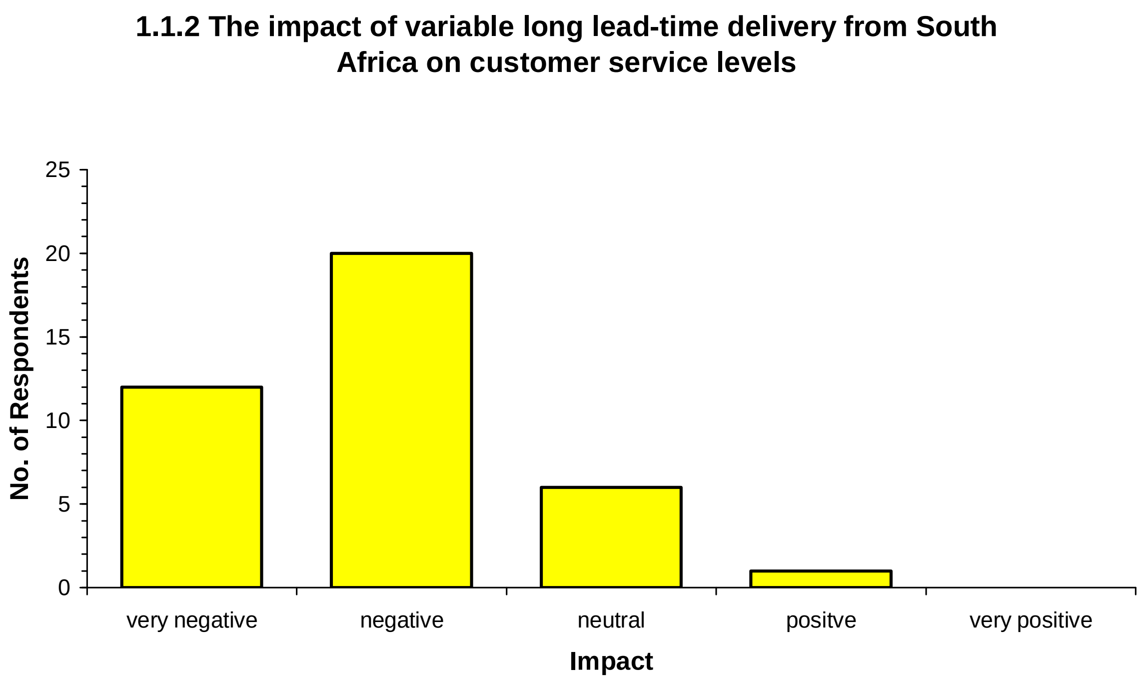
Re-order points:

Count	Mean	Standard Deviation	Standard error	Min	Max	LCL (95%)	UCL (95%)
39	2.23	0.67	0.11	1	3	2.01	2.45

From Figure 7, it can be noted that the distribution of the answers are skewed to the negative side and that no positive effect was recorded. The mean is 2.23, which would indicate a negative impact, and the range is limited to between one and three.

In Figure 8, the results for the second part of the question, the impact of variable long lead-time on customer service, can be seen.

Figure 8: Summary of the impact of long lead-times on customer service levels



Long lead-time

Count	Mean	Standard Deviation	Standard error	Min	Max	LCL (95%)	UCL (95%)
39	1.90	0.75	0.12	1	4	1.65	2.14

The results of this question had a wider range although the average is 1.90, which indicates a slightly higher standard deviation. Again, this question leans toward the negative side.

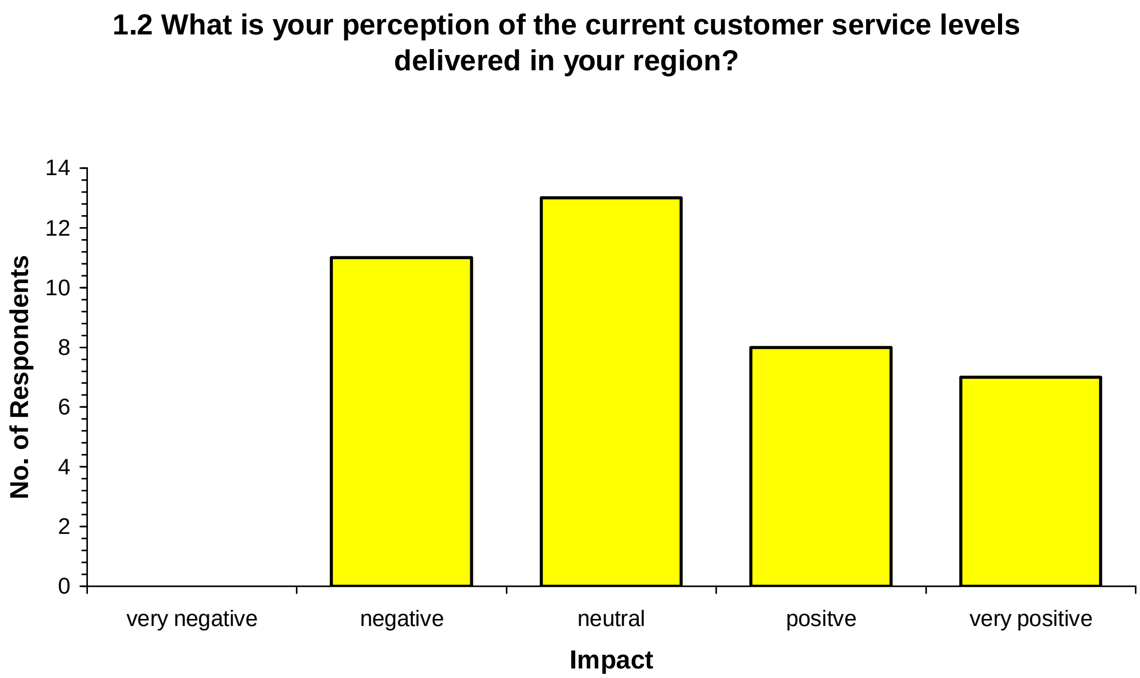
The second section of Question 1, related to the current perceptions of the existing customer service levels in the different regions which are all characterised by both the:

- Inability to control inventory re-order points, and

- Variable long lead-time supply

The summary of the results can be seen in Figure 9.

Figure 9: What is the perception of the current customers service levels delivered in your region?



Customer service levels

Count	Mean	Standard Deviation	Standard error	Min	Max	LCL (95%)	UCL (95%)
39	3.28	1.07	0.17	2	5	2.93	3.63

The feedback from this question ranged between two and five with a mean of 3.28 and a standard deviation of 1.07. This larger standard deviation is explained when considering the histogram in Figure 9, which illustrates the random distribution of the responses.

5.2 Question 2 – Supply and demand variability

In Question 2, focus moved away from long lead-time and supply to safety stocks. Respondents were first asked whether they implemented safety stocks in their regions. These results can be seen in Table 8.

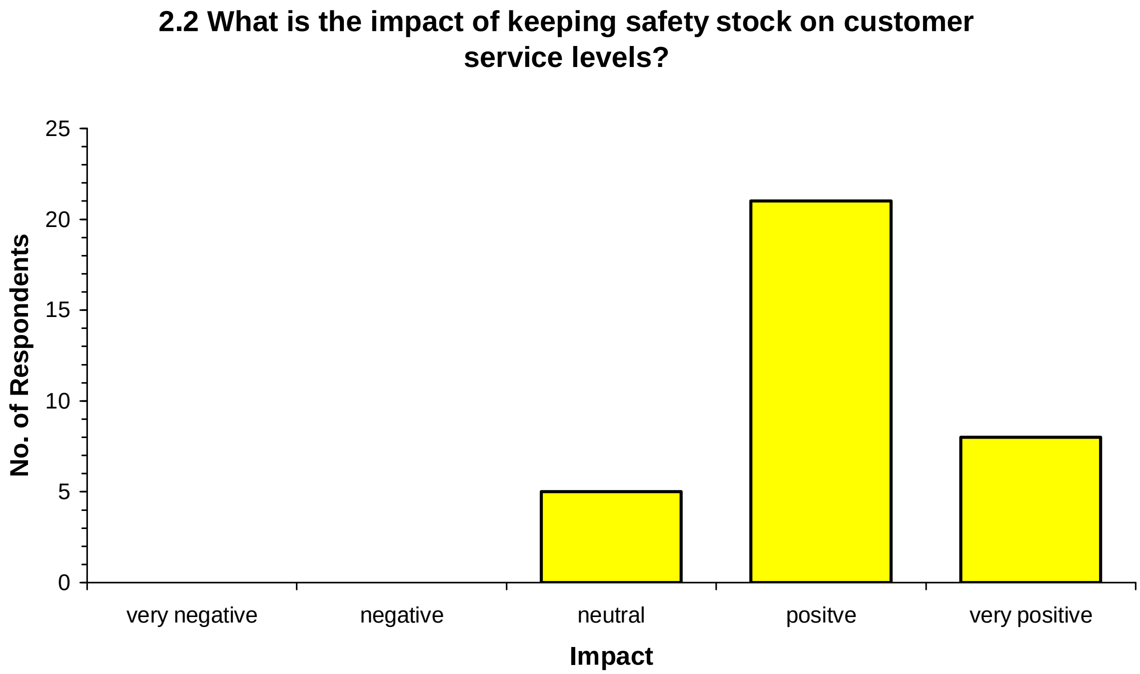
Table 8: Do you have safety stocks in you region?

