Ensuring sufficient capacity of logistical infrastructure for future growth

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Declaration

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously in its entirety or in part, submitted it at any university for a degree.

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Abstract

This study explore how forecasting techniques can be combined in linear programming (LP) as a tool to optimise the parameters of forecasting methods in order to ensure sufficient capacity of logistic infrastructure exist for future growth. This study will use greenfield and brownfield projects from Sasol, a petrochemical company from South Africa, to test the methodology on.

The methodology followed in the study was to firstly look at previous literature studies on logistical infrastructure and how to create sufficient capacity. Secondly, understandings of supply chain planning principles in general as well as supply chain planning in context of Sasol were investigated. Thirdly, different forecasting methods like; qualitative include judgemental, life cycle, Delphi method, market research etc. and quantitative methods including time series and causal methodologies had been investigated. Fourthly, decision making tools to incorporate multiple forecasts were investigated to understand why Sasol decided to use i2. Fifthly, the current capital project approach in Sasol had been investigated to fully understand where room for improvements would be possible. Finally the theory from the study was applied on two different projects in Sasol, one greenfield and one brownfield project.

The results found that by using sound supply chain planning methodologies, sound supply chain design principles and multiple forecasts being combined by using LP decision making tools a better decision can be made with regards to logistical infrastructure investment as well as ensuring sufficient logistical infrastructure capacity. The two case studies have shown that this approach is flexible enough, apart from a few minor changes and can be adopted for both scenarios and that great results can be achieved. Logistical infrastructure could be optimised due to collaboration and the overall costs and performance of a supply chain improved.

Opsomming

Hierdie studie ondersoek hoe lineêre programmering (LP), as n hulpmiddel, gebruik kan word om vooruitskattingstegnieke te kombineer om sodoende die vooruitskattingsmetodes te optimaliseer en te verseker dat voldoende kapasiteit van logistieke infrastruktuur bestaan vir toekomstige groei. Hierdie studie se metodes sal getoets word op groenveld- en bruinveldprojekte van Sasol , 'n petrochemiese maatskappy van Suid –Afrika.

Die metode gevolg tydens die studie, was eerstens om te kyk na vorige literatuurstudies oor logistieke infrastruktuur en hoe om voldoende kapasiteit te skep. Tweedens, om ‘n breë oorsig van die beginsels van voorsieningsketting-beplanning te bekom sowel as voorsieningsketting-beplanning in die konteks van Sasol te ondersoek. Derdens, verskillende vootuitskattingsmetodes soos kwalitatiewe metodes (insluitend veroordelende-, lewensiklus- en Delphi-metode en marknavorsing) en kwantitatiewe metodes (insluitend die tydreeks- en oorsaaklike metodes) is geondersoek. In die vierde plek is besluitnemingshulpmiddels, wat verskeie vooruitskattings kombineer, geondersoek om te verstaan waarom Sasol besluit het om i2 aan te koop. In die vyfde plek is die metode van Sasol se kapitaalprojekte geondersoek om te verstaan of daar nie moontlik ruimte vir verbeterings sou wees nie. Laastens is die studie se metode op twee projekte van Sasol toegepas, een groenveld- en een bruinveldprojek.

In die studie is gevind dat beter besluite geneem kan word aangaande beleggings in logistieke infrastruktuur en om te verskere daar is voldoende logistieke infrastruktuur kapasiteit - deur gebruik te maak van optimale metodes in voorsieningsketting-beplanning en voorsieningskettingontwerp. Die twee gevallestudies het getoon dat hierdie benadering buigsaam genoeg is, afgesien van 'n paar klein veranderinge, om vir beide moontlikhede gebruik te kan word en goeie resultate te behaal. Deur die samewerking van verskeie besigheidseenhede kon logistieke infrastruktuur geoptimaliseer word terwyl die kostes en algehele prestasie van voorsieningsketting verbeter kon word.

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1 Introduction

The globalisation of companies have led to global supply chains emerging as complex integrated corporate structures consisting of different layers of customers, vendors and manufacturing sites all connected and operating in a market environment for a given industry as a loosely or tightly network. A petrochemical company in South Africa took the decision to become a global organisation by expanding beyond the South African Coal-to-liquid (CTL) operations by investing in upstream natural gas fields in Mozambique, shale gas in Canada, and oil in Gabon as well as investing in the construction of possible new production plants in Nigeria, Uzbekistan, USA and Canada. This required a substantial market investment causing the company to look at ways to optimise their capital expenditure on privately owned logistical infrastructure going forward. With the global recession from 2008 onwards companies needed to optimise spending due to smaller profit margins and greater competition. According to the Sixth Annual State of Logistics (Ittman, Schoeman, King Bean & Viljoen, 2010:3), the world is slowly emerging from the recession, of 2008-2010, organizations have identified areas and factors that led to this situation and learned valuable lessons from it. Now it is time to look at the current situation and find ways to reconsider improve or streamline ways of managing a wide spectrum of factors in efforts to improve efficiency and effectiveness of performance in the future.

Therefore the need was identified to look at ways to better utilise the current privately owned infrastructure asset base and to optimally invest in future expansions of the privately owned logistical infrastructure. With the increasing decline in the availability of non-renewable resources (coal, oil, natural gas etc.), companies are forced to redesign and rethink strategies in order to ensure sustainable operation in the future. (Chaabane, Ramudhin & Paquet 2012:38) Capital investment in logistical infrastructure forms a significant portion of the total capital expenditure enabling the supply chain to move and store direct and indirect material, move and store semi-finished products as well as distribute final product to the customers.

The company that will be used in this study is Sasol Ltd a petrochemical company in South Africa. Sasol has a number of business units that operate over numerous sites in South Africa as well as globally with a very large logistical infrastructure asset base in South Africa.

1.1 Background of Sasol

Sasol is an internationally integrated energy and chemical company that leverages the talent and expertise of more than 34 000 people working in 38 countries. Sasol develops and commercialises technologies, and build and operate world-class facilities to produce a range of high-value product streams, including liquid fuels, chemicals and low-carbon electricity. Sasol was established in 1950 in South Africa and remain one of the country's largest investors in capital projects, skills development and technological research and development. Sasol are one of the world's largest producers of synthetic fuels using feedstock like coal in South Africa, natural gas and condensate from Mozambique, oil in Gabon and shale gas in Canada. (Business overview 2012)

Sasol group of companies are divided into four clusters namely an energy cluster, international cluster, chemical cluster and other businesses. The energy cluster comprises the businesses upon which Sasol was founded, namely Sasol Mining, Sasol Gas, Sasol Synfuels and Sasol Oil. The cluster supplies around a third of South Africa's inland liquid fuels requirements, while delivering on the national transformation agenda and developing values-driven, high-performing people. The international cluster is the key to Sasol's growth aspirations outside South Africa and comprises Sasol Synfuels International and Sasol Petroleum International. The Chemical Cluster comprises Sasol Polymers, Sasol Solvents, Sasol Olefins and Surfactants, Sasol Wax, Sasol Nitro, Sasol Infrachem and Merisol. Sasol is involved in a number of other activities in the energy and chemicals industries in both South Africa and abroad, which, among others, are technology research and development and alternative energy activities. These businesses, namely Sasol Technology and Sasol New Energy, endeavour to leverage their key competitive advantage, and to further technological research and development for their projects around the world. (Business overview 2012)

1.2 Literature overview

1.2.1 Definitions and description of supply chain concepts

A supply chain can be defined as a set of integrated facilities s (e.g. manufacturing plants, distribution centres, warehouses, etc.) that perform certain activities from procurement of raw materials, to transforming these materials into semi-finished and finished goods, to distributing these products to the end users/customers. (Melo, Nickel & da Gama 2005:182) Another definition of a supply chain (SC); is the physical representation of a business' value chain. The anticipated demand for final products, the production facility-(ies) and sources of feedstock are the primary determinants of how a supply chain should be configured. The physical configuration of a supply chain is the operational activities required to enable the flow of inventory. These activities include facilities (manufacturing, storage, handling and packaging), transportation and support services. The supply chain form a critical part of a business’s value chain since it deals with three of the five primary business activities (upstream supply, manufacturing and outbound logistics). With a supply chain operational in a business, supply chain planning processes provide the means for each supply chain partners to align, synchronize and efficiently execute their activities related to an agreed demand and supply plan for the related materials and products. (Louw 2006:1)

According to Nagurney (2010:1) supply chain network design forms the foundation of supply chain management when taking into account, the formulation, analysis and optimal solutions for the under-lying supply chain networks. When designing or redesigning an already existing supply chain, the optimal supply chain design needs to be designed in a rigorous manner to ensure that the system-wide nature of a problem is captured. The supply chain design processes also creates the long term supply chain decisions relating to; network structure design, configuration of the supply chain, logistical infrastructure, inventory flow capacity, business processes and policies. A specific problem being faced in the supply chain design stage is a need to balance the anticipated demand with future capacities. In order to achieve this, robust infrastructure investment decision and efficient capacity utilisation plans are vital due to increasing regulatory pressures and profit margins being eroded. (Shah 2004:929)

Logistical infrastructure can be defined as follows: A large scale logistics system (with a technological dimension) consisting of a collection of basic immovable physical facilities, equipment and installations that fulfil the basic transportation, distribution and storage functions whilst ensuring safe operational procedures, required by management to make the system function according to its functional specifications. (Jiang & Peng, 2008:1) Logistical infrastructure is one of the most important assets of the whole supply chain. Without logistical infrastructure no products can be procured, manufactured or assembled, would be able to be moved, weighed, stored, and transported thus rendering a supply chain inadequate.

Developing a country or a company's infrastructure by using accurate planning and forecasting techniques could serve as an enabler that is critically needed to stimulate economic growth. The logistical infrastructure serves as an enabler for a company's growth plans. (Gupta, Jambunathan & Netzer 2010:9) With the gross domestic product (GDP) of a country as the main indicator to forecast logistical infrastructure demand, there is a direct relevance between the logistical infrastructure and the health of the country's economy. (Ruske, Kauschke, Reuter, Montgomery, von der Gracht, Gnatzy & Darkow 2010:12)

The term greenfield originated in the construction industry where it referred to virgin or green land where there was no need to rebuild or demolish existing structures. In recent times, the term greenfield has been adopted by numerous industries and is used to refer to projects where no prior work was done or having a "clean slate" to start from. Greenfields projects can also be defined as clean slate projects where the design of a new project will be fit for purpose and theoretically will satisfy all the needs while being able to operate at an optimum level. In this study greenfield projects will refer to new logistical infrastructure developments like the building of roads or rail infrastructure, building of new warehouses or storage facilities etc.

A brownfield project is the opposite of a greenfield project. A brownfield project is defined as a project that utilises prior work or where re-engineering of an existing structure or project, piece of equipment etc. is required. A brownfield in this study will refer to project were existing logistical infrastructure will be redesigned or re-engineered in order to enable growth.

1.2.2 Study focus

In this study the focus will be on using supply chain tools like; planning, forecasting methodologies, processes and modelling software, to forecast the logistical infrastructure capacities required to enable the growth of Sasol by comparing greenfield opportunities with brownfield opportunities. The study's focus will be on how the supply chain design methodologies, if applied from the start of a project, can be used to ensure that issues, for example; under-utilised space in warehouses, bottlenecks, system problems, long standing times, claim, high capital costs and operational costs etc. can be eliminated or proactively be addressed before having a negative impacts on the operational environment. The second part of the study will focus on how forecasting tools like; advanced linear programming modelling, simulation modelling and other software packages can assist in order to increase the design accuracy and decrease capital expenditure (CAPEX) costs. Thirdly, the study will investigate if advantages can be found through collaboration of different business units, within the Sasol group of companies, in order to save on CAPEX by creating a consolidated view across all business units. This will serve as a crucial input into making calculated and collaborative decisions on where to inject capital for the building of new infrastructure to ensure that all the possible users of the infrastructure, now and in the future, can benefit from decisions taken. Finally a comparison will also be made between greenfield and brownfield projects and how different approaches are required in order to achieve the best possible results through collaboration.

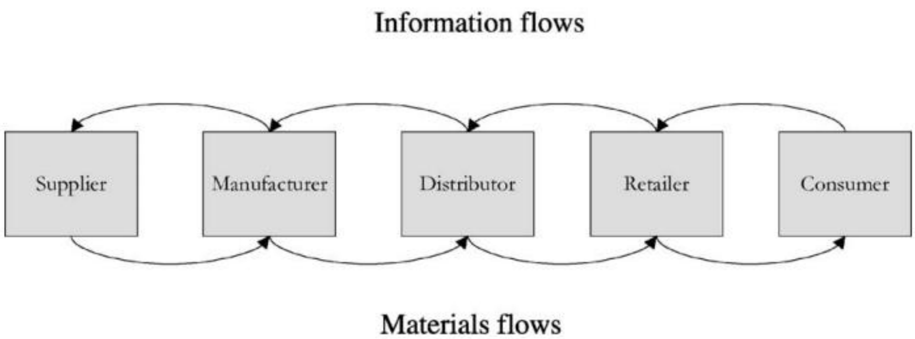
Numerous studies which was found during the investigation phase Sasol like; area blending project, solvents road loading, Sasolburg fuel gantry upgrade, Sasolburg solvents rail loading, Secunda tank farm west upgrade etc. placed the main focus on the optimisation of a specific production site, piece of equipment, a specific business unit's infrastructure or piece of infrastructure of a business unit. No study, which was found in Sasol during the research phase, took a consolidated view across all the different production areas or even one production site to match the current logistical infrastructure capacity with the strategic growth plans. Focusing on Sasol as one entity rather than a collection of twelve business units, the bottom line can be optimised through collaboration and co-investments of multiple business units. For example co-investments in infrastructure like; a tank farm, port, road or rail gantry, which serves multiple business units, will benefit all stakeholders or multiple supply chains using those assets. This will enable the management of movements of physical goods as well as allowing an exchange between business units who require these assets (Kogan & Tapiero, 2009:256)

1.3 Background

1.3.1 Setting the scene

The forward flow of materials and backward flow of information was how traditional supply chains where characterised as seen in Figure 1. In the past the supply chain processes were investigated individually or pieces of the supply chain was analysed in isolation. In more recent years supply chain management have placed more emphasis on an integrated view of all aspects of a supply chain; from integrated procurement, operations, and logistics of raw materials to measuring customers' satisfaction. This include activities like adding value to existing products lines, by improving the quality, reducing production costs, and grow profits by improving vendor relationship and selection, transportation, inventory optimisation, third party vendors etc. (Kovács & Paganelli, 2003:165)

Figure 1: Traditional Supply Chains



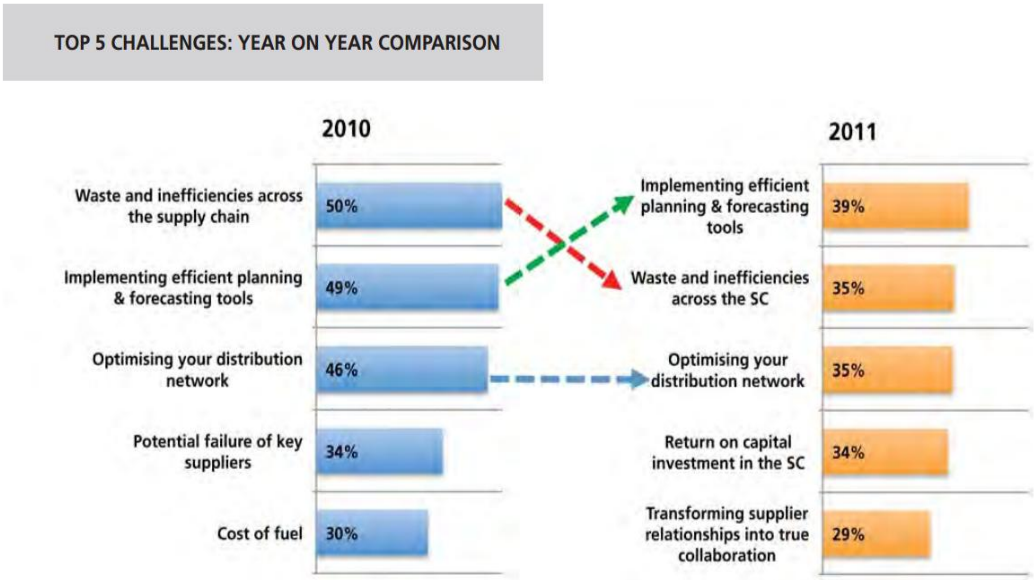
Source (Kovács & Paganelli, 2003:168)

1.3.2 Defining logistical infrastructure

Logistical infrastructure forms the backbone of the logistical/supply chain activities, but because businesses, in most cases, do not own the majority of the logistical infrastructure they use, they have to rely heavily on publicly owned logistical infrastructure to operate their supply chains. The condition of the logistical infrastructure normally goes unnoticed until there are breakdowns, bottlenecks, inefficiencies or safety incidents that directly result in a loss of sales, product losses, loss of profits and ultimately deaths. (Beamon 1998:281)

Supply Chain Foresight (Barloworld 2011:10) shows that planning and forecasting tools became Supply chain managers' number one challenge for 2011 as seen in Figure 2. The planning tools mentioned here can refer to Sales and Operation Planning (S&OP), where the supply and demand needs must be balanced, but also demand planning, transportation planning, production planning etc. Secondly, it can also be interpreted as forecasting to ensure that sufficient logistical infrastructure is available and in such condition that it enables the business to function optimally.

Figure 2: Challenges for Supply Chain Managers 2011



Source: Barloworld (2011:10)

1.3.3 Public vs. privately owned logistical infrastructure

Public infrastructure is defined to include all immovable assets, including public buildings, roads, water and sewerage, systems, electricity and other services (Wall, Milford & Kubuzie, 2007:5-6) Included under the definition of public infrastructure for this study, is infrastructure under the custodianship or ownership of district, local municipalities, state-owned enterprises, agencies and provincial and national government line departments. The following infrastructure types are covered under public infrastructure; roads, bridges, tunnels, pavements, freight rail, pipelines (gas, fuel), airports and air traffic navigation infrastructure, ports, harbours, breakwaters, lighthouses, and other coastal infrastructure, telecommunication, e.g. broadband/fibre optic cable, electricity generation, transmission, distribution and alternative/renewable energy facilities.

Sasol's privately owned logistical infrastructure is defined as; production facilities, storage facilities, distribution chains, and retail outlets which requires very high capital investments and regular maintenance. This includes all warehouses, weighbridges, gantries, tank farms, roads, rails tracks, berths, pipelines etc. The real difficulties are that significant capital investment costs are required to enable the growth forecasts with little or no assurance of generating profitable returns but rather enabling the supply chain and preventing losses through inefficient or ineffective logistical infrastructure. From a planning point of view, the biggest obstacle to implement optimistic growth plans is the lack of adequate logistical infrastructures in order to enable the supply chain to execute these plans.