2.1	*Respondents*	%
Yes	31	79%
No	5	13%
Maybe	3	8%
Total	39	

If respondents answered '*No*' to this question, their questionnaires were considered to be completed and they did not continue to the next question. Thus, from this point forward, only 34 respondents from the previous 39 were considered for further analysis.

The second part of Question 2, tried to establish what the impact of keeping safety stock was on the customer service levels in the different regions. Responses were measured on a Likert scale where very negative = 1 and very positive = 5 (and neutral as 3). In Figure 10, the summary results of this question can be seen.

Figure 10: What is the impact of keeping safety stock on customer service levels?



Impact of safety stock

Count	Mean	Standard Deviation	Standard error	Min	Max	LCL (95%)	UCL (95%)
34	4.09	0.62	0.11	3	5	3.87	4.30

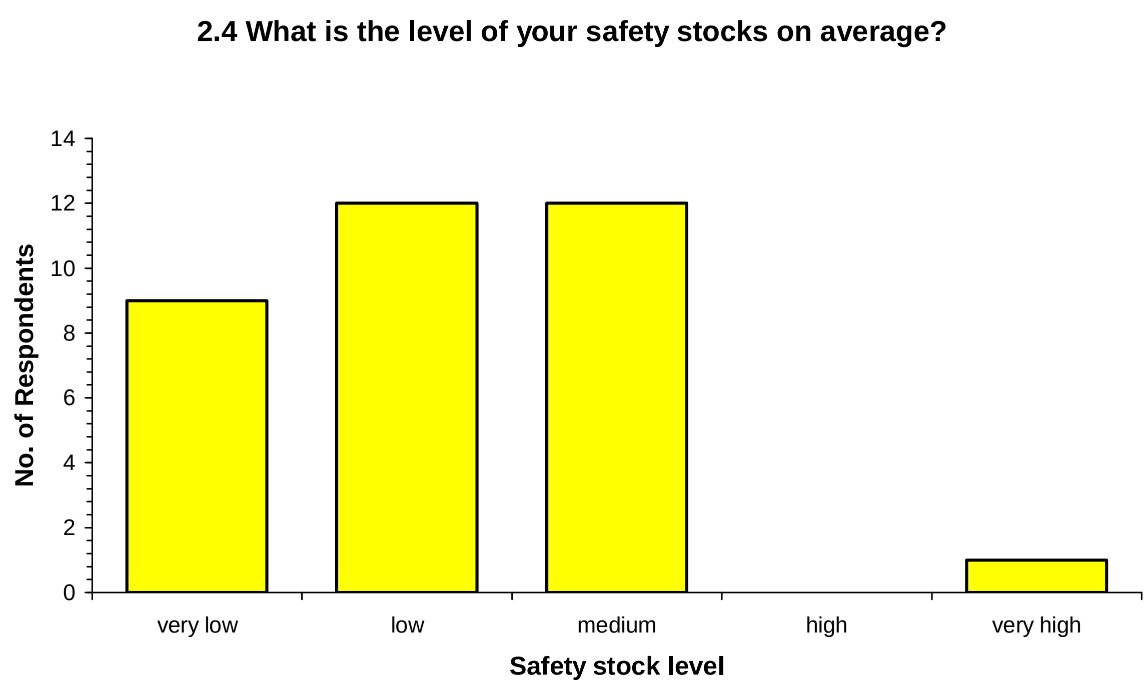
There was an overwhelming positive response to this question with the mean equalling 4.09 with a standard deviation of 0.62. The range was only from three to five. Respondents were then asked if the unavailability of inventory, when faced with a possible sales opportunity, related to lower customer service. The results are shown in Table 9.

Table 9: If a sale is not made due to low stock levels, does that relate to lower customer service levels?

2.3	Respondents	%
Yes	22	65%
No	3	9%
Maybe	9	26%
Total	34	

This illustrated that only 9% of the respondents agreed that depleted inventory does not relate to lower customer service levels. Question 2 then ended by assessing the average safety stock levels in the regional storage hubs. The scales of measurement were changed from this question going forward. The responses were rated on a Likert scale where very high = 5 and very low = 1 (with medium as 3). The results are shown in Figure 11.

Figure 11: What is the level of your safety stocks on average?



Average safety stock levels

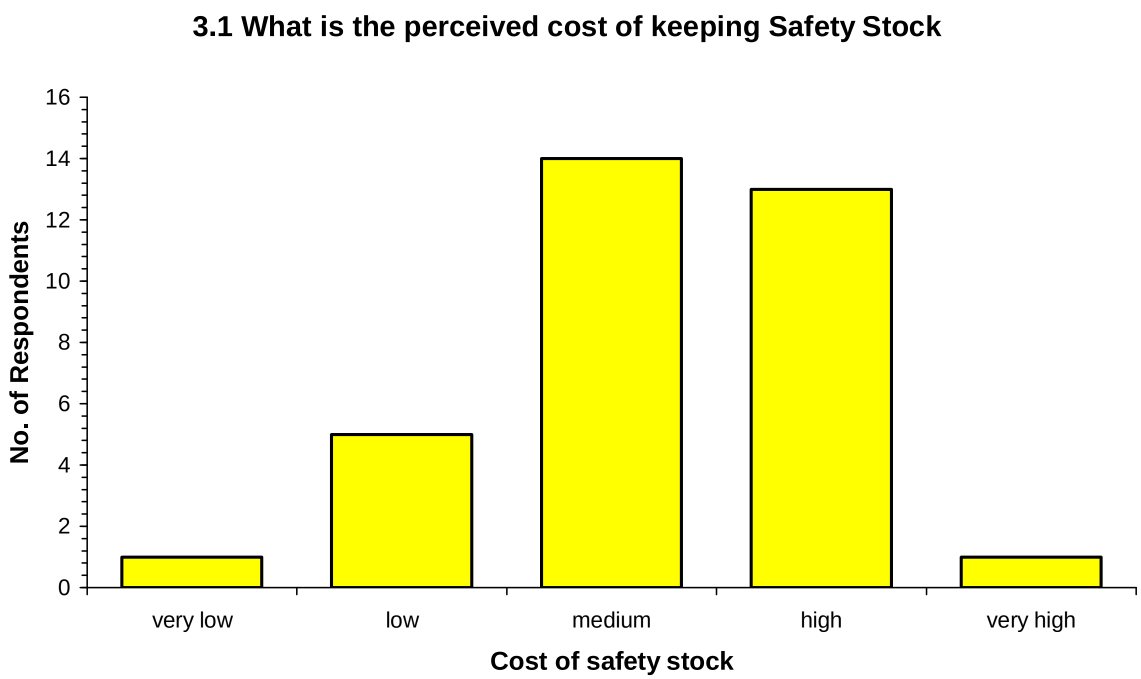
Count	Mean	Standard Deviation	Standard error	Min	Max	LCL (95%)	UCL (95%)
34	2.18	0.94	0.16	1	5	1.85	2.50

The average safety stock was 2.18, which would tend to indicate that safety stocks are low. There is however, an outlier as illustrated by the histogram in Figure 11, which is increasing the standard deviation to a larger 0.94. The responses are however mostly on the low side.