1.3.4 An African perspective

The development of logistical infrastructure used for transportation is in dire need of long-term planning. Logistical infrastructure like ports, roads, railroads, airports and tunnels have a life span that stretch over a few decades or even centuries. For those reasons, there is a need for long-term planning and forecasting for the development of logistical infrastructure for transport and how the environment and economy will be impacted by this. (Ruske et al. 2010:1)

In many low-income countries a key obstacle for growth and development is the lack of infrastructure. If the focus is placed solely on Sub-Saharan Africa, the amount of paved roads is only sixteen percent of the total road network. A significant constraint is being put on trade expansion, as a result of infrastructure costs that are the highest in the world as shown in Table 1.

Table 1: High cost of infrastructure in Africa

Sector	Africa	Other developing regions
Power tariffs ($ per KW/h)	0.02-0.46	0.05-0.1
Water tariffs ($ per Cubic meter)	0.86-6.56	0.03-0.6
Road freight tariffs ($ per ton-km)	0.04-0.14	0.01-0.04
Mobile telephony ($ per basket per month)	2.6-21.0	9.9
International telephony ($ per 3min call to USA)	0.44-12.5	2.0
Internet dail-up service ($ per month)	6.7-148.0	11

Source: Foster, Briceño-Garmendia (2010:50)

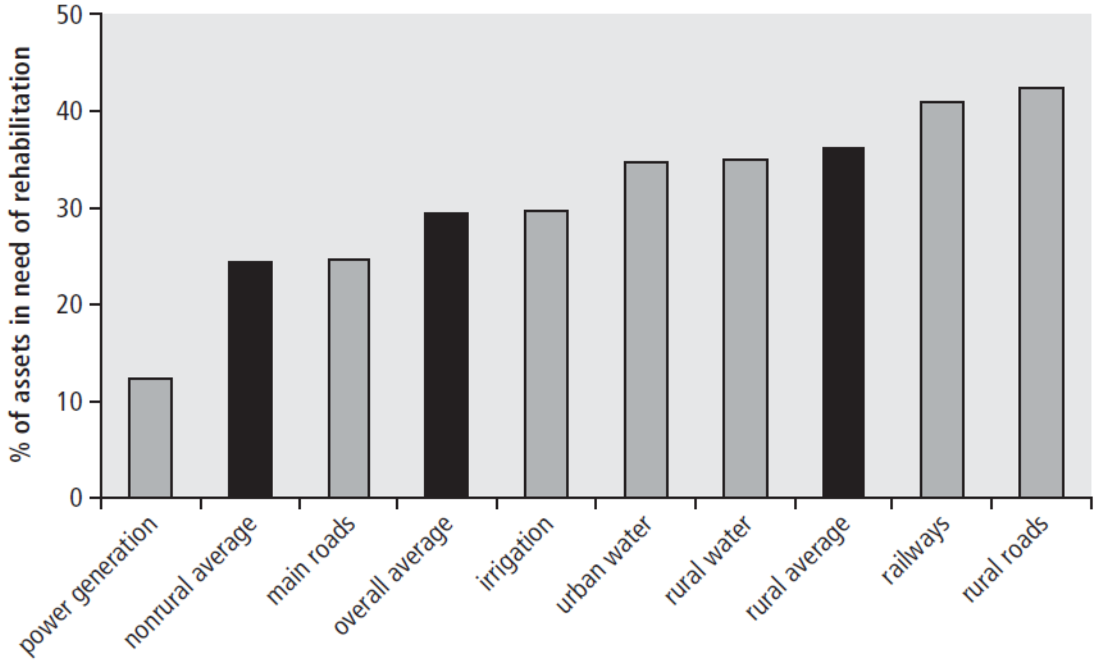
According to the Underpowered: The State of the Power Sector in Sub-Saharan Africa report, it shows how exports, in Africa, are affected by the poor quality of publicly owned infrastructure when measured in terms of the average amount of days per year that load-shedding or electricity disruptions occurs. (Foster, Briceño-Garmendia 2010:11) Improvements can be made on growth and poverty constraints, but this will only happen if the public investment in infrastructure increases, in line with the big push view of Rosenstein-Rodan (1943:202–211). The idea behind the big push theory is that a big push or a big and comprehensive investment package can be helpful to bring economic development. In other words, a certain minimum amount of resources must be devoted for developmental programs, if the success of programs is required. A relatively good known argument for achieving the big push view is when logistical infrastructure assets have an impact on the production costs and the rate of return on capital (ROC). Recently researchers have put emphasis on logistical infrastructure having an indirect and direct effect through affecting the supply chain's health and environmental outcomes as well as through a variety of other channels. (Agénor 2010:932-933)

Infrastructure that functions optimally can be very advantageous for a company, country or continent. Infrastructure can be an enabler for people, products, services and companies to reach markets and reduce the bottom line cost of doing business. Infrastructure can also lead to improvements in all sectors, improve sub-optimal geographical location for example; enable African based companies to compete with global markets etc. Optimal logistical infrastructure investments can be the catalyst to create productive employment in the construction phase as well as the operating of the infrastructure and ultimately stimulate the expansion of businesses in Africa. According to the Africa's infrastructure: a time for transformation report, the financing need for Sub-Saharan Africa's logistical infrastructure is estimated at $39 billion per year, divided more or less equally between capital expenditure ($22 billion) and operating expenditure and maintenance ($17 billion). The recommendation is that a doubling of spending on infrastructure in this identified regions are needed and to support this, an increasing of donor allocations of more or less $10 billion was required in 2010. (Briceño-Garmendia & Foster 2010:31-32) This just shows that companies must do a lot more in looking holistically at their infrastructure to find opportunities to collaborate to ensure that the privately owned and publicly used infrastructure are maintained properly to prevent unnecessary major investments in the future.

With global competition continuing to accelerate during the past few years, supply chain performances have become a critical source of creating a sustainable advantage within the global environment. A critical element contributing to supply chain performance is the availability and condition of logistical infrastructure.

According to Briceño-Garmendia & Forster (2010:10) forecasts shows that on average, more than 30 percent of a typical African country's infrastructure assets needs rehabilitation as shown in Figure 3.

Figure 3: Rehabilitation needed in Africa



Source: Briceño-Garmendia & Forster (2010:10)

There are huge rehabilitation backlogs that are caused by the underfunding of maintenance of logistical infrastructure, high labour costs, procurement inefficiencies, failed projects, corruption etc. One of the major wastes of funds is reflected by the high costs of rehabilitation of logistical infrastructure and that are exponentially higher than sound preventive maintenance. This can be changed by doing adequate planning and developing maintenance strategies that will enable the logistical infrastructure asset base owners to save more money. Ruske et al. (2010:11) stated that by spending a mere $1 on the sound preventive maintenance of roads a country's economy can save more than $4.

Emphasis is placed on the logistical infrastructure due to continuing globalisation and growing populations around the world, with many regions already lacking sufficient infrastructure capacities or have aging, inadequate or overburdened logistical infrastructure due to disjointedness or total lack of planning. The question that is left unanswered is, do these countries have enough money to invest, or can investments be generated to match the current growth and catch up on the current backlog? (Ruske et al. 2010:12).

Ruske et al. (2010:13) stated that global trade in goods and services are predicted to triple over the next 20 years to more than US$27 trillion. Emerging economies like the BRICS nations are expected to be responsible for more than half of this predicted growth. (Ruske et al. 2010:12) That is why there is a need to design and redesign supply chains, by making use of strategic planning and forecasting methods, in order to achieve a greater cost saving, competitiveness or to enhance the revenues generated and to ensure enough capacity exists in order to support the growth. This can be achieved by the re-engineering and aligning of business processes to the newly designed supply chain. The improvement of customer services or/and inventory optimisation can be achieved by improving the supply chain planning and forecasting of logistical infrastructure to integrate the supply chain more effectively. Even a greater possibility of saving exists, by involving supply chain from as early as idea generation and the prefeasibility phase to ensure sufficient logistical infrastructure is in place to accommodate growth or creation of new products. (Kovács, Paganelli 2003:166)

The five sub-areas of logistics performance measures, reviewed by Mentzer & Konrad (1991:33-62) included transportation, warehousing, inventory control, order processing and logistics administration. They focused on effectiveness and efficiency perspective, by paying more attention to inter-urban level freight transport, because of the evolution of supply chain analysis, but more specifically minimizing the cost factors for improving the logistic infrastructure system’s efficiency. Their findings showed that the logistical infrastructure should be re-engineered and improved to promote competition, efficiency and effectiveness of the supply chain. (Jiang, Peng 2008:1)

1.3.5 A South African perspective

According to the Seventh Annual State of Logistics (Ittman, Schoeman, Bean & Viljoen 2011:10), supply chains are the main users/operators of logistical infrastructure. That is why it is important to make use of proper and modern technologies for the maintenance of logistical infrastructure like; ports, rail, roads, pipelines, storage facilities, production facilities, weighing facilities or airports remains absolutely critical for the economic growth and development of any business, country or continent. In the Ninth Annual State of logistics (Viljoen, Bean, Havenga, Simpson, Jankauskaite, Gounder, Steyn, de Jong, Sambandan & Laubscher 2013:11) increases in the amount of freight traveling on the two main corridors in RSA, KwaZulu Natal – Gauteng and Western Cape – Gauteng, have increased from 2010 in terms of tonnes, increased by 15.9%, as well as the average distance travelled, increased by 19.7% on combining road and rail figures.

According to Miller (2010:12), there is a need for significant investment to eliminate logistical infrastructural bottlenecks by 2030 with the main emphasis being placed on storage and transportation infrastructure. Figure 4 shows the amounts of capital needed per annum to be invested in logistical infrastructure per region or country for the next decade to eliminate bottlenecks by 2030. Transport infrastructure and the overall health of the world economy has direct relevance due to the GDP being a main indicator of the status of infrastructure forecasts but more specifically the need for transport and storage of products to be optimised. (Ruske, et al. 2010:12)

Figure 4: Global view of required Infrastructure Investment

Source: Ruske, et al (2010:28)

According to the Business monitor International (2011:5) the South African Government have multi-billion dollar projects in the pipeline to upgrade the infrastructure and to bridge maintenance gaps. This ambitious CAPEX plan mainly focus on the infrastructure operators', Eskom, Transnet, Prasa and Sanral assets but financing have proved to be, and continues to be a big problem. With little to no government funding available huge investments from international finance sources are required. Apart from areas that catered for the World Cup in 2010, there has been a lack of investment in South African Infrastructure resulting in an increase of bottlenecks. In order to correct this significant maintenance work needs to be done and much more that still needs to be built. Appendix A shows a Table of planned/ongoing projects in both the transport as well as the energy infrastructure domain. Even though that a lot is planned to expand the current infrastructure base, a lot of funds are require to ensure the aging existing infrastructure is kept in a good condition. (Business Monitor International, 2013:7-27)

1.4 Research problem

The need has been identified to relook investments in logistical infrastructure due to market and economic conditions becoming more unstable and competitive because of globalisation of companies and supply chains. Most if not all countries and companies around the world compile a budget, rolling infrastructure plan etc. each year that includes improvements or upgrades required to their assets which includes the logistical infrastructure. A major issue is that in some cases these investments are made incorrectly due to a lump sum being allocated to improve or expand the asset base per business unit/production area. Yearly budgets are setup and money is pushed into systems to where the local authorities, logistics infrastructure teams, consultants or governing bodies thinks/believes improvements on existing infrastructure should be made or new logistical infrastructure should be constructed. In some cases these decisions are not made optimally due to the lack of time, funds or relative knowledge to plan, design and forecast correctly which result into the mismatch of the predicted growth plans and possible expansion projects to the available logistical infrastructure asset base.

Companies consisting of a single business entity should find the task of planning, designing and forecasting more accurate to be a lot easier. However for a company like Sasol, that have different business units operating over a large infrastructure asset base and geographical area, planning, design and forecasting correctly are not so easy or a familiar practice. Historically this was not necessary as market capital was mainly invested in South Africa and funds was widely available due to less competition, higher profit margins and capital was spend easier without the necessary governing thereof. The biggest advantage was that the maintenance cost was low due to the young age of the infrastructure. With aging infrastructure, higher maintenance costs and more breakdowns production have decreased and losses were increasing. Plant improvements and optimisations were possible to increase outputs which resulted in higher profits.

The recession that started in 2008-2009 and the possible recession looming over the world economy today, forced Sasol to look to ways, initiatives and ideas to more efficiently and effectively spend capital, reduce operating costs, increase outputs but also to look at ways to eliminate the possibility of spending capital as the only way of improving the current asset base. To achieve this Sasol is required to take a holistic view of the whole logistical infrastructure asset base. Having this holistic view across all logistical infrastructure asset bases is currently not happening at Sasol, as there are a number of different business units and these business units only focus on their individual logistical infrastructure they are using without looking for synergies. Therefore it is required to start matching the growth plans from production to the sales targets from marketing and sales by looking at the supply chain, but more specifically the logistic infrastructure, to ensure that the capacity and capabilities exist to achieve this.

1.5 Research questions

This study will address the question and sub questions below in order to show what would be advantages to Sasol's business/competitiveness if the supply chain planning, design and forecasting were improved.

- Would the competitiveness of Sasol be improved if investments in logistical infrastructure are improved?
- What would be the best way to determine where to invest in logistical infrastructure?
- Should Sasol look to invest in greenfields and/or brownfields projects for logistical infrastructure?
- Can this theoretical study be applied to a project in Sasol and can improvements be shown and quantified?

1.6 Objective of this study

The objectives of this study is to do a literature review of how strategic planning should be done in conjunction with the forecast and designing of the infrastructure requirements to achieve more accurate results. This will be done by looking at how strategic planning can translate the business strategy into a supply chain strategy to improve the decisions made with regards to logistical infrastructure. By understanding and investigating the current supply chain design and forecasting method that Sasol uses a possible improved alternative method could be found to improve the results and increase competitiveness. Also to identify which specific areas in supply chain design needs to be improved or changed in order to be able to identify which forecasting tools/techniques should be used to improve capital expenditure on logistical infrastructure.

Secondly, to look at different forecasting techniques, methodologies or tools can/should be used in conjunction with planning methodologies to get the optimal results by simulating what the impact of logistical infrastructure will be on the growth plans of Sasol. This includes finding the best software, methodologies or tools in order to forecast the logistical infrastructure requirements as accurately as possible. Thirdly, to look at practical examples of how the findings can be applied in Sasol in order to achieve the best results theoretically and also how these results can be implemented. The implementation will be done on the logistical infrastructure of one site across a number of business units to test this methodology and findings of the study for greenfield and brownfield opportunities whilst ensure an optimal capital investment can be made.

1.7 Research Design and methodology

1.7.1 Methodology

Firstly, an in-depth literature study will be compiled so that the knowledge gained through relevant previous studies and publications could be captured and understood. With this literature study, the aim will be to lay a basic theoretical foundation regarding logistical infrastructure and the effects it has on petrochemical companies. Investigate supply chain design principles as well as best practices outside Sasol through doing an in-depth literature study and also establish current practices inside Sasol by conducting interviews with relevant subject matter expertise in Sasol. These interviews will be used to establish the current practices as well as training to understand the history to why these were implemented as well as to get their opinion on where Sasol needs to improve and how Sasol possible can do that. Lastly the literature study will focus on the different forecasting techniques in order to understand the different possibilities as well as the application of each in order to find the best fit to the current problem experienced in Sasol.

Before a decision on which tool will be the best, for Sasol, to combine multiple forecasts can be made, firstly the planning methodology and forecasting methodology as well as what needs to be achieved from these forecasts will have to be established. The objective of this exercise is to investigate the possible planning/forecasting methodologies as well as the application of each of them. This will assist in formulating the best methodology for Sasol to implement in order to get the best results. This will be done starting off by defining different planning methodologies and establishing which will be the best strategic fit for this study. Then an in-depth analysis will be conducted in order to establish which tool will be best to combine multiple forecasting methodologies to ensure sufficient logistical infrastructure capacity for future growth requirements. Then a detailed selection process will be followed in order to find the best tool for Sasol. A data analysis will be done on the current growth plans for one site in order to establish a baseline to be used to show possible improvements after the study is completed. The data analysis will be done by collecting, analysing and combining the growth plans from different BU's on one site. Finally a practical application of how the theory developed throughout the study can be used to see if this methodology is flexible enough to be applied to real projects in Sasol for greenfield and brownfield opportunities.

1.7.2 Data analysis

The data analysis started off with one-on-one as well as group interviews that were conducted to gather vital information from key stakeholders within Supply Chain fraternity. These stakeholders include individuals from different Centre of Excellences (CoE's); Supply Chain Infrastructure and Design CoE, Master Data CoE, Strategic Planning and Optimisation CoE, Facilities and asset management CoE, Logistics CoE etc. the Logistics Operations Centre (LOC), capital projects team and other business partners. Typical questions asked include; the current way of work; why the current way of work methods were selected; what needs to be done to improve planning, supply chain design and forecasting; which changes would they implement and how would they go about doing it; is the current infrastructure enough to cater for future growth; what would they do or how would they ensure that capacity is sufficient to cater for growth etc. All the data from the interviews was used to formulate and test findings against. The finding from the interviews ensures that the solution will satisfy the needs from business as well as improve current practices.

For the brownfield opportunities the current master/transactional data like; sales, production, indirect material, storage levels, etc. will be drawn from the ERP system, Systems Application and Products (SAP), Business Warehouse (BW) etc. For the greenfield opportunity similar product types to the new products will be used and data will be extracted from SAP and BW etc. in order to use as the baseline for the demand patterns, sales figures, storage quantities etc. Individual plant production rates needs to be determined and adjusted based on the design for the new greenfield plant, sales forecasts needs to be adjusted accordingly and compiled with the help of sales and marketing teams whilst storage, handling and transportation requirements also needs to be established with the help of the production, operations and supply chain teams.

After all this data was gathered and sales forecasts, demand patterns etc. compiled, the data was used as input data in a model to determine what effect the predicted growth volumes had on the future requirements of the infrastructure asset base. Firstly, a baseline model was built in order to test the effects that all the different scenarios had on this case study. The initial behaviour of the model and findings was then presented back to the subject matter experts within the business units and the supply chain centres of excellence in order to be validated and refined to ensure the model's assumptions and the model's behaviour is as closely as possible to the real production environment. The final results will then be compared to the original results obtained from the initial project team to determine if this is a viable option to implement in order to ensure that the logistical infrastructure have enough capacity to cater for future growth.

1.7.3 Limitations

One of the main limitations is the lack of studies that have looked at the similar problems experienced in Sasol. No previous studies could be found in Sasol where logistical infrastructure asset base where multiple business units' growth plans were combined to test the effect on the capacity of a piece of logistical infrastructure or a site as a whole. Time is a major constraint as this is a production facility and key stakeholders were not always available.

1.7.4 Report structure

The report consists of 5 chapters. Chapter 2 focuses on the background of supply chain planning and forecasting and how it can assist business to translate the business plans to supply chain plans, the purpose of forecasting, different forecasting methodologies and choosing the right methodology and right tool to use to do forecasts. In chapter 3 investigates what supply chain design is and how supply chain design can be used to achieve different objectives. Chapter 4 focuses mainly on the current approach used by Sasol to execute capital projects and establish the need from Sasol to forecast when executing capital projects. Chapter 5 reviews practical examples where the study's methodology is compared to two types of projects; greenfield and brownfield projects in Sasol to see if improvements could be achieved. In chapter 6 the conclusions, recommendations as well as all lessons learned and results of this study are captured.

2 Supply chain planning and forecasting

The second chapter takes an in-depth look into the supply chain design of logistical infrastructure and what is required to develop and implement an optimum design. Firstly, there will be focused on what strategic supply chain planning entails, why it is necessary for strategic planning in supply chain design and how supply chain planning can assist to translate the business strategy into a supply chain strategy during a supply chain design. The second focus will be on the function of planning in forecasting and lastly this chapter will focus on the different type of methodologies or tools that could be used to translate the strategic plans into optimised forecasts for logistical infrastructure.

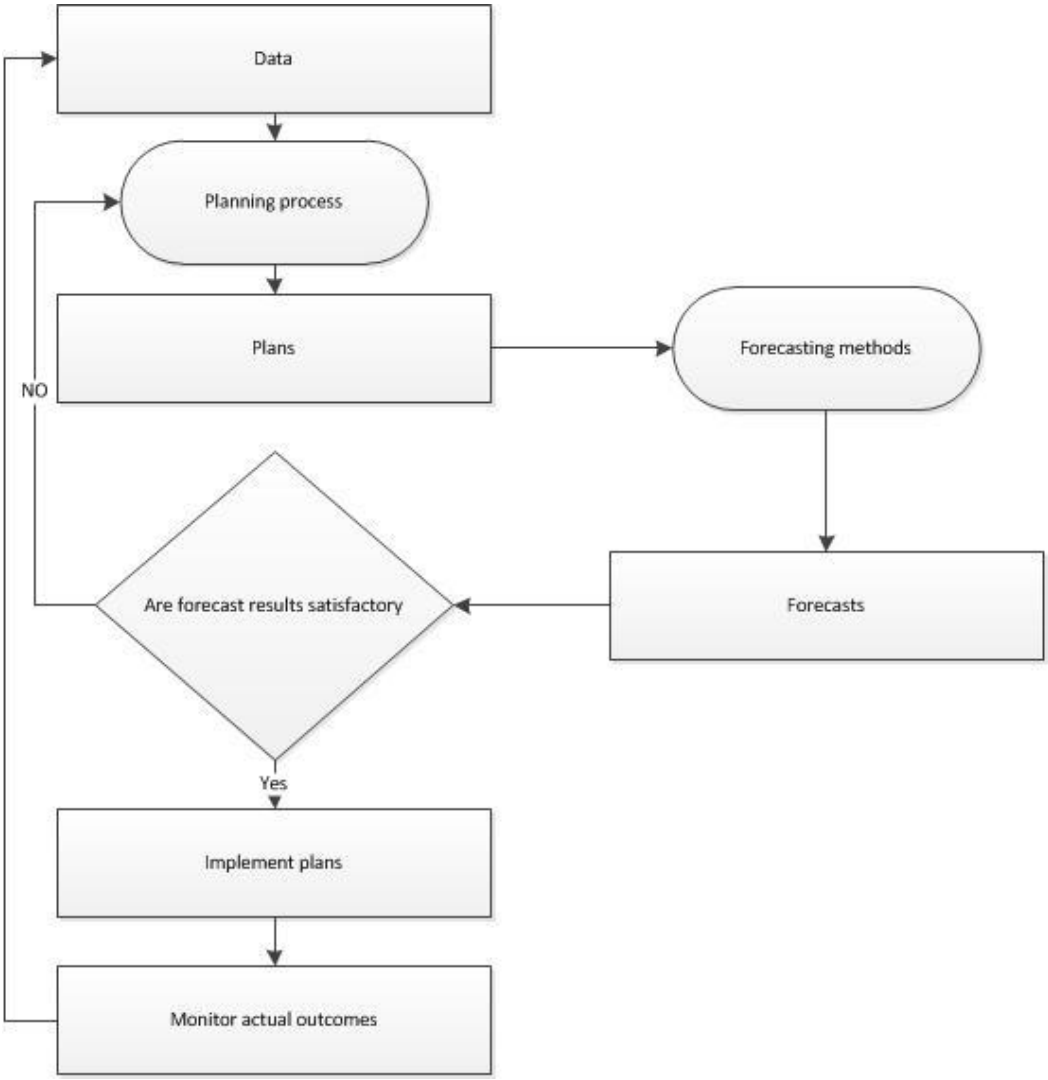
2.1 Background on supply chain planning and forecasting

With an operational supply chain in a business, the supply chain planning process provide the means for each supply chain partners to align, synchronize and efficiently execute their activities related to an agreed demand and supply plan for the related materials and products. Strategic planning aids the supply chain design process to formulate and translate the business strategy into a supply chain strategy to direct the supply chain operation in order to manage the flow of material, products, information and funds. These processes will balance the market demand requirements with supply resources across inbound supply, manufacturing and outbound logistics (taking into account agreements, capacity, availability, efficiency, service level and profitability) and establish/communicate plans to all supply chain parties involved, all in a constantly changing environment. Planning orchestrates the future flow of materials and products, getting them to the right location, at the right time. (Louw, 2008:3)

Forecasting methodologies are defined by Armstrong (1983:123), as unambiguous procedures translating a business' proposed strategy and environmental information into statements about future results. There should be no confusion when referring to forecasting and planning and the differences between them. Planning will establish how the future should more or less look and forecasting on the other hand looks at how the future will be. Business strategies are developed by incorporating the outcomes of planning, given certain forecasts. Whereas forecasts on the other hand will estimate the possible results, given the chosen plan/s. (Armstrong, Green & Graefe 2010:1). As shown in figure 5 the supply chain design process should start off by gathering data from production, sales and marketing, growth plans etc. as this will feed into the strategic supply chain planning process. This process will look slightly different depending on if you have a green- or brownfield project. In greenfield projects you would look at a similar industry or product types to gather data from. In a brownfield project the data history will be captured in an Enterprise Resource Planning (ERP) system and can be extracted or accessed much easier.

Strategic supply chain planning forms the first step in trying to determine what the end results should be, as well as the needs that the design process must address. Also the strategic supply chain planning process determines which solution is the best as well as which is the best process or methodology to follow in order to achieve an optimally designed and configured supply chain. The supply chain plans that are developed as a result of the strategic supply chain planning process are compiled and fed into and influence the process of determining or selecting the appropriate forecasting method that are used in order to deliver the desired forecasted results. After the forecast method is selected the forecasts are made, if the results are satisfactory then the implementation plans are developed. But if the results are not satisfactory the process goes back to the planning process and the whole process will be starting over again.

Figure 5: Framework for forecasting and planning

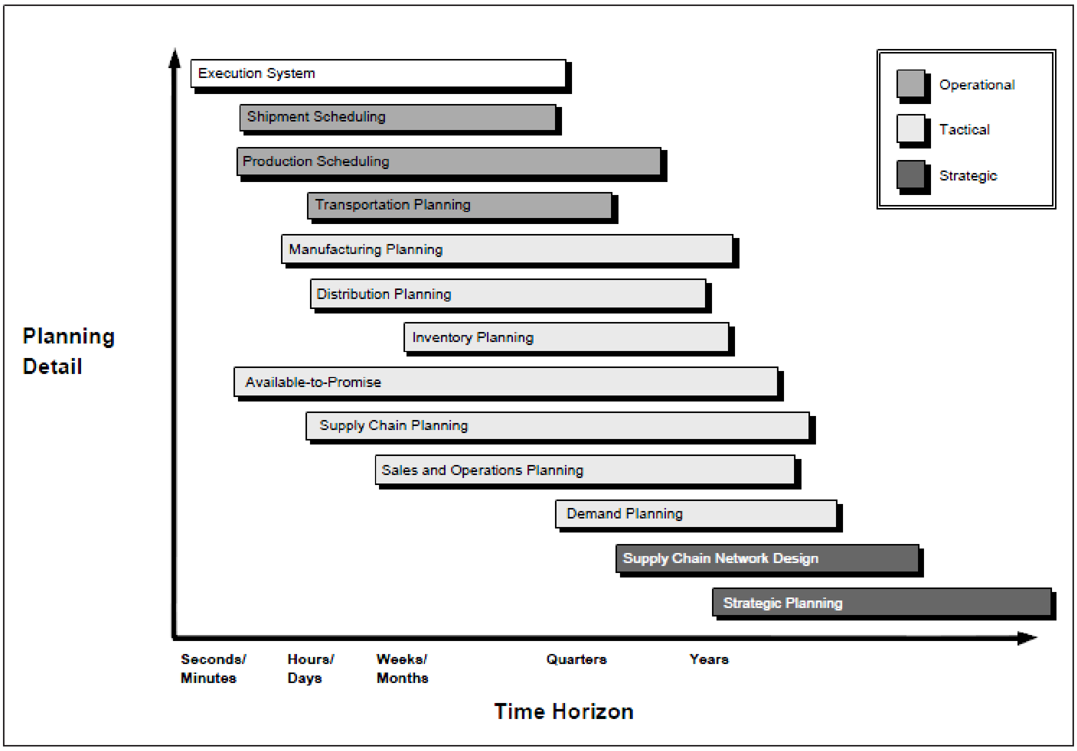


Source: Graefe, et al. (2010:2)

2.2 What is strategic supply chain planning

Strategic supply chain planning is a set of decisions/measures taken to assure that a business has the appropriate resources and assets necessary to support its long term objectives. The strategic objective of supply chain planning is to assure the appropriate planning process exist in a business to support effective and efficient supply chain decision making, execution and monitoring. Strategic supply chain planning decisions work under the umbrella of the corporate and business strategic decisions in order to have a long lasting effect. Three planning levels are found under Supply Chain Management (SCM), these levels are usually distinguished, depending on the time horizons: strategic, tactical and operational. (Badri, Bashiri & Hejazi 2010:1143) The time horizon is typically one to five years ahead in monthly, quarterly, yearly time buckets as shown in Figure 6. Strategic level decisions are decisions that will have a long lasting effect on a company or firm. These decisions include, among many others, the SC design problem, which addresses the optimal configuration of an entire SC network. The tactical level encompasses long- to medium term management decisions, which are typically updated a few times every year, and include overall purchasing and production decisions, inventory policies, and transport strategies. Finally, the operational level refers to day-to-day decisions such as scheduling, lead-time quotations, routing, and truck loading. (Kostin, Guillén-Gosálbez, Mele, Bagajewicz & Jiménez 2011:2540)

Figure 6: Planning levels



Source: Lapide (1998:13)

Strategic planning with regards to the future direction of a company or market expansions, until recent years, was solely based on opinions of managers and leaders in companies who often ignored the supply chain's needs. (Shapiro 2004:855) More recently management have moved to a more fact-based approach, utilising software, planning methodologies and ERP systems etc. to get more accurate answers. A greater focus is placed on using descriptive models including forecasting the demand of customers, projecting future cost of raw materials and modelling the manufacturing and distribution costs by making use of activity-based costing. Prescriptive models are models that are derived from descriptive models and makes use of linear programming and mixed integer programming in order to assist managers in making better decision when it comes to strategic planning. Oil and chemical companies have been seen as the market leaders in utilising linear programming and mixed integer programming to assist with decision-making at all levels of planning for the last 50 years. (Shapiro 2004:855)

For a network of production plants dispersed over a geographical area, decisions with regards to procurement of feedstock, distribution, production capacity utilisation, utilising different modes of transport and demand allocation should be made at a strategic or a global planning level, whilst taking into consideration current capabilities as well as future opportunities. (Lasschuit & Thijssen 2004:867) More manufacturing companies are turning to supply chain network optimisation models to assist them with strategic decisions. Network, in this context, refers to the holistic or integrated analysis of a company's widely spread logistical infrastructure, for example; DC's Plants storage facilities etc. suppliers and markets. (Shapiro 2004:856)

2.3 Importance of strategic supply chain planning in supply chain design process

Supply chains within the petroleum and petrochemical sectors are known as strategic sectors of the modern economy with huge sophisticated logistical infrastructure network that require significant capital investments. With costs increasing and reducing margins due to rise in competition and environmental regulations it has forced petrochemical and petroleum supply chains to increase its efficiency. Research shows that there is a need for companies to focus on methods to optimise the supply chains at a strategic design level. This is done by using different supply chain planning and modelling techniques to optimise the network of production facilities, storage facilities, depots, transportation routes and other logistical infrastructure whilst taking into consideration the supply and demand requirements, growth requirements and possible restrictions on available public infrastructure. (Fernandes, Relvas & Barbosa-Povoa 2011:227) Strategic planning problems faced by petro chemical companies have grown increasingly more complicated due to volatility of the crude oil market, multinational demand markets for petrochemical products, world-wide recession decreasing profit margins, companies being flooded with data from different technology platforms and other factors. (Lasschuit & Thijssen 2004:866)

Supply Chain network design is sometimes employed as a synonym for strategic supply chain planning. In the current economic climate supply chain networks are expected to be viable for extended time periods, during which many parameters may change. The possibility of making future adjustments in the network design is a given to allow gradual changes in the supply chain structure and/or in the capacities of the facilities. Strategic planning/ supply chain design decisions will influence large infrastructure investments and/or facilities that are currently in operation or expected to operate for a long- term horizon. (Badri, Bashiri & Hejazi 2010:1143)

Strategic supply chain planning is a key component in the supply chain design process, specifically referring to the process of designing / re-designing the supply chain in totality for different business units in Sasol for all scenario(s) being considered. Long term planning, especially supply chain network design & logistical infrastructure configuration, typically creates and/or expands the capacity required for future supply chain operations. These capacities then become part of the potential constraining resources used in tactical planning and scheduling. Capacity utilization indicates how effective planning was done in providing for future requirements. Taking a long term perspective and harnessing cross divisional and cross enterprise synergistic opportunities which can result in optimal capacity utilisation and capital avoidance in a business.

Due to the high capital investment involved in infrastructure, it is not always possible for a company like Sasol or one business unit within Sasol to inject the necessary funds required and the option of co-investments should be considered. For example; if one business unit in Sasol invest in a berth at a port as part of the logistical infrastructure asset base, the investment will only benefit one stakeholder or one supply chain and not necessarily a network of business units and consumers that could have made use of the berth. But if a holistic view is taken and synergies are formed then multiple business units could invest in a berth to optimise the volumes and justify such an investment. This could mean that products can be rerouted to use the newly build/procured berth or that possibly new market or product opportunities could be found as a result of more capacity at the port. When making investments, as mentioned above, it will help to manage the physical flow of goods allowing an exchange between the different business units using the berth and its associated infrastructure. But this could only be done if the process is shared, transparent and proper supply chain planning is done from the start by using supply chain design methodologies or models to uncover such possibilities. Also investing in enablers like; communication systems, electronic data interface technologies, inventory systems, planning software etc. provide a way for information to flow or provide the available capacity to meet market demands as soon as they occur. Similarly supply chain planning of logistical infrastructure enables business units sharing a common interest to find opportunities to collaborate to achieve a mutual objective. In order to achieve these mutual goals, co-investments in logistical infrastructure is required. (Kogan & Tapiero 2009:265)

2.4 How strategic supply chain planning helps to translate a business strategy into a supply chain strategy

As indicated in the introduction, one of the key strategic supply chain planning decisions revolves around the deriving and formulation of the supply chain plans to direct the supply chain operations from the supply chain strategy. This is done by using the corporate and/or business strategy and translating it into an appropriate supply chain strategy that will enable the business to achieve the business strategy. To make a supply chain strategy successful, the supply chain strategy should be closely aligned with business strategy as it shapes supply chain practices. (Roh, Hong & Min 2014:200)

A business strategy is defined as a scope of a business or the direction the business wants to move to create a sustainable advantage, in the long term, by the way it configures its resources in an ever changing environment to fulfil market demands. In short it is the approach to be taken to achieve the business' goals and objectives. (Lambert, Stock & Ellram 1998:384)

When developing and implementing a supply chain strategy there is a logical process to follow that will assist to ease the process. In the White Paper: Supply Chain Strategy (Happek 2005:1), a supply chain strategy is defined as a continuous process that evaluates the cost benefit trade-offs of different operational components. Where the business strategy creates the overall direction an organisation strives to pursue, the supply chain strategy actually supports the organisation's operations and the extended supply chain to ensure that specific supply chain objectives are met. Supply chain strategies are said to form the backbone of business organisations today, by creating efficient market coverage and availability of products at different geographical locations. Revenue recognitions are dependent on the effectiveness of roll out of those supply chain strategies. Putting it in simple terms, when a new product enters a market and is advertised, the entire region or country that the advertisement reached needs access to the product in order to reach potential customers. Unavailability can have devastation effects on the product's sales figures. That is why it is important to have an adequate transportation network and logistical infrastructure in place to support the sales and marketing strategy. (Management Study Guide 2008:1)

According to Fisher (1997:105-116) there are two distinctive supply chain strategies; 1) an efficient strategy and 2) a responsive strategy with regards to the product type: functional or innovative. Mason-Jones, Naylor & Towill (2000:4061) took the strategic framework developed by Fisher (1997:108) further and characterised it into three types of supply chain strategies; lean, agile and leagile. To elaborate on the three types, a lean supply chain strategy aims to develop a value stream from the suppliers to the final customers in order to eliminate all kinds of buffering cost in the supply chain whilst ensuring a stable schedule in production in order to improve process efficiency and then maintain the competitive advantage through economies of scale in a stable and predictable market place. In contrast to a lean supply chain strategy, an agile supply chain strategy aims to develop a reconfigurable and flexible network with business partners to share competences and market knowledge in a fluctuating market environment by achieving a rapid response to any changes in the market. Leagile supply chain strategies, combines some elements of both lean and agile strategies, utilises make-to-stock/lean strategies for stable and high volume demand products, while using make-to-order/agile strategies for everything else. Thus, a leagile supply chain strategy can provide flexible production capacity to meet surges in demand (e.g. seasonal demand). (Christopher & Towill 2001:235-246) (Goldsby, Griffis & Roath 2006:57-80)

Lee (2002:105-119) takes the strategic framework even further by introducing four types of supply chain strategies, efficient, risk-hedging, responsive, agile. A typical example of an efficient strategy is when a firm is achieving a competitive advantage through low cost and high production in a mature market. An efficient supply chain strategy is implemented to efficiently manufacture quality products and provide customers with reliable service. A risk-hedging supply chain strategy is developed when a supply chain is faced with risk and uncertainty. Hydro-electricity, retail industry and some food producers provide samples of this category. (Lee 2002:105-119; Boone, Craighead & Hanna 2007: 594-611) To mitigate supply uncertainties, companies will increase buffer stock held for its core products whilst attempt to share the cost of safety stock with its supply chain partners. For companies with a variety of innovative or tailor made products a responsive supply chain strategy would be used. (Fisher 1997:109) To counter variations in demand this strategy will postpone final assembly till after the demand signal is received. For fashion apparel and high-tech industries this is a common strategy to implement. (Lee 2002: 108) Of the four strategies, an agile supply chain strategy is the most market driven and most flexible strategy. An agile strategy aims to improve flexibility while being adaptive to market changes and unpredictable sources of supply. Thus, an agile supply chain strategy focuses on fast market responses and quick new product development, while minimising supply disruptions by stream lining information flows across the supply chain. (Roh, Hong & Min 2014:201)

The supply chain strategy should not just be a linear derivative of the business strategy but must rather be an enabler of the business strategy. If the business strategy strives to lower the operational cost, the supply chain strategy should support this. Similar to when creating a business strategy, supply chain executives need to look at the different focus areas or core competencies available in the supply chain and find means of differentiation to develop a supply chain strategy that can enable the business strategy.