5.3 Question 3 – The impact and effect of safety stock

In Question 3, the costs associated with keeping safety stock and the cost of loosing sales opportunities due to depleted stocks were measured by Likert scales. The scales were developed such that very high = 5 and very low = 1 with medium = 3. The first section considered the cost of safety stocks. This is illustrated in Figure 12.

Figure 12: What is the perceived cost of keeping safety stock?



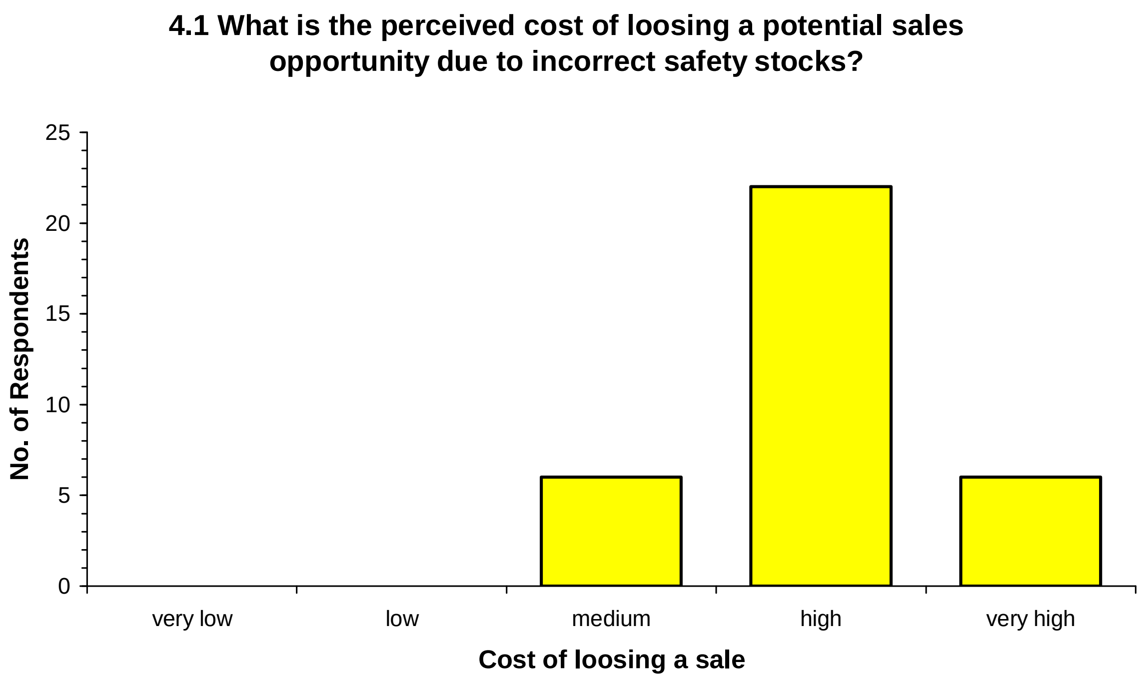
Cost of safety stock

Count	Mean	Standard Deviation	Standard error	Min	Max	LCL (95%)	UCL (95%)
34	3.24	0.85	0.15	1	5	2.94	3.53

The mean of the responses were 3.24, which would indicate a medium to high cost. The responses are spread across the whole range, which tends to approach a slightly skewed normal distribution. The standard deviation is calculated as 0.85.

The costs associated with loosing a potential sale due to incorrect safety stocks were then considered on the same scale as above. The results are illustrated in Figure 13.

Figure 13: What is the perceived cost of loosing a potential sales opportunity due to incorrect safety stocks?



Cost of lost sales opportunities

Count	Mean	Standard Deviation	Standard error	Min	Max	LCL (95%)	UCL (95%)
34	4.00	0.60	0.10	3	5	3.79	4.21

The average of the responses was 4.00 with a standard deviation of 0.60. The responses were however only on the medium to very high range.

The last section of Question 3, tries to establish what is perceived as more important:

- Reducing safety stocks
- Increasing customer service levels
- Both of the above

The results are shown in Table 10. Only one of the respondents indicated that reducing safety stocks are more important. The majority indicated that the optimisation of both is required.

Table 10: What is perceived to be more important?

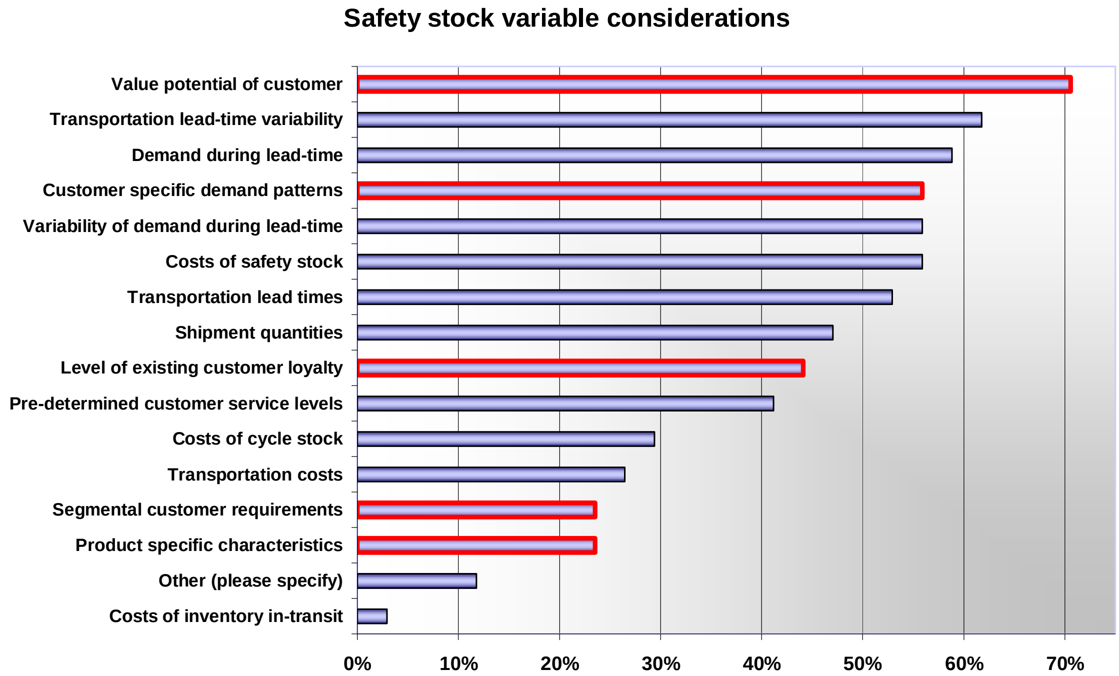
4	Respondents	%
Reduce SS	1	3%
Increase CS	10	29%
Both	23	68%
Total	**34**	

In total, 32% of the respondents indicated that only one of the choices offered is more important for consideration.

5.4 Question 4 – Determining correct safety stocks

In Question 4, the aim was to determine what both supply chain and sales personnel consider as the important characteristics for determining the adequate safety stock levels in the regions. The questionnaire was populated with variables that are traditionally being used to determine safety stocks as well as variables that are proposed by literature in an effort to enhance product differentiation through inventory availability. The frequency analysis can be seen, in ranked order, in Figure 14.

Figure 14: Frequency rank of characteristics that determine optimal safety stocks



In Figure 14, the bars highlighted in red are variables that are not currently being used in the determination of safety stocks but are proposed by literature for consideration. A detailed ranking is shown in Table 11.