Supply chain executives should determine the capabilities as well as the capacities that exist among the supply chain personnel. It is important to do an objective assessment of the business' supply chain assets by making use of external parties and do an evaluation of how well the supply chain assets will support the business strategy. It is important to look for an external party that can compare the supply chain assets to that of other business units' assets within a company but also compare to market leaders who have implemented best practices. Once these assessments are completed and the results analysed, form a team that can prioritise the proposed recommendations, identify the risks, test the opportunities and determine the recommendation for implementation. If there is any differences between the supply chain strategy and the available supply chain assets a capital investment may be required to close the gap. Then an implementation plan for the supply chain strategy must be developed. This is a highly detailed plan containing a set of implementations requirements and possible contingencies. The implementation plan typically includes the roles and responsibilities, timelines, key performance indicators (KPI) and a detailed project plan containing the timelines, cost and milestones.

Finally share the project details on a high level with other supply chain partners to see if mutual goals and benefits can't be achieved. This will help to identify possible areas where synergies could be found between different business units.

2.5 Purpose of the forecasting

According to Lapide (2001:12) strategic forecasting is forecasts generated over a long period, namely in yearly periods, which are used for long term planning for businesses, strategic decision making for capital investments and capital planning.

Due to globalization more companies have started focusing and monitoring the global environment to see what is happening. Transport and logistical infrastructure together with the crime rate, tax and the educational system of the country, forms the criteria for competitiveness and the success for an economy. (Ruske, et al. 2010:72) Petrochemical companies, like Sasol, also have to start focusing and monitoring what is happening with global logistical infrastructure projects, changes in legislation and regulations due to the ever increasing user-base forcing countries to change the rules for users to utilise these assets. The purpose of forecasting is to aid supply chain executives in making accurate and optimised decisions with regards to the possible futures, probable futures and the preferable futures for example the future which Sasol wants to achieve.

Forecasts provides the forecaster with a basis to understand the process changes and dynamics of change required as well as a systematic methodology using a basis to set up the supporting assumptions to discover possible futures. Forecasting also help to identify which future opportunities will be preferable to pursue and which will be undesirable. Additionally forecasts are used to assist our intuitions about investment opportunities, outlooks and plans etc. to give a more accurate view of the future possibilities. Forecasting has evolve to an essential tool to aid businesses and individuals to plan, design, manage, implement, steer and control change by identifying the best possible future scenarios to support the business strategy. (Joseph 2010:1)

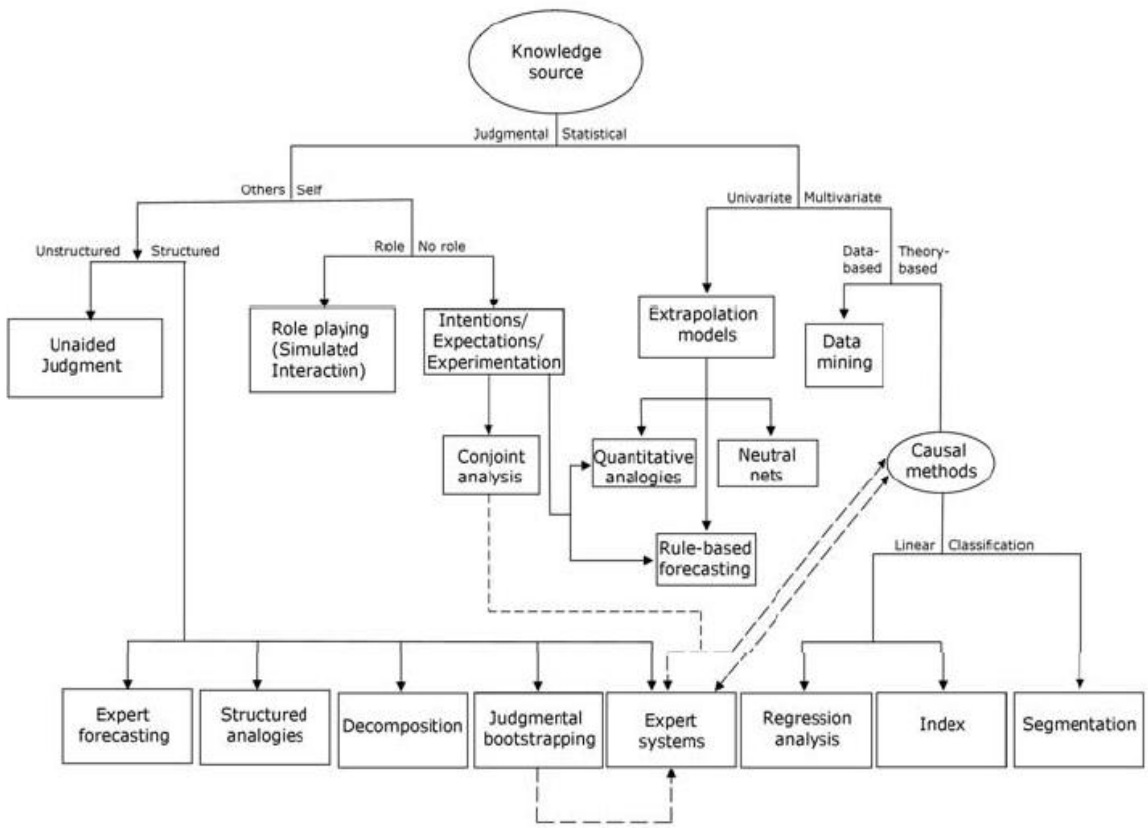
The proposed design of the logistical infrastructure during the supply chain design process will be the direct result of using supply chain planning to translate the business strategy into a supply chain strategy and the execution thereof. Creating and executing a supply chain strategy is very important for Sasol in order to achieve and maintain a competitive advantage in a specific market or markets. This is done by ensuring that the available supply chain capacity can support the business' growth plans and direction management want to steer Sasol into the future. This is done so that Sasol can become substantial market force in a market or a country without abusing its power to out price smaller competitors but rather improve efficiency and effectiveness. The vehicle available to supply chain executives to achieve this, is to ensure that collaborations between business units can be found through accurate forecasting in order for logistical infrastructure to be optimised, costs can be minimised in operating the logistical infrastructure or reducing capital investments required for logistical infrastructure can be achieved by making optimal investments in order to create a competitive advantage. (Louw 2006:8-26)

2.6 Different forecasting methods

There are different types of forecasting methods namely; Qualitative and quantitative. Qualitative include judgemental, life cycle, Delphi method, market research etc. Quantitative methods include; time series and causal methodologies. Figure 7 shows a methodology tree for forecasting.

The different types of qualitative methods are explained by, new developments in business forecasting (Lapide 2002:12) and in Operations management (Russell & Taylor 2000:497-518), as follows. Judgemental methodologies are based on opinions of stakeholders such as; gurus, customers, market influencers etc. Life cycle is the methodology which uses demand profiles or curves as the input data to forecast the future. Delphi methodology makes use of a panel of experts anonymously answering questions that is fed back to a panel member who consolidates the responses to formulate an answer but may change the original responses but must comprise of a combination of forecasts made by at least two rounds of anonymous interactions between different experts. Market research methodology consists of questionnaires, surveys, panels and test markets. Under the quantitative methods, the time series methodology looks at historical data to predict how the future will look. The casual methodology uses methods such as the cause-effect relationship to forecast what will happen in the future, by predicting a cause with more ease than its effect.

Figure 7: Methodology tree for forecasting



Source: Graefe, et al. (2010:3)

The most common type of forecasting is to ask an expert or a panel of experts to predict the outcome of a situation based on previous experience and knowledge. If experts derive the forecasts in an unstructured way, it is referred to as *unaided judgment forecasting*. When a forecast is referred to as an *expert forecast*, it is normally because the results are a combination of results obtained from different experts or a panel of experts' opinions that were made using structured techniques. The *NGT or nominal group technique* used to forecast, eliminate some of the problems traditional gatherings had, by allowing group members to work individually to generate results then discuss the results in a unstructured meeting before working independently again to generate the final results.

Another useful forecasting method is *prediction markets* where forecast are combined to give continuously updated probability or numerical forecasts. *Structured analogy* forecasting method makes use of similar situations and the information thereof to make a calculated forecast. When having to forecast an aggregated problem it is easier to break down complex situations into easier components by using the *decomposition forecasting method*. Using the forecast results made by experts and comparing this information against the information experts originally used to make their forecasts, is called *judgmental bootstrapping*. Expert systems are forecasting rules resulting from diverse sources used by experts such as interviews, protocol analysis and surveys, to explain the process during forecasting.

Experiments are also a forecasting method as results are obtained by changing the key variables in a systematic way and relationships estimated to derive forecasts. *Role playing's* purpose is to predict behaviour of people while simulating interaction. *Simulated interaction* is when used when minimal or no quantitative data are available or the forecasting situation is unique or decision makers want to test various effects/impacts of proposed decisions. *Extrapolation models* uses exponential smoothing of time-series data, obtained over a specific time period for different situations of interest, with the principle that recent data will carry the bigger weight. *Rule-based* forecasting is a combination of statistical techniques for extrapolation of time series and expert domain knowledge. *Causal forecasting models* make use of the index method, segmentation method and regression analysis. The above mentioned methods are extremely useful if there are available data on variables that could influence the situation of interest. (Graefe et al. 2010:3-8)

With so many different forecasting methods available the above mentioned ones are only to highlight but a few. By understanding what each method entails and the application there of it enables the forecaster to select the appropriate method for their indented application. It is not necessary to either choose qualitative or quantitative or judgmental but also by using a combination of these methodologies the right forecasts can be achieved.

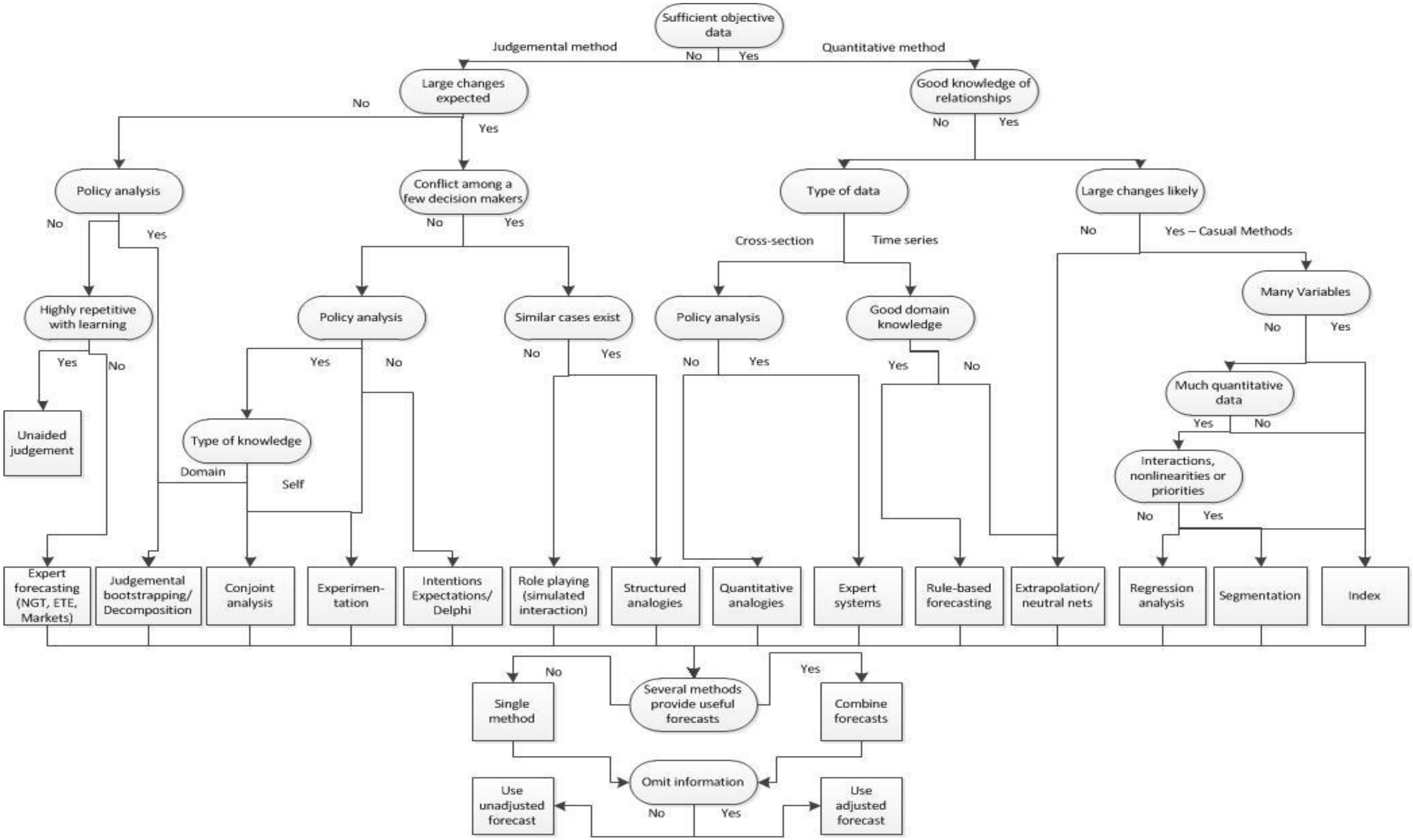
2.7 Selecting the optimal forecasting methodology

Figure 8 shows a decision tree that will provide guidance to the forecaster with the selection of forecasting methodology that can be used. The decision tree contains questions about the data that is available to the forecaster as well as the state of knowledge about the situation that must be forecasted. The tree's first question is whether statistical analyses can be done by having enough objective data available otherwise one must use the judgemental method.

When determining which judgemental procedures to use, one must first determine if the future will differ substantially from the past, whether there is a need for policy analysis and if the decision makers within the situation have conflicting interests. Considerations like whether forecasts are made for recurring and familiar problems and whether domain knowledge and information for problems of similar nature are available.

If quantitative methods can be used, due to the availability of objective data, it is the forecaster's responsibility to determine if major changes are involved, the availability of time-series data and if any knowledge about causal relationships are available that can be used. In cases where little to no realistic knowledge exists about relationships, there should be determined if an expert's expertise will be better than a policy analysis. If excellent information is available that the future will change and be considerably different than what it currently is and the absence or presence of interactions between the number of available variables and available number of observations the casual method will be selected. (Graefe, et al. 2010:9-11)

Figure 8: Selection Tree for Forecasting Methods



Source: Graefe, et al. (2010:10)

In order to get the most accurate forecast results one need to start by analysing the purpose of the forecast. By answering the following questions together with the forecasting tree one will be able to find the best forecasting method in order to achieve the goal. Firstly, what is the purpose of the forecast? What is the time horizon for the forecast? Use the forecasting decision tree to find the appropriate method for the forecast. Gather and analyse the data. Make the forecast and lastly monitor the forecast.

By applying this method explained above to the two different practical examples one can find the right forecasting methodology. The brownfield project example that will be used in the case study is based on a project initiated by the Research and Technology (R&T) business unit. They were facing supply chain problems due to the increasing pressures to render a service to the ever expanding Sasol group of companies. Their logistical infrastructure was designed on the basis of rendering a service to the Sasol group of companies across two Sasol production sites. In recent years this has expanded to 8 production sites across a larger geographical region. This resulted in high storage cost, over procurement, slow customer, response times and decreased profit margins. The purpose of this forecast is to determine what capacity is required in terms of the logistical infrastructure in order for R&T to be able to render these services to a larger geographical area with more production sites. The forecast will help to establish cost, time and resources required in order to get the optimal results. The time range will be in the strategic time frame spanning over the long and medium term.

When analysing the data for the brownfield example, one see that some of the data consist of sufficient objective data, thus the path of using quantitative methods are followed for them. For the data that do not have enough objective data, one will have to use judgemental methods. This mean that the result will have multiple different forecasts that need to be combined using a decision making tool in order to get the best results.

For the greenfield project example, the need was identified for the fertiliser supply chain to be design due to plans to expanding the current product range with the addition of a new manufacturing facility as well as the debottlenecking of the current facilities that would increase the current output. The purpose of this study was to find the lowest possible cost with the highest rate of return on investment (ROI). This project time frame will be strategic and look at the next 2-5 years. When looking at the data and by using the decision tree, the findings shows that one will be required to use both judgemental as well as quantitative models. This is mainly due to the large number of data sets that needs to be incorporated in order to find the best solution. The data will be gathered from a range of sources; from SAP & BW for historical data on sales, production and storage; to data from SME's on predicted sales; increased estimated capacity due to debottlenecking of the existing plan to new theoretical production rate of the new manufacturing facility. The end result is multiple forecasts that need to be incorporated into a decision making tool to tests different sensitivity analysis and scenarios in order for the decision makers to end up with the best possible result.

2.8 Choosing a decision making tool for multiple forecasts

Linear programming have been chosen as the decision making tool to combine the multiple forecasts. Linear programming (LP) is certainly one of the most renowned tools in the field of operational research (OR). From the formulation of the first LP problems by Leonid Kantorovich in 1939 and the simplex algorithm development by George B. Dantzig in 1947, linear programming, the tool of choice, for optimisation problems that are found in business and management, such as transportation routing, project planning, production planning, supply chain management and portfolio optimisation. (Panagiotopoulos 2011:1)

The main reasons why linear programming was chosen is firstly, according to the research done by Panagiotopoulos (2011:52-164), he found that linear programming, as a tool to combine forecasts, outperformed traditional combination approaches that can be found in forecasting literature and in practice. Secondly, this study decided to use linear programming as the preferred decision making tool due to the flexibility over longer periods of time and because this has been the tool of choice over the last 50 years in the petrochemical industry. Thirdly, Sasol had invested in i2 Supply Chain Strategist software which is a linear programming modelling tool. For these reasons, linear programing was the tool of choice to combine the multiple forecasts, for brownfield and greenfield examples, to obtain the best possible results in order for management to make optimal decisions. To have as accurate as possible forecasts, is very important managerial activity as it forms the first stage of every planning procedure.

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2.9 Why has Sasol selected i2 Supply Chain Strategist

In the State of the art survey of commercial software for supply chain design (Funaki, 2008:1), thirteen tools for supply chain design were compared. Table 2 shows the name, vendor, year released and website of all thirteen tools. The scope of the study was to show the status of supply chain design tools available in the market. Table 3 show the survey questions that were asked to all the different software vendors. The findings of the study showed that four areas where technology supported supply chain design namely; supply chain optimization model, optimization technologies, visual technologies and software technologies for installation. Also six major streams were identified that drive the functional evolution of the tools namely; data preparation support, modelling support, analysis and reporting support, international factors, carbon emission evaluation and inventory evaluation. Because of confidentiality agreements with the vendors, the vendor's detailed information could not be disclosed for the different areas. What it boils down to is that all the tools have different strengths and weaknesses because they focus more attention on certain areas mentioned above. It is up to the company to select the appropriate tool that will provide them with the best solution in order to make the best decisions.

Table 2: The list of currently available commercial software tools for supply chain design and their vendors together with years of release and web sites

Name	Vendor	Year released	Web site
CAST	Barloworld Optimus	1989	http://www.barloworldoptimus.com/home.aspx
4flow vista	4flow	2001	http://www.4flow.de/logistikberatung/4flow-vista.html
LogicNet Plus	ILOG/IBM	1995	http://www.ilog.com/products/logicnet-plus-xe/
LOPTIS	Optimal Software	N/A	http://www.ketronms.com/loptis.shtml
NETWORK	Supply Chain Associates	1968	http://SupplychainAssoc.com/NETWORK.htm
Opti-Net	TechnoLogix Decision Sciences	1993	http://www.technologix.ca/solutions/optinet_supplychain.ht m
PowerChain Network Design	Optiant	2000	http://www.optiant.com/content/blogcategory/72/119/
PRODISI SCO	Prologos	1985	http://www.prologos.de/English/Prodisi.htm
SAILS	Insight	1984	http://www.insight-mss.com/_products/_sails/
SITELINK	CGR Management Consultants	1995	http://www.cgrmc.com/index.html
Strategic Network Design	Infor	N/A	http://www.infor.com/solutions/scm/strategicnetworkdesign/
Supply Chain Guru	LLamasoft	1998	http://www.llamasoft.com/index.html
Supply Chain Strategist	i2 Technologies	N/A	http://www.i2.com/solutions/solution_library/supply_chain_ strategist.cfm

Source: Funaki (2009:5)

Table 3: Inquiry sheets used in the survey contain questions regarding technical features, functional features and implementation features.

Category	Question item	Question
[1] Technical features	[1-1] Technology used for optimization or simulation	What algorithms and methodologies, or what kind of engines if available, are used for optimization and simulation?
	[1-2] Technical leader or adviser, if available	Who leads technology development, if available?
	[1-3] Typical model	What is the typical model the tool can describe? (Typical objective functions and major constraints)
	[1-4] Other technical features	-
[2] Functional features	[2-1] Data preparation support	What support is provided by the tool in preparing input data?
	[2-2] Analysis and reporting support	What analysis methods and reporting styles are available by the tool?
	[2-3] Consideration of international factors	What international factors can be modeled by the tool?
	[2-4] Carbon emission evaluation	Can the tool evaluate carbon emission? Can it optimize supply chain network considering carbon emission? If so, how?
	[2-5] Inventory evaluation	What types of stock can be modeled by the tool? Can it optimize supply chain network considering stock placement? If so, how?
	[2-6] Other functional features	-
[3] Implementation features	[3-1] Standard estimated price to implement the software	-
	[3-2] Standard steps and period needed to implement the software	-

Source: Funaki (2009:7)

Historically in Sasol, strategic planning decisions were made by separate teams focused on their portion of the enterprise. These important decisions were made using complex spreadsheets developed to address a specific problem—a task that was tedious, cumbersome, and unrepeatable. It resulted in the separation of different parts of the strategy, which lead to problems interpreting and reconciling the analyses of different groups.

i2 Supply Chain Strategist™ provided a modelling and optimisation environment that was capable of representing the appropriate breadth and depth of the supply chain required to answer the strategic questions at hand. i2 Supply Chain Strategist contains a mature, robust engine that uses the latest linear/mixed-integer technology to efficiently solve strategic planning problems. This is way Sasol decided to invest in Supply Chain Strategist as their tool of choice to solve complex supply chain design questions with.

3 Supply chain design

3.1 What is supply chain design

According to Supply Chain modelling: past, present and future (Min & Zhou 2002:231), businesses have historically placed an emphasis on separate business units/functions' efficiency and effectiveness. However more recently an increasingly number of companies has begun to understand and realise the importance of strategic planning, controlling and designing a supply chain holistically. In order to assist the company to capture synergies of inter-functional/inter-organisational integration possibilities and coordination across the supply chain to improve supply chain decisions.

The goal of supply chain network design is to find the optimal design of a supply chain in order to maximise the economic performance over the long-term. Strategic and tactical planning decisions will typically be covered by the supply chain design. Typical strategic planning decisions will include; strategic decision on distribution, sales, production and sourcing. Whereas tactical planning decisions will include supply chain network planning of how the flow of goods will be affected through the network. Some of the supply chain strategies that have been develop to adapt to the ever changing supply chain environment is; flexibility, robustness, responsiveness, agile etc. The reason why this is not showing in supply chains today is due to management constant pursuit of short term profitability which has been contributing to the slowdown of the current global economy. (Chaabane, Ramudhin & Paquet 2012:37)

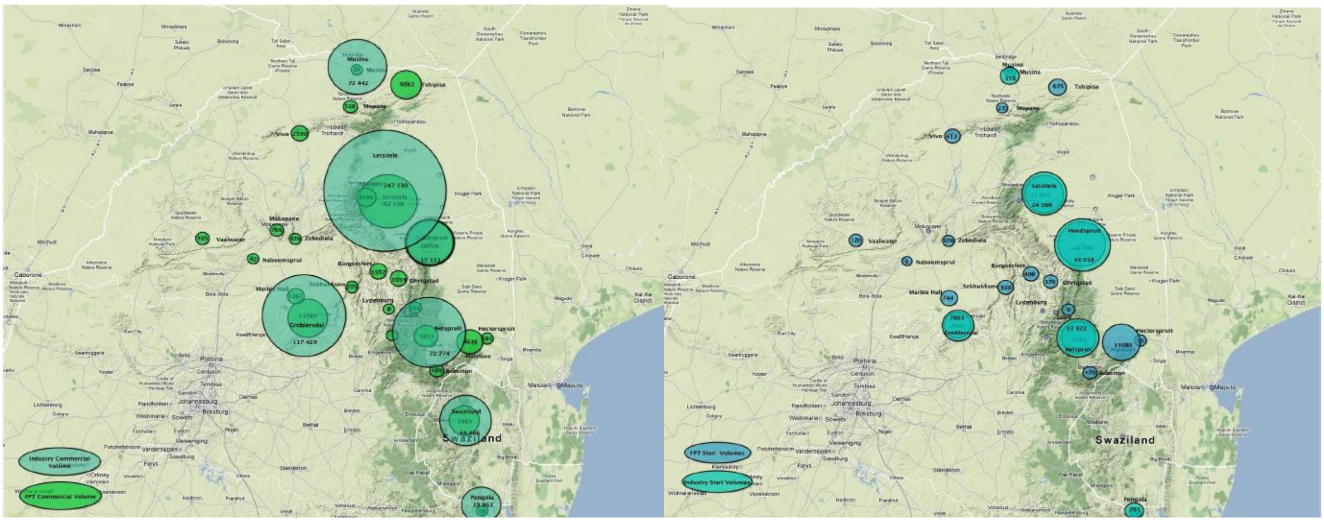
3.2 Different objectives of supply chain design

Supply chain design can have different objectives each requiring a different approach and will also require a tailor made solution in order to achieve these different objectives. It should not be a one-size-fits-all solution. Some examples of different supply chain design objectives according to Stout (2013:30) are; market share expansion, inbound visualisation for raw material optimisation, risk management, industry collaboration for working capital reduction, customer service optimisation or job creation to name just a few. These objectives can be achieved by using modelling software that will help to increase or create visibility of the current supply chain, help to optimise product flow paths/patterns, determine the right size of inventory or demand segmentation, help with production footprint analysis and transport route optimisation etc. (Brzoznowski 2013:6)

3.2.1 Market share expansion

Figure 9 is an example of a company that required a supply chain design that would enable them to expand their market share. Company A wanted to redesign their supply chain in order to increase their market share but was not sure where to increase their production facilities capabilities, open or close new warehouses/distribution centres or just expand the current warehouses/distribution centres etc. Supply chain design software and techniques were used to determine where to expand their market share in order to increase profitability and avoid spending unnecessary capital.

Figure 9: Market share expansion (Before) **Market share expansion (After)**



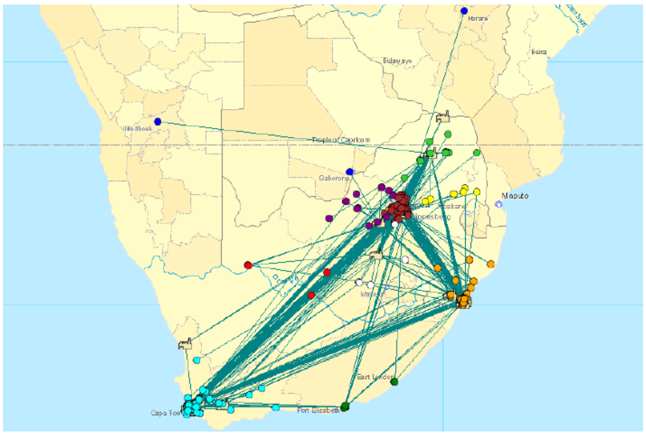
Source: Stout (2013:9)

In Figure 9 the green areas represent the volume of Company A before the supply chain redesign, where the objective was to expand their market share whilst the light blue represent the industry volumes. The right-hand side of Figure 9 shows after the supply chain redesign where the market share was increased and where some less profitable distribution points and/or warehouses was closed down. The dark blue shows Company A's remaining facilities. Supply chain design assisted to find the right mix between the amounts of distribution points, location of warehouses as well as where the stock should be kept in the supply chain to increase customer satisfaction and decrease transport costs and long lead times.

3.2.2 Inbound visualisation for raw material optimisation:

Creating visual representation of the supply chain will enable a business to more effectively further realise opportunities for optimisation, collaboration and cost saving by providing more sophisticated analysis views like; overlaid map with statistical graphs and flexible zooming-in and -out with multi-level views from entire network to local facilities. Figure 10, 11 and 12 are examples of a visual representation of supply chains. By creating these visual views it enables the opportunity for improvements. Looking at figures 8 and 10, it shows respectively a simple and a complicated inbound supply chain for raw materials. Opportunities for collaboration can now be identified more easily. By making use of modelling software and supply chain design tools and techniques, a company can optimise on these routes, see where empty backhauls can be eliminated. Figure 13 and 14 shows the improved supply chains after the collaboration opportunities were identified, implemented and utilised. Significant cost savings was achieved by utilising collaboration opportunities, between the manufacturer and the company, by eliminating empty back hauls and dead legs.

Figure 10: Visualisation of Inbound Supply Chain (Before)

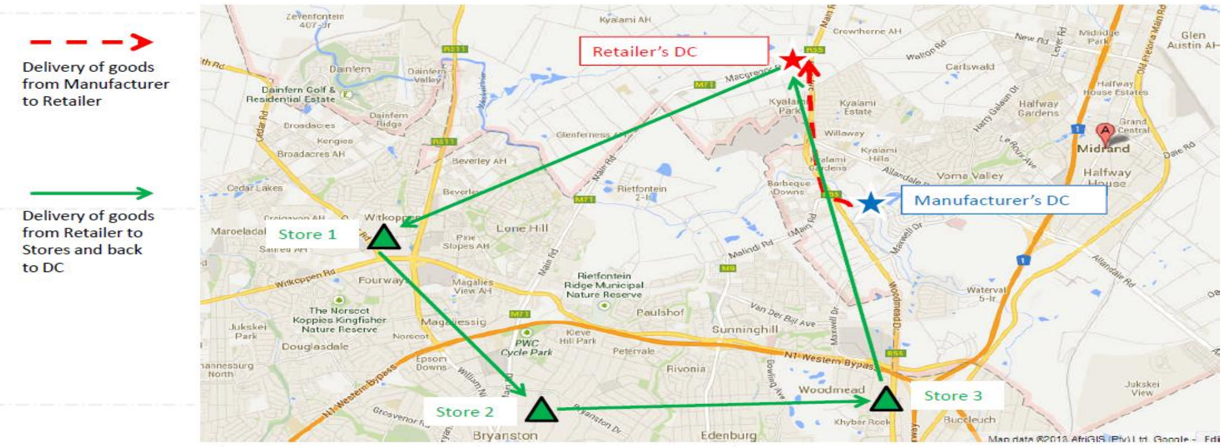


Source: Stout (2013:12)

Figure 11: Visualisation: What does my supply chain look like

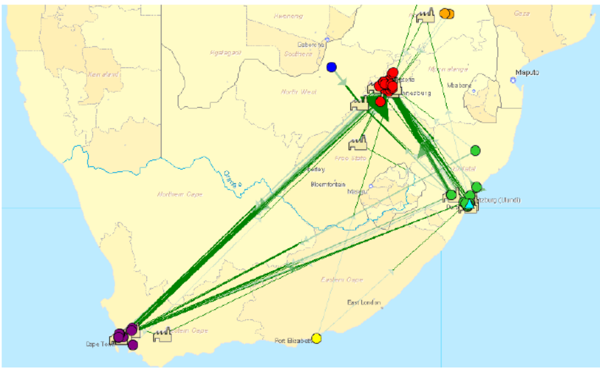
Source: ***Brzoznowski*** **(2013:7)**

Figure 12: Collaboration - A simple example (Before)



Source: Gower-Winter (2013:19)

Figure 13: Visualisation of Inbound Supply Chain (After)



Source: Stout (2013:13)

Figure 14: Collaboration - A simple example (After)

Source: Gower-Winter (2013:20)

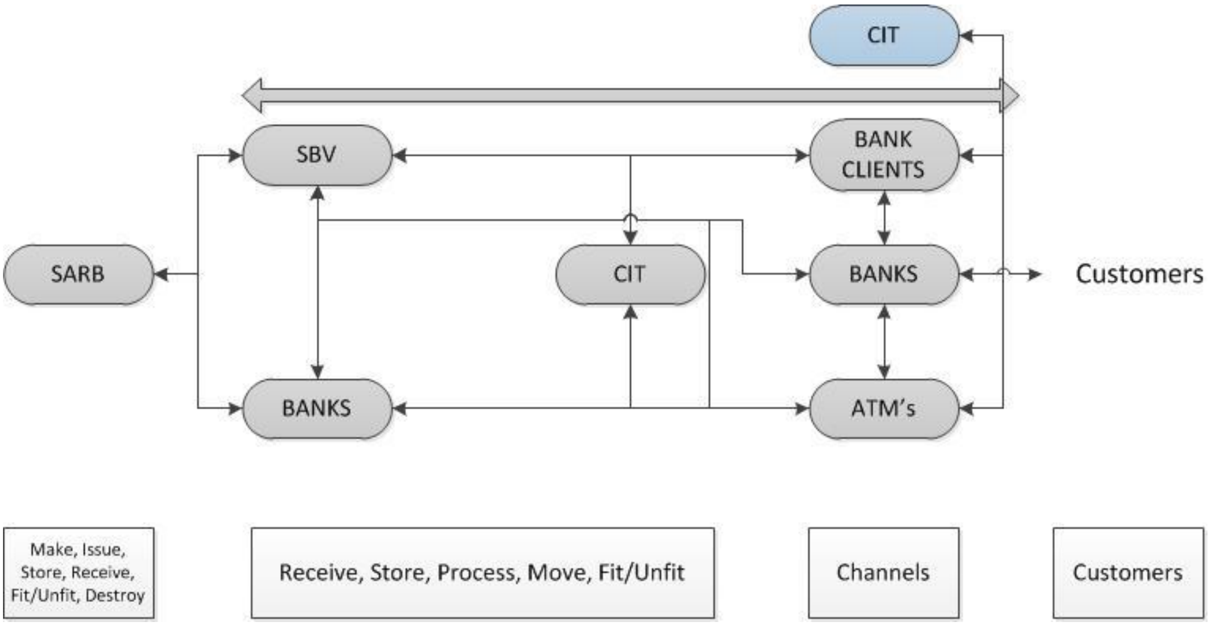
3.2.3 Risk management

According to Stout (2013:15), one of the biggest advantages of utilising modelling software is that it can be used to minimise business risk. Taking environmental risk contingency planning as an example, supply chain models can be used to evaluate a company's contingency plans, help to balance the production and sourcing against the changes in demand, prioritise demand during supply short-falls and restructure when cost assumptions fails.