Table 11: Ranking of parameters

	Variable	Count	%
1	*Value potential of customer*	24	70.6%
2	*Transportation lead-time variability*	21	61.8%
3	*Demand during lead-time*	20	58.8%
4	*Costs of safety stock*	19	55.9%
5	*Variability of demand during lead-time*	19	55.9%
6	*Customer specific demand patterns*	19	55.9%
7	*Transportation lead times*	18	52.9%
8	*Shipment quantities*	16	47.1%
9	*Level of existing customer loyalty*	15	44.1%
10	*Pre-determined customer service levels*	14	41.2%
11	*Costs of cycle stock*	10	29.4%
12	*Transportation costs*	9	26.5%
13	*Product specific characteristics*	8	23.5%
14	*Segmental customer requirements*	8	23.5%
15	*Other (please specify)*	4	11.8%
16	*Costs of inventory in-transit*	1	2.9%

5.5 Summary of descriptive statistics

The descriptive statistics summary resulting from the coding of the Likert scale responses is shown in Table 12.

Table 12: Summary of descriptive statistics

Very negative = 1, Negative = 2, Neutral = 3, Positive = 4, Very positive = 5	Num of respondents	Mean of responses	Standard deviation of responses
1.1.1 The impact of not being able to control your inventory re-order points for supply from South Africa on customer service levels	39	2.23	0.67
1.1.2 The impact of variable long lead-time delivery from South Africa on customer service levels	39	1.90	0.75
1.2 What is your perception of the current customer service levels delivered in your region?	39	3.28	1.07
2.2 What is the impact of keeping safety stock on customer service levels?	34	4.09	0.62

Very low = 1, Low = 2, Medium = 3, High = 4, Very high = 5

2.4 What is the level of your safety stocks on average?	34	2.18	0.94
3.1 What is the perceived cost of keeping Safety Stock	34	3.24	0.85
3.2 What is the perceived cost of loosing a potential sales opportunity due to incorrect safety stocks?	34	4.00	0.60

5.6 Summary of descriptive statistics per grouping variable

In the questionnaire, a number of categorical questions were asked. These questions will now be illustrated in descriptive statistics per category.

In Table 13, the descriptive statistics summary for the departmental categories can be seen. Only the first three questions of the questionnaire were applicable to the sample response. From Question 2, filtering was done to ensure that only applicable respondents answered the sections following.

Table 13: Descriptive statistics per department

Very negative = 1, Negative = 2, Neutral = 3, Positive = 4, Very positive = 5	Department	Count	Mean	Stdev	Min	Max
1.1.1 The impact of not being able to control your inventory re-order points for supply from South Africa on customer service levels	Other	7	**1.57**	0.53	1	2
	Sales	11	**2.27**	0.65	1	3
	SC	21	**2.43**	0.60	1	3
1.1.2 The impact of variable long lead-time delivery from South Africa on customer service levels	Other	7	**2.00**	0.82	1	3
	Sales	11	**1.64**	0.67	1	3
	SC	21	**2.00**	0.77	1	4
1.2 What is your perception of the current customer service levels delivered in your region?	Other	7	**3.29**	0.76	2	4
	Sales	11	**3.09**	1.22	2	5
	SC	21	**3.38**	1.12	2	5
2.2 What is the impact of keeping safety stock on customer service levels?	Other	6	**4.50**	0.55	4	5
	Sales	10	**4.20**	0.63	3	5
	SC	18	**3.89**	0.58	3	5
Very low = 1, Low = 2, Medium = 3, High = 4, Very high = 5						
2.4 What is the level of your safety stocks on average?	Other	6	**1.67**	0.82	1	3
	Sales	10	**1.90**	0.74	1	3
	SC	18	**2.50**	0.99	1	5
3.1 What is the perceived cost of keeping Safety Stock	Other	6	**3.17**	0.75	2	4
	Sales	10	**2.90**	1.10	1	4
	SC	18	**3.44**	0.70	2	5
3.2 What is the perceived cost of loosing a potential sales opportunity due to incorrect safety stocks?	Other	6	**4.00**	-	4	4
	Sales	10	**3.90**	0.74	3	5
	SC	18	**4.06**	0.64	3	5

In Table 14, results taking into account the category of safety stock ('do you have safety stock?') is shown. This was the filtering question and therefore Table 14 is only applicable to the first three questions.

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Table 14: Descriptive statistics as per actual safety stock

Very negative = 1, Negative = 2, Neutral = 3, Positive = 4, Very positive = 5	Safety Stock	Count	Mean	Stdev	Min	Max
1.1.1 The impact of not being able to control your inventory re-order points for supply from South Africa on customer service levels	Maybe	3	**1.67**	0.58	1	2
	No	5	**2.80**	0.45	2	3
	Yes	31	**2.19**	0.65	1	3
1.1.2 The impact of variable long lead-time delivery from South Africa on customer service levels	Maybe	3	**1.67**	0.58	1	2
	No	5	**1.80**	0.45	1	2
	Yes	31	**1.94**	0.81	1	4
1.2 What is your perception of the current customer service levels delivered in your region?	Maybe	3	**3.33**	0.58	3	4
	No	5	**2.60**	0.89	2	4
	Yes	31	**3.39**	1.12	2	5

In Table 15, the results from the response relating to lower customer service if a sale cannot be made due to inaccurate safety stocks, is illustrated.

Table 15: Descriptive statistics per 'customer service result'

Very negative = 1, Negative = 2, Neutral = 3, Positive = 4, Very positive = 5	Result	Count	Mean	Stdev	Min	Max
1.1.1 The impact of not being able to control your inventory re-order points for supply from South Africa on customer service levels	Maybe	9	**2.33**	0.71	1	3
	No	3	**2.00**	1.00	1	3
	Yes	22	**2.09**	0.61	1	3
1.1.2 The impact of variable long lead-time delivery from South Africa on customer service levels	Maybe	9	**2.22**	0.67	1	3
	No	3	**1.67**	0.58	1	2
	Yes	22	**1.82**	0.85	1	4
1.2 What is your perception of the current customer service levels delivered in your region?	Maybe	9	**3.22**	0.97	2	5
	No	3	**3.33**	1.53	2	5
	Yes	22	**3.45**	1.10	2	5
2.2 What is the impact of keeping safety stock on customer service levels?	Maybe	9	**3.78**	0.83	3	5
	No	3	**4.33**	0.58	4	5
	Yes	22	**4.18**	0.50	3	5
Very low = 1, Low = 2, Medium = 3, High = 4, Very high = 5						
2.4 What is the level of your safety stocks on average?	Maybe	9	**2.44**	0.73	1	3
	No	3	**1.67**	0.58	1	2
	Yes	22	**2.14**	1.04	1	5
3.1 What is the perceived cost of keeping Safety Stock	Maybe	9	**3.44**	0.73	2	4
	No	3	**2.00**	1.00	1	3
	Yes	22	**3.32**	0.78	2	5
3.2 What is the perceived cost of loosing a potential sales opportunity due to incorrect safety stocks?	Maybe	9	**3.89**	0.33	3	4
	No	3	**3.67**	0.58	3	4
	Yes	22	**4.09**	0.68	3	5

In Table 16, results according to the perception of importance of reducing safety stock, increasing customer service or both, is shown.

Table 16: Descriptive statistics per importance category

Very negative = 1, Negative = 2, Neutral = 3, Positive = 4, Very positive = 5	Importance	Count	Mean	Stdev	Min	Max
1.1.1 The impact of not being able to control your inventory re-order points for supply from South Africa on customer service levels	Both	23	**2.13**	0.69	1	3
	Increase CS	10	**2.20**	0.63	1	3
	Reduce SS	1	**2.00**		2	2
1.1.2 The impact of variable long lead-time delivery from South Africa on customer service levels	Both	23	**1.87**	0.81	1	4
	Increase CS	10	**2.00**	0.82	1	3
	Reduce SS	1	**2.00**		2	2
1.2 What is your perception of the current customer service levels delivered in your region?	Both	23	**3.57**	1.16	2	5
	Increase CS	10	**3.00**	0.82	2	4
	Reduce SS	1	**3.00**		3	3
2.2 What is the impact of keeping safety stock on customer service levels?	Both	23	**4.04**	0.64	3	5
	Increase CS	10	**4.20**	0.63	3	5
	Reduce SS	1	**4.00**		4	4
Very low = 1, Low = 2, Medium = 3, High = 4, Very high = 5						
2.4 What is the level of your safety stocks on average?	Both	23	**2.13**	0.87	1	3
	Increase CS	10	**2.00**	0.67	1	3
	Reduce SS	1	**5.00**		5	5
3.1 What is the perceived cost of keeping Safety Stock	Both	23	**3.30**	0.82	1	4
	Increase CS	10	**2.90**	0.74	2	4
	Reduce SS	1	**5.00**		5	5
3.2 What is the perceived cost of loosing a potential sales opportunity due to incorrect safety stocks?	Both	23	**4.00**	0.60	3	5
	Increase CS	10	**4.00**	0.67	3	5
	Reduce SS	1	**4.00**		4	4

6 Analysis of results

The analyses will be done by addressing each research question and its associated questionnaire results as presented in Chapter 5. The research questions will then be viewed in an integrated way to establish if any other possible relationships between the different questions and respondents exist. The main research question will then be answered by way of the knowledge gained from the analyses of the results. The analyses for each research question will now follow.