3.2.4 Industry collaboration for working capital reduction

An example of a supply chain design that was used to reduce the working capital through industry collaboration is the cash supply chain in South Africa. This redesign was initiated after the South African Reserve Bank (SARB) threatened to increase taxes/levies on the paper cash for all banks. The banks of South Africa, Standard bank, ABSA, FNB and Nedbank, came together to find a way to optimise through collaboration. There were a lot of fears that this may lead to collusion but the decision was that if they collaborate the saving must go to the customers and not be shared among them. Figure 15 shows the cash supply chain where the cash flows from the SARB to the different banks or SBV, joint venture between ABSA, Nedbank, FNB and Standard Bank. From the SBV it will flow to bank clients, banks or ATM's via cash in transit (CIT) vehicles.

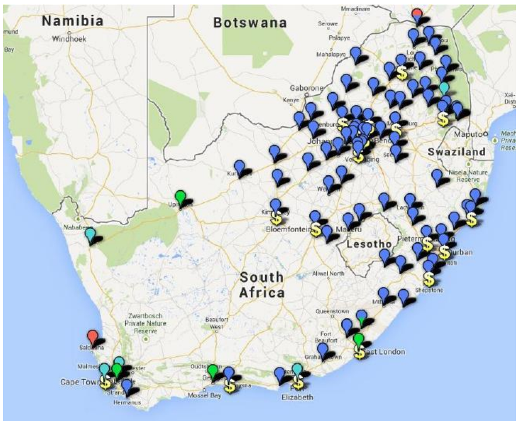
Figure 15: Cash supply chain



Source: Stout (2013:17)

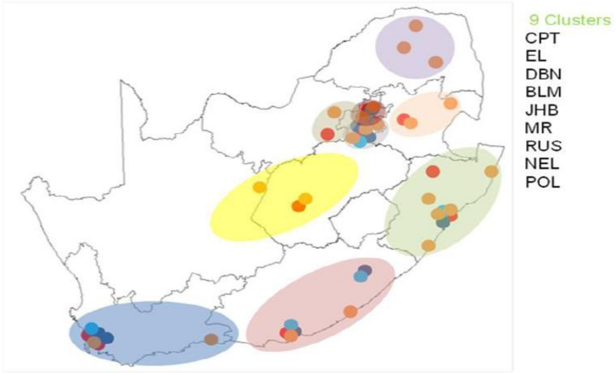
Figure 16 shows a consolidated view of all the ATMs represented in blue red and green markers and all the SBV branches represented by the yellow dollar signs. By mapping all the different banks' ATMs it help to do logical grouping into clusters as show in Figure 17. By servicing all the ATMs from a cluster approach, by the joint venture SBV formed through collaboration, it helped to reduce the working capital cost for all the banks and they managed to reduce the cost for the customer. (Stout 2013:27)

Figure 16: Combined network of Banks' ATMs and SBV branches



Stout (2013:24)

Figure 17: Cluster planning approach

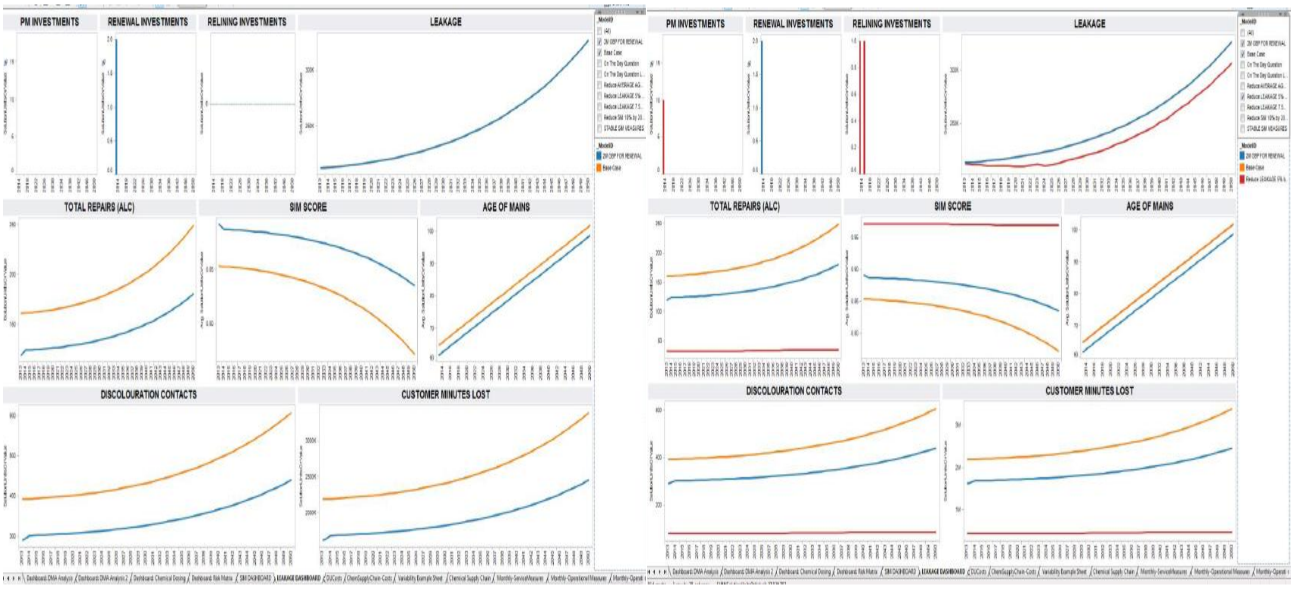


Source: Stout (2013:25)

3.2.5 Customer Service optimisation

The following example was taken from a presentation done by Stout (2013:29) on a company that manage and maintain the drinking water pipeline network. The company made use of supply chain modelling software to increase their customer service levels. They have a constant trade-off between maintaining the pipeline network at the lowest possible cost whilst not delivering water that is discoloured or have any down time of water supply to the customers. The company also wanted to know when to maintain a pipe and went to replace the pipeline since there are penalties for discoloured water as well as water supply being down. Figure 18 shows 3 different scenarios. The orange line represent the base case or the as-is scenario. The Blue lines shows what an investment of R30 million for pipeline renewals will have whilst the red line show if the leakage in the system is reduced by 5%. What was found in the base case was 25% of all the treated water was lost in the system. The end result was that through a balance between investment and maintenance the customer service could be improved significantly.

Figure 18: Customer service optimisation

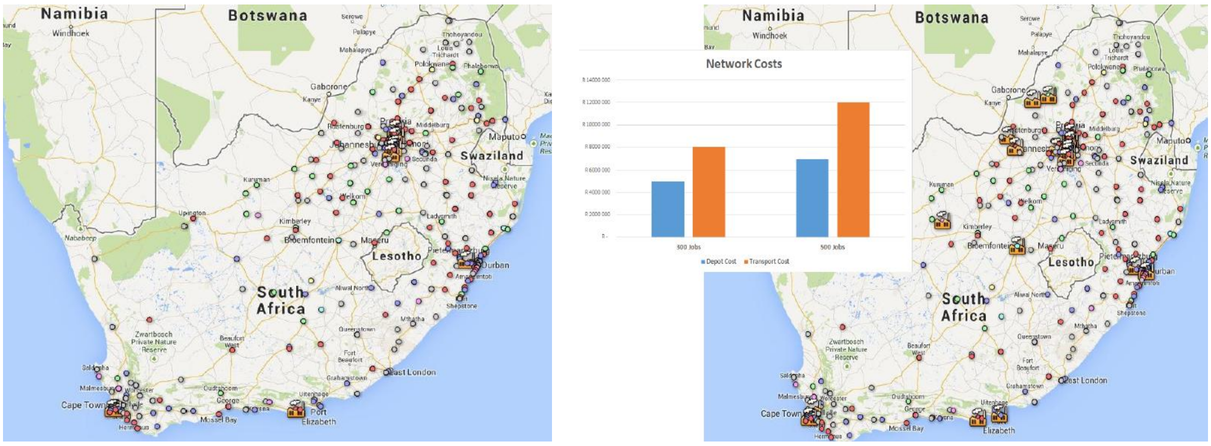


Source: Stout (2013:27)

3.2.6 Job creation

The following example is on using supply chain modelling software to increase job creation rather than reducing cost like the common misperception that exists about supply chain designs. Figure 19 shows two maps were all the manufacturing sites, distribution points, suppliers and customers are represented by different markers on the map. The company for whom this model was done wanted to create more jobs and was wondering how they could do that and wanted to know what the cost implication would be if 300 additional jobs were created vs. creating 500 additional jobs. The graph on the right shows that by spending an additional R8million on transportation and R4.5 million on depot costs 300 more jobs will be created. This had to be balanced with the R12 million needed additionally for transportation and R6.5 million for depot costs in order to create 500 extra jobs. (Stout 2013:32)

Figure 19: Job Creation



Source: **Stout (2013:32)**

These examples listed above just shows how supply chain design modelling tools can assist to deliver a variety of different answers depending on the problem you want to solve. Supply chain design and modelling help organisations achieve multiple strategic objectives. This study will look at a combination of the above mentioned objective of supply chain design in order to find the best result for the green and brownfield examples mentioned in the case studies.

4 Sasol’s current view

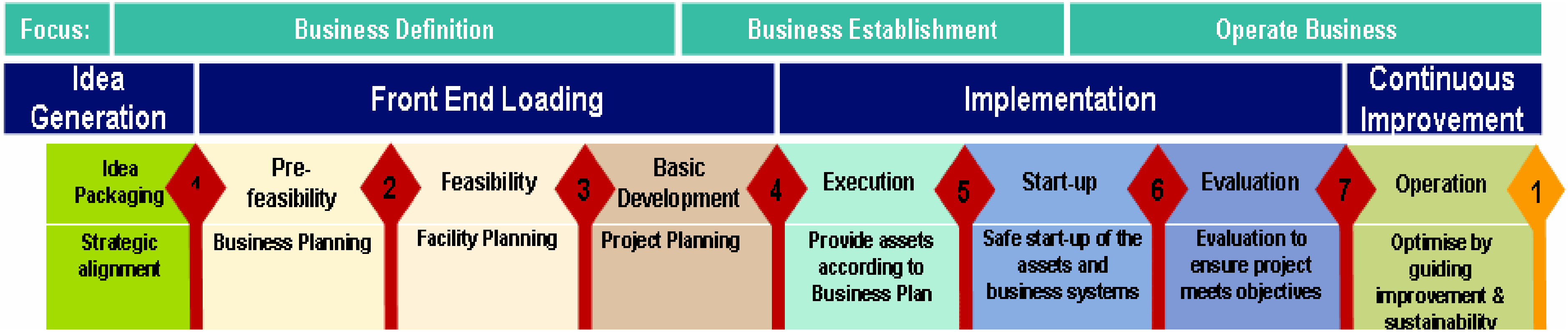
4.1 Sasol’s current approach to capital projects

The current approach/process that is followed for all capital projects, green and brownfield, in Sasol is to make use of a phase gated project model approach. The phases range from idea generation, prefeasibility, feasibility, basic development, execution, start-up, evaluation and operation. By using these 7 gates, it ensures that the optimal decisions are taken with regards to capital expenditure for project and to insure that the projects that pass through the gates is the correct ones and will be advantageous for Sasol and aligned to the business strategy and needs. At every gate there is a steering committee, consisting of subject matter experts, that have to evaluate the findings and make the decision if the project should pass through the gate or not. This sounds very simple and like a very good tool to use, which it is, but the human element causes this tool to fail. The phase gate model was designed to be a project management tool that would make sure that only projects bringing a high return on investment will be allowed to go through the gates and sub optimal projects gets canned at an early stage. The goal of the model is to identify and stop sub optimal project which may have looked good on paper.

In the supply chain fraternity this model has been customised to fit supply chain needs and in this study the supply chain phase gate model will be used. The phase gate model was originally design for big capital projects like building of production plants etc. but was simplified to cater for all projects Tier 1-7. The model consists of different tracks for example; business, technical, project, engineering etc. that flow across all the different phases. The supply chain function falls under the business track in this model. Supply chain subject matter experts (SME) have customised this model so that it can be used for all supply chain related projects big or small. The only downfall of this approach is that a lot of the people in the business units decide to bypass certain steps and phases in the model in order to try and get their projects done as soon as possible. Personal agendas often show to be a huge cause of projects that fail, where the project should have been cancelled in the phase gate approach but was not due to someone driving an agenda.

Within the phase gated model the prefeasibility, feasibility and basic development phases are grouped together to form the front end loading part in this model as shown in Figure 20.

Figure 20: Phase Gate model



Source: SC BD&I development (Supply Chain Development CoE 2011:8)

Figure 21: Phase Gate model

Track Deliverables							
Business/ Operations	Business Case	Business Plan	Final Business Plan	The Business	Running Entity	Post Audit Report	Optimise business & product
Engineering/ Technical	Preliminary Eng. Proposals	Conceptual Eng. Proposal	Basic Eng. Package	Technical Integrity	Start-up Assistance	Performance Certified	Optimise facility safety, reliability & integrity
Project Management	Project Execution Philosophy	Project Execution Strategy	Project Execution Plan	Project as per Execution Plan	Project Close-out & Review Plan	Project Close-out Report	Project Governance
Sponsor	Feasibility Charter	Basic Development Charter	Project Charter	Governance	Governance	Governance	Corporate Governance

Source: Supply Chain Development CoE (2011:8)

The set of deliverables that need to be met are listed for each of these phases and goes into more detail as one progress through these phases. Deliverables are split up into strategic, tactical and operational horizons as these deliverables have an impact on different time horizons. As a project progresses through the different phases, within the model, the deliverables will have a bigger impact on the business and shorter planning horizons, for example in the pre-feasibility phase most deliverables will have an impact on the strategic planning horizon, commonly known as the 1-5 years window, whereas in basic development phase, the majority of deliverables will impact on the operational environment, more commonly known as the day to day operations.

In the front end loading stage, more specifically pre-feasibility and feasibility, where strategic planning and forecasting takes place when new projects are undertaken. Very crude forecasts are used as the first stage of the strategic planning that happen in the prefeasibility section of the BD&I. Then supply chain strategy/ies are derived from the business strategy. Then the inbound, outbound and on-site infrastructure considerations are investigated. This includes strategic sourcing of long lead items, sourcing strategies, storage, loading/unloading, reverse logistics, customer demand and distribution considerations. Table 4 shows an extract of some of the deliverables for the prefeasibility phase, that have an impact on all other areas within the current inbound supply chain, outbound supply chain and on-site/inter-site infrastructures and their impacts on the current operations should be identified as well as opportunities to improve should be highlighted. Alternative supply chains are developed and played back to the relevant stakeholders in order to find the most realistic high-level design.

Table 4: Pre-feasibility – Deliverables

Deliverables and output documentation	• Understand scope and business assumptions
	  o Confirm design parameters (Design Input Questionnaire)
	• Understand the business strategy
	• Develop alternative supply chain strategies
	  o Analyse supply chain considerations that impact the operational environment
	  o Existing Infrastructure analysis (Internal and External)
	  o Analyse the competitive environment from a supply chain point of view
	  o Assess impact of Supply Chain barriers to entry and possible ways to mitigate
	  o Define regulatory / legislative issues that impact opportunity
	• Determine supply chain considerations for Inbound
	  o Identify Tactical and Strategic Sourcing of long lead-time Materials and Services
	  o Identify Sourcing Strategy Considerations
	  o Identify Storage Considerations

	○ Identify Off-loading Considerations ○ Identify Reverse Logistics Considerations ○ Outline and evaluate risks • Determine supply chain considerations for Outbound ○ Identify customer demand management considerations ○ Identify distribution strategy Considerations ○ Identify Storage Considerations ○ Identify loading Considerations ○ Identify Reverse Logistics Considerations ○ Outline and evaluate risks • Analyse oversize logistics requirements ○ Route study ○ Suitable service providers • Determine on-site infrastructure requirements ○ Understand site interfaces / on-site logistics ○ Site infrastructure guiding principles • Determine alternative supply chain designs ○ Facilities / site selection location ○ Inputs to site layout ○ Road, Rail, Water, Pipeline, , Air Storage opex ○ Road, Rail, Water, Pipeline, , Air Storage capex ○ Outline and evaluate risks ○ Outline costs of the integrated supply chain alternatives ○ Clarify the impact of the opportunity on the Green Supply Chain ○ Develop high-level Supply Chain Operating Model ○ Understand the impact of possible decommissioning of supply chain infrastructure • Recommend alternative designs that support the supply chain and business strategy • Summary of key outputs • Supply Chain gate report • Risks • Go / No Go • Infrastructure report

Source: Supply Chain Development CoE (2011:23)

The type of forecasting method used in Sasol is normally expert forecasting experts in the field are used to get more or less 50% accuracy on what the final design's size, throughput and capacity should be. Expert forecasting can be explained as a mixture of knowledge obtained from experts and structured techniques. (Graefe et al. 2010:3) This will give the baseline for any possible improvements that could be made during the next phase, namely feasibility, in order to find the most optimal solution.

In feasibility all the deliverables in pre-feasibility will be relooked at, but this time in much more detail and drilling down to get 70% accuracy. The supply chain strategy will be confirmed to check the validity and if any changes are necessary. Then all the deliverables for prefeasibility, as shown in Table 4 should be relooked to see how these set of deliverables will impact the different part of the supply chain and to ensure that all impacts are highlighted and possible opportunities for optimisation or improvements are listed and thoroughly investigated.