6.1 Research question 1: Are complex long lead-time supply chains prone to deliver low customer service levels?

The questionnaire was constructed in such a way that Question 1, would specifically address this research question. In 5.1, the result for this section is illustrated. Each section will now be analysed in more detail.

6.1.1 Inventory re-order points

The first section of the question was intended to examine a supply chain characterised by the inability to control inventory re-order points and the resulting impact thereof on customer service levels. It was found from the sample that the inability to control your inventory re-order points resulted in a negative impact on customer service levels. The mean of the sample was 2.23 where 3.00 was seen as a neutral impact and less than 3.00 as negative. The lower confidence level (LCL) and upper confidence level (UCL) with a $\rho = 0.05$, was 2.01 and 2.45

respectively. Therefore, with a 0.95 confidence level, it can be concluded that the true mean is located between these values, which are located on the negative side of the Likert scale. It is therefore apparent that there is negative influence on customer service levels when there is no ability to control re-order points for stock replenishment.

Stock re-order points are the output of inventory models and therefore assumed to be under the control of management (Aghezzaf et al, 2007, Mattsson, 2007, Cetin et al, 2004). The analyses, however, indicated that the inability for stock re-order control, results in less than average customer service levels. This phenomenon is however, not considered in safety stock management (Aghezzaf et al, 2007, Mattsson, 2007) as this is a very specific and location based problem. This aspect adds additional complexity to the already complex, variable long lead-time supply chain under investigation.

6.1.2 Variable long lead-time

The results of the questionnaires indicated that the effect of variable long lead-time supply on customer service levels was negative. The mean from the sample was 1.90 with LCL of 1.65 and UCL of 2.14 (with $\rho = 0.05$). This clearly indicates that variable long lead-time has a negative impact on customer service levels. This result comes as no surprise as Gargeya and Meixell (2005) concluded that global supply chains are much more difficult to manage. Chandra and Grabis (2006) were also clear in their findings that risks increase with long lead-times in terms of unavailability of inventory. When also considering the variability in the inter-arrival times of deep-sea vessels, as have been illustrated in Chapter 1, this result is expected.

It can also be noted that the negative effect of variable long lead-time on customer service levels is perceived to have a greater negative effect than that of the inability to control re-order points (mean of 1.90 vs. 2.23). Thus, focus should rather shift to reducing lead-time variability than trying to establish re-order criteria. In addition, the inability to establish constant stock re-order criteria adds to the increased variability of the lead-times. These two aspects are therefore in a sense related and addressing the variability of lead-times should lead to a lesser impact from the re-order constraint.

6.1.3 Customer service levels

All participants in the questionnaire form part of a multi-echelon supply chain where management are not able to control their inventory re-order points and are at the mercy of variable long lead-times for product supply to the regional distribution hubs. When considering the current customer service levels from the sample in the regions, a mean of 3.28 was found with a LCL of 2.93 and a UCL of 3.63 ($\rho = 0.05$). The distribution of the responses was skewed to the right and it appears that customer service levels are neutral to positive. The standard deviation is however large (1.07) which results in a wider distribution for the confidence levels. It can therefore not be concluded that the true mean is higher than 3.00, which is the neutral point. It should however be noted that the customer service levels are not predominantly negative as would have been expected when considering the analyses in the previous two sections.

Thus, when the inability to control stock re-order points and long lead-time variability are both affecting customer service levels negatively and customer service levels are still maintained at a neutral level (although leaning toward positive), some other forms of intervention are in place. One such measure is to introduce safety stocks to a supply chain. This will ensure that customers receive promised service levels (Blau et al, 2008). This seems to be the case in these supply chains under investigation although neutral customer service levels are not at any stage considered as meeting promised service levels. Service levels are therefore adequate but the whole purpose of safety stock is to increase these service levels to a maximum by absorbing the variability. There are however other measures, as defined by Clarke-Hill et al (2002) that can also ensure better customer service levels. The question would now be if safety stock were in part responsible for maintaining average customer service levels in a supply chain where low service levels are expected.

6.1.4 Conclusion to Research Question 1

Complex long lead-time supply chains are set up for customer service failure. In this case, there is an additional impact relating from the production location, which results in the inability to control the stock replenishment timing. From the results, it is clear that both these factors negatively influence customer service levels. It can therefore be concluded that the type of supply chain under review is prone to low customer service levels due to these two factors that influence the reliable supply of products. It is also apparent that currently there are some other mitigating systems in place that ensures that customers get a neutral service at the least.

Therefore, in a complex long lead-time supply chain, low (negative) customer service levels can be expected in the absence of mitigating actions.

6.2 Research question 2: Are safety stock models successful in absorbing variability of supply and demand?

As stated by Aghezzaf et al (2007), when faced with stochastic demand, safety stocks need to be introduced to protect against stock-outs. In Question 1, the conclusions were made that complex supply chains are prone to deliver low customer service levels in absence of mitigating actions. The role of safety stock will now be explored following the responses from Question 2 in the questionnaire.

6.2.1 Regional safety stocks

It was found that 13% of the respondents did not have safety stocks as part of their regional inventory management systems. Another 8% indicated that they ‘Maybe’ have safety stocks in practice. What is interesting to note is that, when referring to 5.6, Table 14, the respondents who do not have safety stocks in their regions have a lower perception of current customer service levels. The respondents who did not have safety stocks in their regions had a mean of 2.60 (n = 5) compared to that of 3.39 (n = 31) for the 'Yes' respondents and 3.33 (n = 3) for the 'Maybe' respondents. Although the sample is very small for the 'No' respondents, it has a material effect on the perceived level of customer service for the total sample. Thus, for supply chains that do not have safety stocks as part of their inventory management systems, there seems to be a lower perceived customer service level. Due to the small sample of 'No' respondents, this can however not be concluded although it should be noted for possible future research.

This finding however provides some evidence of the impact of safety stocks in this specific supply chain environment. This supports the notion of Butler et al (2007) who stated that safety stocks hedge against supply and demand variability. The next question would be if safety stocks provide adequate improvements in the perceived customer service levels.

6.2.2 Impact of safety stocks on customer service

There was an overwhelming positive response in terms of the positive impact of keeping safety stock in the regional distribution hubs. The mean for response was found to be 4.09, which indicate a positive impact on customer service levels. The LCL and UCL were found to be 3.87 and 4.30 respectively ($\rho = 0.05$). This indicates with a confidence level of 0.95, that the true mean is a positive impact. Thus, safety stocks have a positive influence on customer service levels. This is supported by Blau et al (2008) who also warned that excess safety stock increases operating costs and should therefore be suitably optimised.

When considering the analyses of the first part of Chapter 6, it can be concluded that the presence of safety stock in a regional hub is successful at absorbing the variability of supply as well as mitigating the impact of the lack of control over stock re-order points. The presence of safety stock leads to the neutral customer service levels that are currently experienced when negative service levels are expected. It should however be noted that if the safety stock requirements are defined correctly, that customer service levels should be higher. There is still however some other factors that can also add to the perceived neutral customer service level as is identified by Clarke-Hill et al (2002).

6.2.3 Inventory impact on customer service

Clarke-Hill et al (2002) identified a number of factors that influence customer service levels. One of these was the lack of availability of inventory, which relates directly to safety stocks. The respondents were asked whether the loss of a sales opportunity due to depleted stocks, from incorrect safety stock calculations, resulted in lower customer service levels. Only 9% of the respondents answered ‘No’ (n = 3), where 65% answered ‘Yes’ (n = 22) and 26% ‘Maybe’ (n = 9). This provides evidence that the inability to provide product when sales opportunities arise does lead to lower customer service levels in the long run. Thus, the availability of inventory to supply customers increases the customer service levels.