Table 5: Supply chain deliverables gate 3

Deliverables and output documentation	• A Supply Chain gate report including the following: ○ Executive summary ○ The business opportunity definition and project objectives ▪ Scope and business assumptions ▪ Project objectives ▪ Plant / facility design principles ○ Supply chain study scope, objectives and success factors ▪ Business strategic requirements translated into the required supply chain strategies ▪ The preferred supply chain strategies to be followed for the opportunity ○ Proposed Supply Chain Operating Model ▪ Identified Supply Chain KPIs ▪ Business operating framework ▪ High-Level Supply Chain Structure and Organisational Design ▪ Competency Model and requirements ▪ Supply chain IM requirements ▪ Required SC Business Processes ○ Supply chain considerations that impact the operational environment ▪ Existing Infrastructure analysis (Internal and External) ▪ Analysis of the competitive environment from a supply chain point of view (competing for the same suppliers, infrastructure etc) ▪ Assessment of the impact of Supply Chain barriers to entry and possible ways to mitigate ▪ Regulatory / legislative issues that impact the opportunity ○ Supply chain methodology for the procurement of two year maintenance spares ▪ Master Data (materials) process and data requirements (to be included in the commercial plan for FEED) ▪ Process and methodology regarding the purchasing of two-year spares ○ Supply chain plan for Inbound materials and services ▪ Sourcing analysis of the required materials(catalysts, raw materials, process chemicals, MRO materials, packaging materials) and services. ▪ Confirmed Tactical and Strategic Sourcing of long lead-time Materials and Services ▪ Confirmed Sourcing Strategy Considerations ▪ Confirmed Storage Considerations ▪ Confirmed Off-loading Considerations ▪ Confirmed Reverse Logistics Considerations ▪ Identified risks and mitigating actions ▪ Estimated Opex and impact on Capex ○ Supply chain plan for Outbound goods (products, waste products) ▪ Confirmed customer demand considerations ▪ Defined channels to market for different product categories • Defined distribution options per channel ▪ Defined storage requirements (capacity, basic design requirements) ▪ Defined loading requirements (capacity, quantity, interface requirements) ▪ Defined Reverse Logistics requirements ▪ Identified risks and mitigating actions ▪ Estimated Opex and impact on Capex ○ Supply Chain plan for on-site infrastructure requirements ▪ Site interfaces / on-site logistics ▪ Logistical infrastructure capacities and design requirements ▪ Site plan inputs and requirements. ▪ Estimated Opex and impact on Capex ○ Supply Chain risks and compliance issues ▪ Identified cross business impact and assessments ▪ Safety

	▪ Regulatory environment ▪ tax, fiscal, legal and contractual, royalties, license fees ▪ Environmental sustainability impacts • storage and logistical requirements for CCS (if required) • carbon emissions • energy and water efficient designs • A Project oversize equipment logistics reports (if applicable) ○ as per the separate deliverable guideline • A project execution plan for Basic Development (FEED) phase ○ Resource planning ○ Project Execution methodology (i.e. internal resources, consultants) ○ Estimated duration and budget requirements • Documented lessons learned

Source: Supply Chain Development CoE (2011:26)

When determining the logistical infrastructure requirements in the feasibility phase, with deliverables shown in Table 5, the forecasting methods used will be selected based on the purpose of the study and time horizon. Simulation models will be developed by using software like Arena or Excel to analyse the gathered data (sales, demand, costs, stock control data and accounting data) in order to make a high level forecast based on the selected method. This help to test the design and the operability of the infrastructure using sales/marketing's forecasts and historic results but also refining the assumptions with inputs from experts in the different areas.

During the basic development phase, the designs will be finalised with 90% accuracy. All the supply chain considerations needs to be final as the design can't be changed after this stage. Linear program models will be built in order to assist the decision makers by feeding more accurate forecasts in to the model. Different scenarios and sensitivity analyses needs to be tested to ensure that the design is suited for the needs of the business, for example; be as flexible as possible but also as cost efficient as possible, given the flexibility requirements.

The stage gate or phased approach help that the optimal decisions are made with regards to investments made etc. to prevent that the wrong projects or project for the wrong reasons are followed through and that capital is not lost in the process.

4.2 Forecast to ensure sufficient capacity of logistical infrastructure exist for future growth

When looking at Sasol's logistical infrastructure asset base, which includes a combination of global and privately owned logistical infrastructure footprint of a great magnitude, one must keep a clear mind into what the key problems possibly would be. It is difficult to understand the current logistical infrastructure asset base the company owns and uses because of the geographical footprint and because it's spread across a number of business units. Risks like; bottlenecks, incorrect maintenance, high costs for maintenance and expansions can easily become a reality. That is why it is easier for people working with the specific piece of logistical equipment or - infrastructure to gain valuable knowledge about the possible problems, whilst easily identifying looming problems of what is or could be wrong or what infrastructure will be sufficient or not, by only looking at the operational side and the issues they encounter on a daily basis. For example the person A identifies a problem with the loading-arm on a gantry that is not functioning optimally whereas person B sees the day tanks levels are too low and causing production to decrease without realising this is due to the loading arm not functioning properly because of a silo view.

For these reasons it is important to take a bird's eye view approach of the total logistical infrastructure asset-base, not only for one of the manufacturing sites or a site as a whole, but also to look at Sasol and all logistical infrastructures it uses and also breaking it down per specific geographical region. Understanding the magnitude of such a logistical infrastructure asset base can be done through using different supply chain design techniques, methodologies and/or processes. One method that could help all the key stakeholders to understand what the logistical infrastructure base looks like is to create visibility with the help of software suits. This can be done by using mapping software like Arcview GIS, Google Earth or any other similar interactive mapping software or using supply chain design software packages that contains such functionalities. Figure 22 gives an example of how it possibly could look when the infrastructure is shown through visualisation. Detailed information like; tank capacities, current products stored in tanks, road loading arm capacities and products per arms, rail loading gantries throughout the site etc. can be added in order to display a lot of information through visualisation of the logistical infrastructure. Detailed information was removed from Figure 22 due to privacy issues.

Figure 22: Logistical Infrastructure of Site A

Source: Logistical operation centre planning (2010:6)

New logistical infrastructure can be mapped as soon as it has been built to ensure that the maps are kept up to date. One of the main advantages of using a graphical presentation of the logistical infrastructure, is that when decisions needs to be taken on where to build the new logistical infrastructure synergies can immediately be identified just by looking at the map. One of the problems is that the picture is dependent on Google to keep updated or to pay for new images after the new infrastructure has been built. Although this method is not really value adding to the top management of Sasol, this will help supply chain executives to illustrate business cases and help to convey the message clearer and easier.

Due to the constraints mentioned above, many businesses, including Sasol, have identified an urgent need to stop being reactive when logistical infrastructure issues are encountered, due to growth etc. but rather be proactive by developing methods to forecast in order to prevent bottlenecks, shutdowns, long standing times etc. by ensuring there is enough capacity, long before any difficulties or problems could be encountered.

A key obstacle for growth and development is the lack of having sufficient logistical infrastructure and that is why there is a need for Sasol to start forecasting proactively to ensure sufficient logistical infrastructure is available to enable the growth of the company.

5 Case studies

In this chapter there will be looked at two case studies, one of a greenfield project and the second one will be of a brownfield project. This is to illustrate the differences in approaches required and to test the feasibility of this approach in these different environments and to compare it back to the original project to see the difference in results.

5.1 Applying the theory from the study on a practical example: Greenfield case study

The case study was developed from a greenfield project that was done, where a need was identified for the supply chain to be designed due to plans to expand the current product range, the addition of a new manufacturing facility as well as the debottlenecking of the current facilities that would increase the current output. The facility's design and the supply chain requirements where outsourced to an engineering house on an engineering, procurement, construction and management (EPCM) contract. After the initial designs were completed, by the engineering house, an initiative was launched to test whether the theory in this study is viable. The theory is to use multiple forecasts, strategic planning and LP as a tool to combine the different forecasts to improve the engineering house's designs. Also to compare the CAPEX investment needed and OPEX costs for both the engineering house's design, who makes predominantly use of expert forecasting methods to do their projects. Whereas the study's methodology is to feed multiple forecasts in to the strategic planning using the Sasol's phase gated approach combined with LP tool, i2 supply chain strategist's models. (Gebhardt, Olivier & Visser 2011:2-8)

The objective of this case study was to analyse the design done by the consulting/engineering house SNC Lavalin and to scrutinise their designs to ensure that they have provided Sasol with the optimal results, in order for decision makers to implement the best design. The second objective was, to test the methodology of using multiple forecasts, to feed in to the strategic planning using the Sasol's phase gated approach, combined by using the LP tool, i2 supply chain strategist to create models in order to find the required capacities and to test the operability thereof whilst giving optimising the results. Designs were tested against a similar product with similar attributes and seasonal patterns. By using experts in the process, possible gaps in the design were identified and tested in further detail. Operability, flexibility and responsiveness of the supply chain were tested in to make sure that the design catered for all possible scenarios and sensitivities. A lot of gaps and constraints were identified. This meant that the design was not flexible enough to cater for all the needs required from business. (Gebhardt, Olivier & Visser 2011:9-12)

5.2 Applying the study's methodology

Before starting a supply chain design it is important to determine the requirements for logistical infrastructure, it is also important to focus on more than just an isolated piece of infrastructure but see the supply chain design as an integrated system. The first thing one would do is to look at what the business wants to achieve namely; to clearly define the objective of the supply chain design and to align it to the current business strategy. In this case the business unit wanted to expand their current range of products, with the addition of a new manufacturing facility but also debottlenecking the current production plant to ensure greater capacities can be achieved. Secondly, one would need to determine if the current logistical infrastructure asset base can't be used, be expanded or collaborations formed with other nearby business units so that investments can be kept to a minimum. (Gebhardt, Olivier & Visser 2011:11)

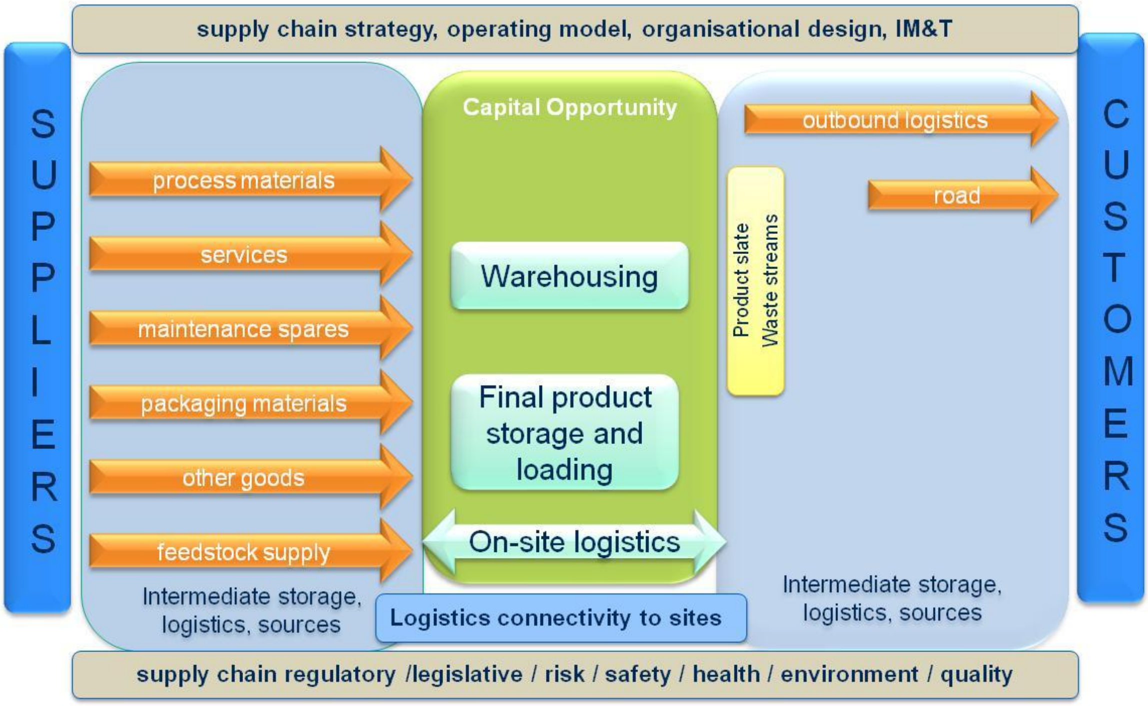
The first investigation needed is to determine if there is a possibility of expanding or optimising the current asset base or to increase the capacity of the current infrastructure. The second investigation needed is to determine if the products can be stored and transported together with the current product range and also with the products of the nearby business units to ensure that no safety risks/incidents will occur if the products are stored together. Once these investigations are completed the supply chain design can be started off with using the strategic supply chain planning structure as defined by the phase gated approach, by creating a supply chain strategy that would best suit the new design by deriving it from the business strategy. This will be done by using high-level forecasts to be fed into the planning process. After the supply chain strategies are created or updated, typically start with mapping the current supply chain to create a visualisation of the supply chain in order to enable discussion with different business stakeholders. Then a few alternative supply chain designs will be made in order to find the best possible design. After the original supply chain is mapped and the alternative designs are completed, an assumption list will be created and validated before any models can be built using the software tool. After the assumptions are validated with business, baseline models can be created in order to see the cost, reliability, flexibility, handling and risk impact for all the alternative designs. When building a model it is important to look at the integrated supply chain to ensure that the forecast takes all possible aspects in to consideration. The more information included the greater the accuracy of the forecast will be. (Gebhardt, Olivier & Visser 2011:13)

5.2.1 Supply chain designs

As final objective of the supply chain design a fully integrated Supply Chain design had to be delivered. An overview of the focus areas can be seen in Figure 23 below. The specific deliverables as required by the SC phase gate model at gate 3 is furthermore listed below:

- Ensure alignment between business, project and supply chain strategies
- Development of the Supply Chain Operating Model
- Development of alternatives for detail development
- Environmental analysis of factors that influence the supply chain (business, regulatory, infrastructure etc
- Development of the inbound (direct and indirect) supply chain solution (infrastructure, sourcing, logistics, storage)
- Development of the on-site supply chain solution (infrastructure, logistics, material handling)
- Development of the outbound (products, waste streams) supply chain solution (infrastructure, sourcing, logistics, storage, product handling)
- Identification and management of cross-functional, cross BU interaction and impacts
- Economic modelling
- Risk Assessment

Figure 23: Integrated Supply Chain



Source: (Gebhardt, Olivier & Visser 2011:15)

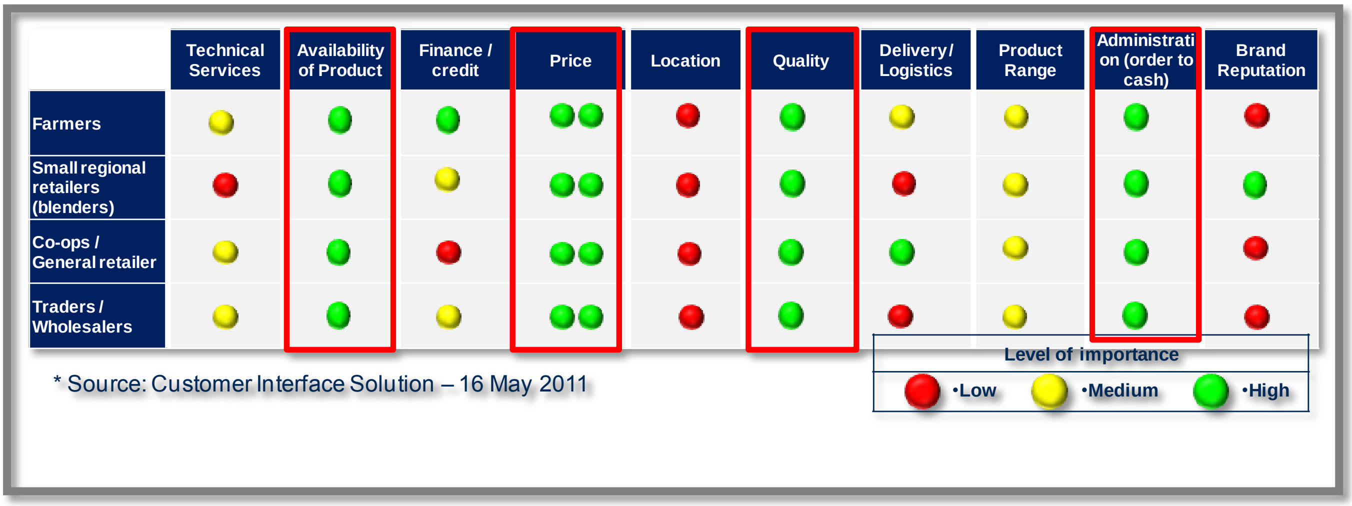
5.2.2 Supply chain strategies

The supply chain strategy is based on the business DNA survey conducted in 2009 as well as the customer interface solution study that was conducted in May 2011. The new product's supply chain strategy is part of the greater business unit supply chain strategy, and therefore, the objective was to identify deviations, if any, from the greater strategy as opposed to developing a new strategy. (Rossouw 2009:4)

Just like the current products, the new product is a typical commodity item driven by market price in securing market advantage over competitors. Apart from cost however, Sasol has control over product quality and availability which increases its market competitiveness. This notion was confirmed by the Customer Interface Solution study, the results of which can be seen in Figure 24 below. The supply chain has a direct influence on all three factors, which makes a proper supply chain strategy and design imperative. Based on two attributes, relationship with customer and predictability of demand, two marketing groups were identified by Sasol Marketing. They are high volume (contract) customers and low volume customers. Sasol therefore have a close relationship with their high volume customers allowing Sasol to better predict their demand, which furthermore allows for better planning.