This confirms that the current perceived customer service levels (as in 5.1) are mostly inventory supply related and not due to other factors as mentioned by Clarke-Hill et al (2002). Thus, if higher safety stock levels were kept, better customer service levels could be expected. The availability of inventory should however be balanced with the cost of keeping this additional inventory (Blau et al, 2008).

6.2.4 Level of safety stocks

It is now known that the availability of inventory, that is made possible by safety stocks, mitigate the negative impact of variable product supply on customer service levels. Further, it is also known that excess inventory levels results in higher risk but also higher customer service levels.

The average stock levels in the regions were found to be low with a mean of 2.18. The LCL and UCL was calculated as 1.85 and 2.50 respectively ($\rho = 0.05$). The true mean is therefore within the range of low safety stock levels. Blau et al (2008) indicated that with higher safety stock levels, better customer service levels can be achieved but that costs also increase with associated risk. In this case, we have seen that customer service levels are neutral even though the supply chain is of a complex and variable nature. These results also show that safety stock levels are in the low range, which makes sense when considering the neutral customer service levels as mentioned earlier.

6.2.5 Conclusion to Research Question 2

When reflecting back to the first research question, it was apparent that complex long lead-time supply chains have difficulty in sustaining expected customer service levels due to the inherent global nature of the activities. This is however currently being managed and customer service levels are perceived as neutral where negative service levels are expected. The question was then be asked, what is being done to achieve this?

In this section of the research, it was found that 87% of the respondents have safety stocks in the regional distribution hubs as part of their inventory management policies. It was found that safety stocks result in a significant positive effect on customer service levels and therefore prove to be successful in mitigating the risks that are immanent from a complex long lead-time supply chain. In addition, the unavailability of inventory leads to lower customer service levels. It was also found that the average inventory levels in the regions are low which explains why regional customer service levels are only maintained at the neutral level.

When considering all these aspects, it can be concluded that safety stock models are indeed absorbing the variability in a long lead-time complex supply chain. There exists some opportunity to increase safety stock levels to enhance the customer service level but this would require some mechanism to determine the optimal level in terms of service and cost. The aspect of costs related to lost sales and inventory investments will therefore play an important role in establishing the optimal safety stocks.

6.3 Research question 3: Are safety stock models optimizing the inventory investment and lost sales opportunities relationship?

According to Kodali & Routroy (2004), there are two main objectives for formulating inventory policies. The one part is to maintain specified customer service levels and the other part considers the optimisation of the inventory investment. A careful balance is therefore required, which should be the outcome of safety stock models. In this case, the objective was to determine what is perceived to be the most important aspect, increasing customer service levels or reducing safety stocks, and if a balance really exist.

6.3.1 Cost of safety stock

Safety stock levels need to be optimised. This is done by using the relevant models as indicated by Love et al (2008). From the feedback of the respondents, it was found that, on average, the cost of keeping safety stock is considered medium to high. The mean of the responses was 3.24 with a LCL of 2.94 and a UCL of 3.53 ($\rho = 0.05$). It can therefore be concluded, with a 0.95 confidence level, that the true mean is within the medium cost range.

6.3.2 Cost of lost sales opportunities

The cost of lost sales opportunities where found to be higher than that of the cost of safety stock. The mean was calculated as 4.00 with a LCL and UCL of 3.79 and 4.21 respectively ($\rho = 0.05$). With 0.95 confidence, it can be concluded that the cost of lost sales opportunities is in the high range of the Likert scale.

6.3.3 Safety stocks vs. Lost sales

Lost sale opportunities have a higher cost than that of safety stock (mean of 3.24 vs. 4.00). This would allude to the consideration that more safety stock should be kept to minimise lost sales opportunities and therefore to ensure higher profitability.

Respondents were asked to decide whether reducing safety stocks, increasing customer service levels or both of these aspects were considered as the most important aspect to focus optimisation efforts on. The feedback indicated that 68% ($n = 23$) of respondents were of the opinion that both of the aspects require equal attention. This supports the notion of Kodali and Routroy (2004) as well as Blau et al (2008) that both these areas need to be optimised and a cost effective balance found. The feedback did however indicate that 26% of respondents felt that the primary objective should be to increase customer service levels.

6.3.4 Conclusion to Research Question 3

It would appear that the perceived cost of keeping safety stock is less than that of lost sales opportunities. With the purpose of optimising profitability, more safety stocks should therefore be kept to ensure higher customer service levels. This is in contrast to the findings when considering the low safety stock levels and the neutral customer service levels in the previous analyses. As Blau et al (2008) has indicated, higher safety stock levels relate to higher customer service levels. In this case, the safety stock levels are low and the customer service levels neutral.

This begs the question if the correct models are being used to determine the optimal safety stock levels. In this case, safety stock levels are low and customer service neutral although the cost of safety stock is much lower than the cost of loosing sales opportunities. It can therefore be concluded that in this specific case and sample, there does not seem to be an adequate balance between the costs of safety stock versus that of loosing sales opportunities and that the actual preference, as from the results, is weighed towards reducing safety stock even though this should be the incorrect action to take. It is of utmost importance that this relationship is balanced to ensure maximum profitability. Therefore, safety stock models are not optimizing the relationship between the costs of safety stock and that of loosing potential sales opportunities in a long lead-time supply chain.

6.4 Research question 4: Are the parameters used in customer service safety stock models applicable to a long lead-time supply chain?

A number of variables are used in customer service safety stock models to determine the optimal levels for servicing customers at some pre-determined customer service level. The safety stock models attempts to establish a balance between the inventory investment and the cost of loosing sales opportunities. The parameters used in the questionnaire were a combination of variables identified by Aghezzaf et al (2007), Mattsson (2007), Cetin et al (2004), Wouters (2004), and Clarke-Hill et al (2002). Respondents were asked to select the most relevant parameters when considering the calculation of safety stocks. The responses were then ranked in a frequency table. This is once again illustrated in Table 17.

Table 17: Ranking of parameters

	Variable	Count	%
1	*Value potential of customer*	24	70.6%
2	*Transportation lead-time variability*	21	61.8%
3	*Demand during lead-time*	20	58.8%
4	*Costs of safety stock*	19	55.9%
5	*Variability of demand during lead-time*	19	55.9%
6	*Customer specific demand patterns*	19	55.9%
7	*Transportation lead times*	18	52.9%
8	*Shipment quantities*	16	47.1%
9	*Level of existing customer loyalty*	15	44.1%
10	*Pre-determined customer service levels*	14	41.2%
11	*Costs of cycle stock*	10	29.4%
12	*Transportation costs*	9	26.5%
13	*Product specific characteristics*	8	23.5%
14	*Segmental customer requirements*	8	23.5%
15	*Other (please specify)*	4	11.8%
16	*Costs of inventory in-transit*	1	2.9%

The results were surprising in that the highest-ranking variable identified, was one that is not currently being used in the safety stock models. In the previous section, it was concluded that the current models are not successful at finding a balance between safety stock investment and the cost of lost sales.

The *'value potential of a customer*' was identified as the highest-ranking parameter with 70.6% of the responses. When considering earlier analyses, this should not be surprising. The cost of loosing sales is directly related to this variable and in the previous section this cost was identified as high. If the value potential of a customer were very high, the lost sales opportunity would then also be high causing an imbalance in the safety stock calculations and optimal profitability. The reverse, lower value potential would also be true in this case. Unfortunately, such a variable does not exit in the safety stock models used even though ranked as the highest priority by the sample under investigation. This finding points to a potential gap in terms of safety stock calculation and model construction. This occurrence can also play a role in this case where sub-optimal safety stock levels are only providing neutral customer service levels while minimising regional safety stock. The balance of safety stock and lost sales opportunities seems to be incorrect.

The next two variables in the ranking were the two variables that play the most important role in mitigating the impact of long variable lead-times in a global supply chain. The *'transportation lead-time variability*' parameter were selected by 61.8% of the respondents and the '*demand during lead-time'* variable by 58.8%. These variables form the basis of the current safety stock models in use. The variables that followed in ranking after these variables were standard parameters, which are used in existing models and came as no surprise. These included *'variability of demand during lead-time'* (55.9%) and *'costs of safety stock'* (55.9%).

The next surprising variable, with 55.9% support was *'customer specific demand patterns'*. This notion is supported by Closs et al (2005) who indicated that the chemical industry should have deeper knowledge of their customer requirements. Again, no such variable is currently considered for safety stock model analysis.
The next four variables are mentionable although their frequency rankings were on the lower side. These variables are self-explanatory and were:

- *Transportation lead-time (52.9%)*
- *Shipment quantities (47.1%)*
- *Level of existing customer loyalty (44.1%)*
- *Pre-determined customer service levels (41.2%)*

From the other variables in Table 17, the only further mention would be that of *'costs of inventory in-transit'*, which received only 2.9% of the responses (n = 1). This would indicate that this variable poses to be obsolete although it forms part of most of the current safety stock models.

When considering all the information above, it can only be concluded that the current variables used in determining safety stocks have some gaps especially in terms of customer requirements and integration and that more work is required to integrate these variables into new safety stock models. This notion is supported by the fact that current safety stocks are low even when lost sales opportunities are considered as having a higher cost than keeping additional safety stock. The balance between inventory investment and lost sales opportunities are therefore not being optimised by the current safety stock models, as critical parameters are not included in the calculations.

7 Conclusion on the research topic

7.1 Research findings

A number of findings were made through the analyses of the results. These findings were:

- **Finding 1** – Long lead-time supply chains have the expectation of lower customer service levels due to the inherent nature of the global activities. The specific supply chain under investigation however have further complexities due to the inability to control and ensure stable inventory re-ordering criteria. To sustain customer service levels in this environment, specific mitigation actions need to be applied otherwise customer service levels will be low (negative). When considering a commodity market, this poses a real threat to profitability and eventually business sustainability. The mitigating action that best addresses the issue at hand is safety stocks.

- **Finding 2** – The core purpose of safety stocks is to absorb the variability of supply and demand. It was found that safety stock models are successful in achieving this but in the case at hand, it only provided neutral results. Thus, maintaining acceptable customer service levels rather than improving them. It was also found that low safety stocks were kept in the regions, which resulted in only average customer service levels. It is therefore apparent that if the wrong (generic) safety stock models are applied to a specific case, a sub-optimal customer service level will result, as is the case in the research in question.

- **Finding 3** – Safety stock is considered to be of a lower cost than loosing a potential sales opportunity which would motivate the case that higher safety stocks are more favourable and in this case, of least cost. It was also found that the regions preferred to simultaneously optimise both the safety stock levels and lost sales opportunities although some respondents believed that increasing customer service should take preference. It was concluded that there is not an adequate balance between the inventory investment and the cost of loosing sales opportunities and that the root of this cause is the safety stock models in use. The models currently used are generic and not adaptable to specific cases.

- **Finding 4** – There are some gaps in terms of parameters used in the current safety stock models under review. Variables that were identified as very important in the research were not included, and defined, as part of the safety stock models currently in use. The absence of these variables in the safety stock calculations is the probable cause of the imbalance between safety stock levels and the perceived customer service levels for this particular supply chain. If a balance can be found, profitability would increase by optimising the inventory investment and the cost of lost sales opportunities. Thus, ensuring the highest levels of customer service with the least amount of investment. A review of safety stock models and literature is therefore proposed.

Considering these findings, there seems to be a need to establish new customer service safety stock models for complex long lead-time supply chains. The current safety stock models, as illustrated in Table 18, need to incorporate the most important of the variables identified and then ensure that the balance between the cost of keeping safety stock and the cost of lost sales opportunities are optimised and maintained.

Table 18: Safety stock models

	Time Supply (TS)	Order Costing (B)	Service-Level (S)
Objective	To set safety stock equal to a certain time of inventory supply	To minimise the total of ordering cost and carrying cost	To minimise carrying cost subject to satisfying a certain pre-specified percentage of customer demand

(Aghezzaf et al, 2007; Mattsson, 2007)

The basic variables used in the existing models are relevant although some review is required for inclusion of new variables. The safety stock models to be developed should be adaptable and able to change with the relevant changes in customer demands and preferences. The new safety stock models, when considering the findings above, would then ensure the optimisation of the profitability of a commodity organisation.

7.2 Stakeholder recommendations

The research were focused on a very specific supply chain originating in South Africa and then distributing products to a number of fixed regional storage hubs. The stakeholder recommendations will therefore be limited in terms of the context of application to a broader audience. The following recommendations can however be made:

- ✓ **Location of regional hubs** – The further away the regional hub is from the supply origin, the longer the lead-time and more inevitable the increase in variability of supply. When selection is made for a regional hub, consideration should be given to the location of the storage hub. A storage hub like Japan that is supplied directly from South Africa, should rather be supplied from a geographically closer storage hub. This would ensure that the lead-time, and order booking, is minimised. Therefore ensuring a type of 'de-coupling' from the lead-time and variability experienced from South Africa. This location optimisation would reduce long lead-time and allow for less demand variability during supply. The specific shipping trade route applicable to a storage location should also be considered in terms of availability and frequency of supply. This would however call for further investment in storage and safety stock.

- ✓ **Direct the focus to lead-time optimisation** – The two aspects that make this particular supply chain unique is the exceptionally long lead times and the lack of control over stock re-order points. It is recommended that focus should rather shift to reducing lead-time than trying to establish re-order criteria that would allow for possible better control. The reduction in long lead-time and the associated variability will reduce the randomness of the re-order points. Thus, when enough attention is given to the optimisation of the lead-time duration and associated variability, re-order control criteria should theoretically also improve.

- ✓ **Educate customers** – A long lead-time supply chain like the one under investigation is prone to disappoint customers in terms of reliability of supply. Safety stocks can be successful in increasing customer service levels and mitigate this disappointment. However, educating the customer in terms of what can and should be expected in terms of reliability of supply also plays a very important role. Instead of attempting to adapt 100% to customer needs, a balance should be found that benefits both supplier and customer. Managing expectations can add to mitigating occurrences of customer unhappiness. This also takes some pressure of safety stock models. It should be noted that safety stock models attempt to absorb variability. They can however not absorb outliers. This is where educating the customer will play an important role.

7.3 Recommendations for future research

Due to the unique supply chain under review, a number of aspects should still be considered for future research. These are:

- **Larger, multiple organisations sample** – The sample used in the research was limited to one global organisation and was relatively small which does not allow inferences to be made onto a bigger population. Similar research should be conducted that focus on a number of global companies with similar supply chain configurations. A bigger sample should then ensure a better representation of the true requirement of new safety stock models.

- **Re-order points** – Further research should be conducted to establish if the negative customer service level impact of not being able to control stock re-order points can be improved by optimising the lead-time duration and variability.

- **Safety stock vs. no safety stock** – The sample in the research did not allow conclusions to be made on the differences in customer service levels between regions with safety stock and regions without safety stock. A bigger sample would allow conclusions to be made for this specific supply chain environment.

- **New safety stock models** – From the research, it was apparent that new safety stock models with newly defined variables are required. Further research should be conducted to establish which variables should be included in the newly defined models and how the models can be constructed to be adaptable to rapid change in supply and demand patterns.

The field of safety stocks have had a lot of attention in the last couple of years. There is however still a number of research gaps that need to be addressed to make this field inclusive of all types of supply chains. This is however made particularly difficult by the constantly evolving demands and needs of customers.

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Appendices 1: Questionnaire design

The questionnaire was constructed using a number of references from literature. Each question and the literature that motivated the questions will be discussed in detail in the following sections.

The first principle of a questionnaire is to ensure that every question is absolutely necessary and contributes to answering the research theme (Murray, 1999). This principle will form the basis of the questionnaire. According to Murray (1999), easy and basic background questions should be asked first to ease the respondent into the questionnaire and to increase their confidence. In Figure 15, the pre-section of questionnaire is shown.

Figure 15: Question i of questionnaire

i General questions

i.i Which regional distribution hub do you represent? *(Please mark with an "X")*

- *Sasol Chemical Pacific* ☐
- *Sasol Chemicals North America* ☐
- *Sasol Chemicals Germany* ☐
- *Sasol Middle East* ☐
- *Sasol Solvents South Africa* ☐
- *Other (please specify)* ☐

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i.ii Which department do you represent? *(Please mark with an "X")*

- *Supply Chain* ☐
- *Sales* ☐
- *Other (please specify)* ☐

____

These questions categorize the respondents into the regions and allow some categorical analysis. The data captured is nominal and that can allow further inferential analyses related to the later questions.

The first part of the questionnaire addresses the impact of long lead-times and the inability to re-order inventory on demand. This question establishes the impact, if any, of long lead-times and variable re-order points on customer service levels. This is illustrated in Figure 16.

Figure 16: Question 1 of questionnaire

1 Long lead-time supply chain

1.1 What is the impact of the following aspects on your customer service levels?

(Please mark with an "X")

i ***Not being able to control your inventory re-order points fro supply from South Africa***

Very negative	*Negative*	*Neutral*	*Positve*	*Very positive*

ii ***Variable long lead-time delivery from South Africa***

Very negative	*Negative*	*Neutral*	*Positve*	*Very positive*

1.2 What is your perception of the current customer service levels delivered in your region?

Very negative	*Negative*	*Neutral*	*Positve*	*Very positive*

The following literature relates to the questions stated:

1.1

i – Boedi *et al* (2007), Aghezzaf *et al* (2007) and Mattsson (2007) describe safety stock models in terms of a re-order point that can be determined and then executed accordingly. This question tries to establish if the ability to control stock re-order points play a role in ensuring better customer service.

ii – Chandra & Grabis (2006) and Leng & Parlar (2009) indicated that a reduction in delivery lead-time could result in better customer service levels. This question tries to identify if this phenomena is true for a supply chain where re-order points cannot be accurately predicted.

1.2 Gargeya & Meixell (2005) concluded that global supply chains are more difficult to manage than local supply chains. This question concludes this section with determining if there is a substantial difference in a long lead-time supply chain in terms of customer service levels.

In the second section of the questionnaire, the focus shifts to safety stocks and their intended purpose of absorbing stochastic supply and demand variability. This is illustrated in Figure 17.

Figure 17: Question 2 of questionnaire

2 Supply and Demand Variability: Safety Stocks

2.1 Do you have safety stock in your region? *(Please mark with an "X")*

- *Yes* ☐
- *No* ☐
- *Maybe* ☐

If answered 'Yes', please continue with the completion of the questionnaire.

2.2 What is the impact of keeping safety stock on customer service levels?

Very negative	*Negative*	*Neutral*	*Positve*	*Very positive*

2.3 If a sale is not made due to low stock levels, does that relate to lower customer service?

- *Yes* ☐
- *No* ☐
- *Maybe* ☐

2.4 What is the level of your safety stocks on average?

Very High	*High*	*Medium*	*Low*	*Very Low*

2.1 The first question is a simple category selection from fixed alternatives. This question rationalises the questionnaire to those respondents that are applicable to the rest of the questionnaire.

2.2 According to Blau *et al* (2008) and Aghezzaf *et al* (2007), safety stocks are introduced into supply chains to hedge against uncertainty and to ensure that customers receive the promised service levels. This question assesses what the impact on service levels are in a long lead-time supply chain with variable re-order points.

2.3 This question relates to **2.2** and assesses if the purpose is truly as stated, that customer service levels decrease if variable supply cannot be met with variable demand. This question also determines the impact of stock-outs on customer service.

2.4 Blau *et al* (2008) stated that higher safety stock levels guarantee higher customer service levels. This notion is tested in this question and can be related to the response in **2.2** per respondent.

The third part of the questionnaire covers the perceived importance of safety stock concerning costs in terms of increasing inventory levels or lost sales. This question is illustrated in Figure 18.

Figure 18: Question 3 of questionnaire

3 The impact and effect of Safety Stock

3.1 What is the perceived cost of keeping Safety Stock *(Please mark with an "X")*

Very High	*High*	*Medium*	*Low*	*Very Low*

3.2 What is the perceived cost of loosing a potential sales opportunity due to incorrect safety stocks?

Very High	*High*	*Medium*	*Low*	*Very Low*

3.3 What is perceived to be more important?

i *Reduction in safety stocks* ☐

ii *Increase in customer service levels* ☐

iii *Both of the above* ☐

3.1, 3.2 and **3.3** all relate to the conclusion made by Kodali & Routroy (2004) and Love *et al* (2008) that the formulation of inventory policies should balance customer service levels and the cost of inventory. This question should clarify if this is applicable in a long lead-time supply chain in a commodity market and if, due to the more variable supply, higher inventory is perceived to be more essential and therefore changing the perceived balanced requirement.

In the last part of the questionnaire, the actual variables used in determination of safety stock models and the measures proposed as part of customer integration in a commodity market is combined to assess the importance of each characteristic. The options are limited to a checklist and an 'other (specify)' option is included as a contingency measure (Murray, 1999). This is illustrated in Figure 19.

Figure 19: Question 4 of questionnaire

4 Determining safety stocks

Please select the characteristics which you believe should determine regional safety stock levels

(Please mark with an "X")

- *Demand during lead-time* ☐
- *Value potential of customer* ☐
- *Transportation costs* ☐
- *Costs of cycle stock* ☐
- *Product specific characteristics* ☐
- *Costs of safety stock* ☐
- *Pre-determined customer service levels* ☐
- *Shipment quantities* ☐
- *Transportation lead times* ☐
- *Transportation lead-time variability* ☐
- *Costs of inventory in-transit* ☐
- *Segmental customer requirements* ☐
- *Level of existing customer loyalty* ☐
- *Variability of demand during lead-time* ☐
- *Customer specific demand patterns* ☐
- *Other (please specify)* ☐

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Question 4 is a combination of work relating from:

- **Safety stock literature** – Aghezzaf *et al* (2007), Mattsson (2007), Dullaert *et al* (2008), Cetin *et al* (2004) and Chopra and Meindl (2000).
- **Commodity differentitiation and customer service** – Wouters (2004), Clarke-Hill *et al* (2002), Closs *et al* (2005) and Love *et al* (2008).

The results of this question will be used to compare against what is currently in use as part of the customer service safety stock literature. The aim would be to highlight possible discrepancies between the variables used in safety stock models and the actual perception of what is important to focus on for increased customer integration.

Appendices 2: Coding table

To enable descriptive statistics, numerical coding was required for the Likert scale questions. The coding of the research results can be seen in Table 19.

Table 19: Coding table for questionnaire responses

	Code	Description
i.i	SCP	**Sasol Chemicals Pacific**
	SCNA	**Sasol Chemicals North Am.**
	SCG	**Sasol Chemicals Germany**
	SME	**Sasol Middle East**
	SSS	**Sasol Solvents South Africa**
	O	**Other**
i.ii	Supply Chain	**Supply Chain**
	Sales	**Sales**
	Other	**Other**
1.1 i	1	**Very negative**
	2	**Negative**
	3	**Neutral**
	4	**Positive**
	5	**Very positive**
ii	1	**Very negative**
	2	**Negative**
	3	**Neutral**
	4	**Positive**
	5	**Very positive**
1.2	1	**Very negative**
	2	**Negative**
	3	**Neutral**
	4	**Positive**
	5	**Very positive**
2.1	Yes	**Yes**
	No	**No**
	Maybe	**Maybe**
2.2	1	**Very negative**
	2	**Negative**
	3	**Neutral**
	4	**Positive**
	5	**Very positive**
2.3	Yes	**Yes**
	No	**No**
	Maybe	**Maybe**
2.4	5	**Very High**
	4	**High**
	3	**Medium**
	2	**Low**
	1	**Very Low**
3.1	5	**Very High**
	4	**High**
	3	**Medium**
	2	**Low**
	1	**Very Low**
3.2	5	**Very High**
	4	**High**
	3	**Medium**
	2	**Low**
	1	**Very Low**
3.3	Reduce SS	**Reduction in safety stocks**
	Increase CS	**Increase in customer service levels**
	Both	**Both of the above**