Low volume customers on the other hand have varied demand, although at smaller volumes. The uncertainty in demand will have to be managed though market intelligence and statistical forecasting methods. (Rossouw 2009:8)

Figure 24 Customer Perception: Drivers of Purchase

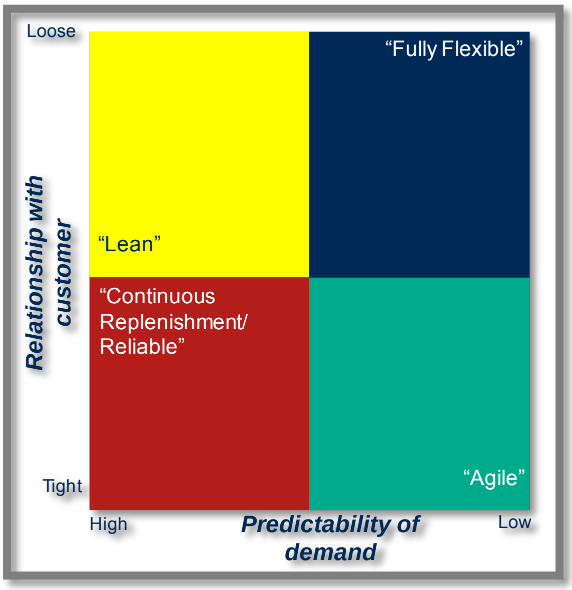


(Rossouw 2009:10)

Based on the planning and marketing strategies matrix shown below in Figure 25, a reliable strategy should be employed for high volume/contract customers, while a flexible strategy is required for low volume customers to achieve high customer service levels. It is important to note, that even though the marketing strategies might differ, product quality and service level does not. The reliability strategy will require Sasol to ensure product availability, even at a higher cost. Storage as well as loading capacity is of high importance for the reliability strategy. A high safety stock level will therefore be required. The flexible strategy will require Sasol to keep lead times as low as possible, requiring them to reserve equipment capacity should demand arise unexpectedly. (Gebhardt, Olivier & Visser 2011:14)

By analysing a breakdown of the existing Sasol customers and their volumes required in comparison to total demand it can be seen that customers classified as low volume customers only account for approximately 20% of total demand. Because of the low volumes, the variable and uncertain demand of the low volume customers can be serviced with the safety stock kept for the high volume customers. The reliability strategy is therefore to cater for both marketing channels. (Gebhardt, Olivier & Visser 2011:14)

Figure 25: Planning and marketing strategies based on marketing group



Source: Gebhardt, Olivier & Visser (2011:14)

5.2.3 Direct Supply chain design

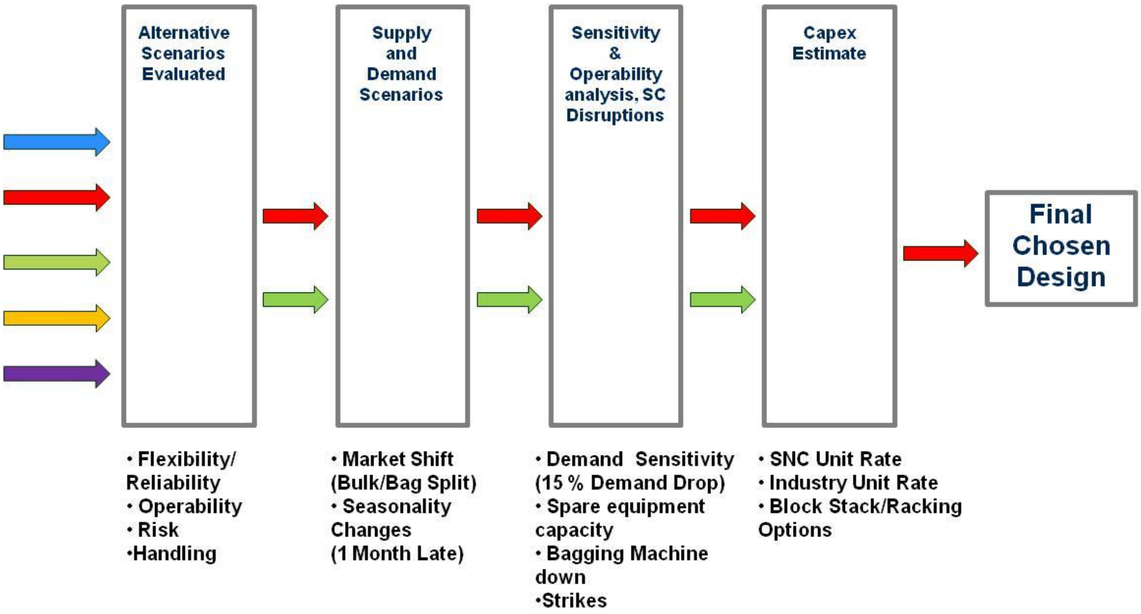
The direct supply chain is the part of the supply chain from when; the raw materials are acquired, the product is manufactured or produced, value is added to these products through either being stored in bulk or packaged and stored as a bagged product in the store. (Min, H.; Gengui, Z.; 2002:231) The design methodology followed can be seen in Figure 26. The first step was to evaluate the alternative scenarios based on their flexibility, reliability, perceived risk, and handling requirements. A matrix, see Table 6 below, was used to evaluate each attribute using low, medium and high ratings. Since demand information cannot be determined with 100% accuracy, a flexible design is required to achieve reliability. (Gebhardt, Olivier & Visser 2011:17)

Table 6: Design alternatives rating matrix

Design	Flexibility/ Reliability	Handling	Risk
Direct bagging	Low	Medium	High
Silo bulk outloading	High	Low	Low
Traditional bulk outloading	High	Medium	Low
No direct bulk store link	Low	Medium	Medium
Existing bag store used	Low	High	High

Source: Gebhardt, Olivier & Visser (2011:17)

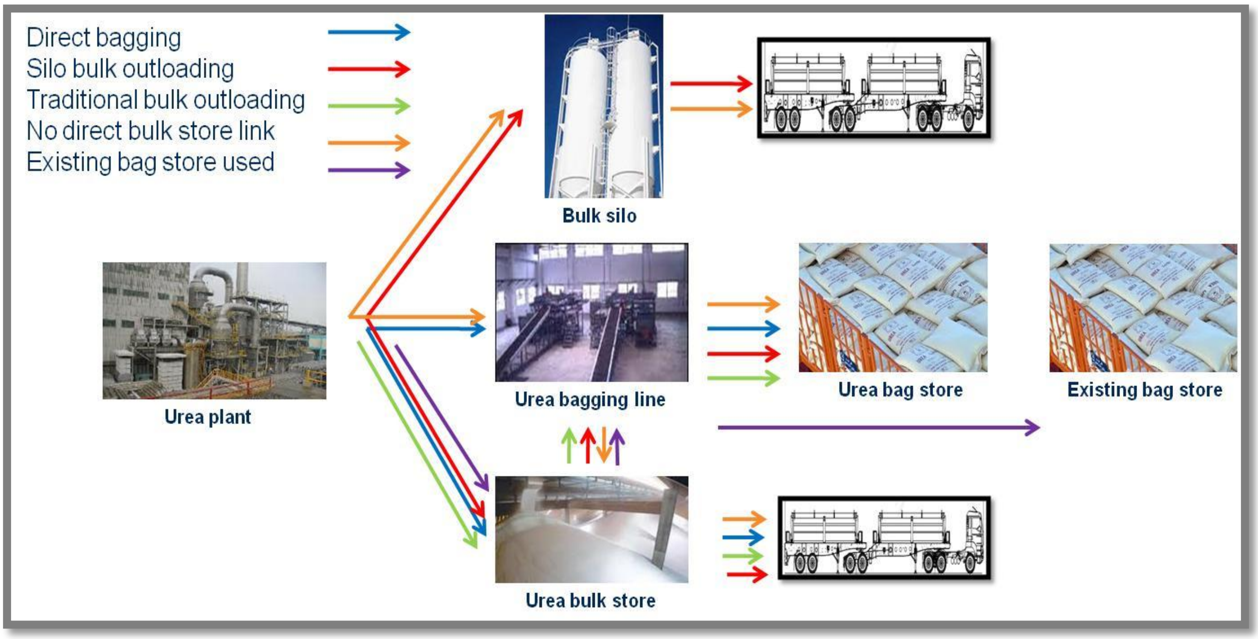
Figure 26: Design methodology



Source: Gebhardt, Olivier & Visser (2011:14)

The different designs considered for the direct supply chain can be seen in Figure 27 below. Each design differs in terms of the flexibility and reliability it offers, the capital cost involved, the amount of product handling that is required and the level of risk of the design.

Figure 27: Different supply chain alternative designs



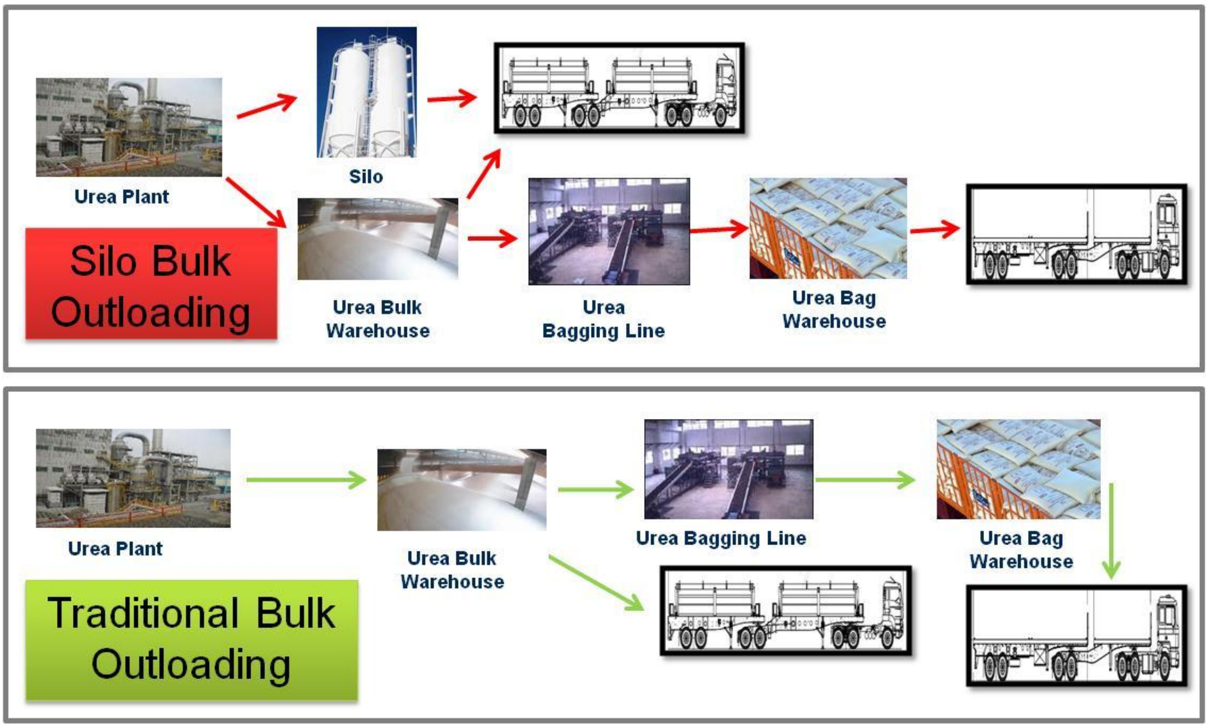
Source: Gebhardt, Olivier & Visser (2011:18)

Based on the baseline models that was created for each of the scenarios, two designs ("Silo bulk outloading" and "Traditional bulk outloading") were chosen to be analysed in further detail out of the five alternative designs for the direct supply chain. The basis for choosing these two designs were done by comparing the capital cost, flexibility, reliability, handling and risk. These two designs showed the most favourable results for as shown in Table 6, both chosen designs involve less risk when compared with other designs and also allows for a more flexible and reliable supply chain designs. The capital cost comparison is shown in Table 7 below. The reason for choosing the silo option is that extra flexibility is given to the system. The designs can be seen in further detail in Figure 28 below. (Gebhardt, Olivier & Visser 2011:16-20)

The design: Silo bulk outloading; makes use of a silo to unload bulk product. The reason for the silo is to firstly minimize material handling, and secondly to increase peak season unloading rates. The design: Traditional bulk outloading; is identical to the current product line's supply chain where product produced by the current plant, is sent to the bulk store and then either bagged or sold as bulk depending on demand. (Gebhardt, Olivier & Visser 2011:19)

The two designs that were chosen as the best alternatives to be evaluated further, S*ilo bulk outloading* and *Traditional bulk outloading*. The other three designs were excluded due to incompatibility of storage of current and future products as well as the high supply chain costs involved moving the finished products to nearby storage facilities. The effects of different supply and demand scenarios on the two designs were furthermore tested. Sensitivity analysis was then performed on the chosen designs by looking at market shifts (bulk/bag splits), seasonality changes, demand changes (demand drop) and supply chain disruption were factored in. Warehouses were sized such that they are flexible with regards to market demand (bulk/bag split) while keeping the design cost at an acceptable level. The capital cost of each design was finally determined using different costing scenarios. (Gebhardt, Olivier & Visser 2011:16-20)

Figure 28 Chosen design options in detail



Source: Gebhardt, Olivier & Visser 2011:18

Table 7 High-level Baseline results for all alternative supply chain designs

Baseline for alternative designs - High Level Cost Model									
		Bag Storage (tons)	*Bulk Storage (tons)*		*Bagging line output (tons/day)*	*Bag Storage cost*	*Bulk Storage cost*	*Bulk silo cost*	**Total**
EPCM design - Base Case		20000	20000		720	R 38 580 000	R 33 000 000		R 71 580 000
		Capacity required				**Cost**			
	Actual Bag store	*Bag Storage (tons)*	*Bulk Storage (tons)*		*Bagging line output (tons/day)*	*Bag Storage cost*	*Bulk Storage cost*	*Bulk silo cost*	**Total**
Direct bagging ***Base Case***	11 128	9273	17000		720	R 21 465 140	R 28 050 000		R 49 515 140
		Capacity required				**Cost**			
		Bag Storage (tons)	*Bulk Storage (tons)*	*Silo*	*Bagging line output (tons/day)*	*Bag Storage cost*	*Bulk Storage cost*	*Bulk silo cost*	**Total**
Silo bulk outloading ***Base Case***	4 366	3638	17000	4737	720	R 8 421 242	R 28 050 000	R 21 529 665	R 58 000 907
		Capacity required				**Cost**			
		Bag Storage (tons)	*Bulk Storage (tons)*	*Silo*	*Bagging line output (tons/day)*	*Bag Storage cost*	*Bulk Storage cost*	*Bulk silo cost*	**Total**
Traditional bulk outloading ***Base Case***	9 284	7737	17000	0	720	R 17 909 608	R 28 050 000		R 45 959 608
		Capacity required				**Cost**			
		Bag Storage (tons)	*Bulk Storage (tons)*	*Silo*	*Bagging line output (tons/day)*	*Bag Storage cost*	*Bulk Storage cost*	*Bulk silo cost*	**Total**
No direct bulk store link ***Base Case***	5 935	4946	17000	4737	720	R 11 449 001	R 28 050 000	R 21 529 665	R 61 028 666
		Capacity required				**Cost**			
		Bag Storage (tons)	*Bulk Storage (tons)*		*Bagging line output (tons/day)*	*Bag Storage cost*	*Bulk Storage cost*	*Bulk silo cost*	**Total**
Existing bag store used ***Base Case***	Not feasible due to safety concerns and capacity constraints in existing store								

Source: Gebhardt, Olivier & Visser (2011:19)

5.2.4 Integrated Supply Chain

One of the main advantages of using a phase gated approach to assist with the design is that it helps that important detail can't be overlooked due to the systematic process approach. This became evident as the engineering consultants neglected to include storage considerations for the process chemicals that would be required in the manufacturing process and which turned out to have a big impact as new infrastructure; namely storage tanks, were required which was excluded in the engineering consultants' design. Also the placement of the expanded existing bagged store was not feasible due to underground mining operations with makes it impossible to expand existing store. (Gebhardt, Olivier & Visser 2011:18)

The feedstock to the manufacturing facility was constant and was also modelled accordingly. An initial assumption was made, by the engineering consultants, that the same pallets and bags should be used to standardise across the plant. Due to the difference in density between the current and future products, the project team realised that different bags and pallets should be used in order to get the optimal number of tons per square meter. By introducing a new bag and pallet that can be sourced from the current suppliers led to a saving of 30% in space. This also came in useful as the option of racking was also investigated over the current practise of block stacking, which lead to further reductions in the overall footprint of the warehouse. The physical site layout was also challenged as the EPCM made use of unnecessary long and complex conveyor systems that was found to be expensive unpractical and would require a lot of maintenance due to the corrosive nature of the products and geographical nature of the site involved. (Gebhardt, Olivier & Visser 2011:20)

5.2.5 Network model

A network model was developed using i2 Strategist. i2 Strategist is a software package that allows its user to solve complex linear program problems, in essence optimizing an object function given a set of constraints and requirements as mentioned in chapter 3. In project Spud's case the objective was to determine the optimal storage requirements for bulk and bagged product stores. The solution had to minimise CAPEX and optimise the storage to increase flexibility. Scenario testing was furthermore conducted to derive the most optimal solution given expected scenarios. (Gebhardt, Olivier & Visser 2011:19-20)

5.2.5.1 **Network model assumptions**

Assumptions were obtained from the technical and business tracks that were used in the model's development. The assumptions can be seen below in Table 8. Figure 29 shows the demand, according to the months of the year, experienced. The graph starts off with the month of July and ends at June to be aligned to the financial year in Sasol.

Figure 30 below is an overview of the figures involved in the analysis. Total demand exceeds supply four months per year. In order to be able to supply product during those four months, inventory must be built up. The aim therefore is to build up just enough stock during the low season to ensure demand can be met in the peak season, while minimizing the required storage space. The bagging line's instantaneous capacity furthermore, is almost just as high as the maximum instantaneous product demand, which indicates that the supply chain should be operated on a pull basis for the majority of the year, only pushing for stock to be built up leading up to the peak season. This strategy will furthermore allow for the majority of inventory to be stored in bulk, which is cheaper than storing product in bagged product stores. (Gebhardt, Olivier & Visser 2011:21)

Table 8: Network Model Assumptions

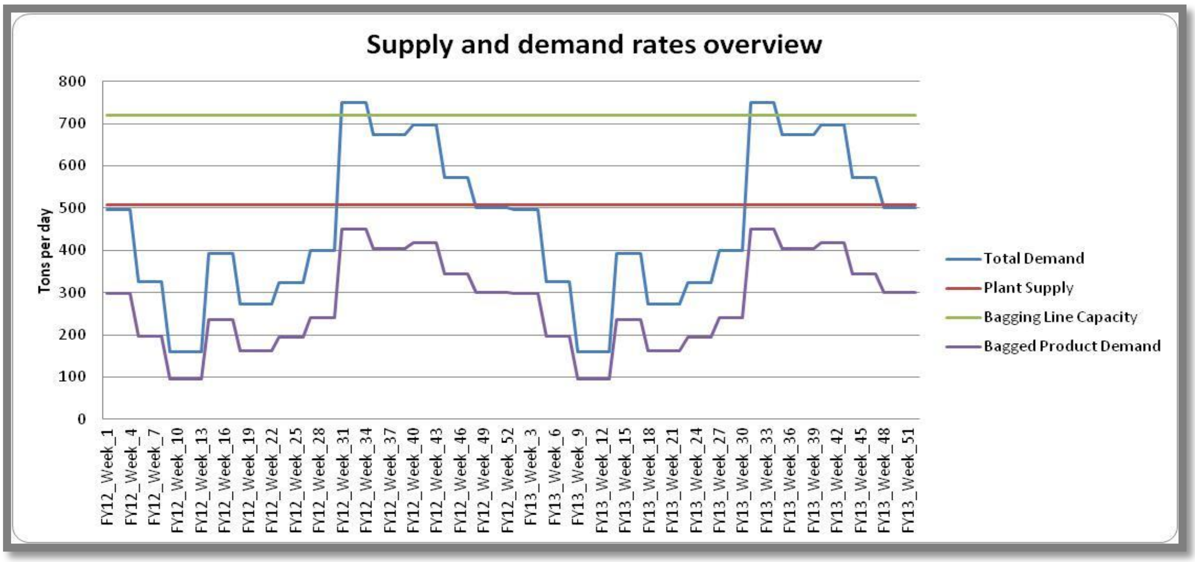
	Area	Assumption
1	Urea Plant	508 ton/day production capacity, 24hours/day, 340 days/year operation
2	Bulk Product Store	Currently 20 000 ton capacity, but could potentially be enlarged
3	Bagging Line	60 ton/hour nameplate capacity, 12 hours per day operation
4	Bagged Product Store	No size constraint. Minimum size required by business of 3500 tons
5	Total Product Demand	Demand curve the same as existing product's demand curve (see Figure 27 below)

Source: Gebhardt, Olivier & Visser 2011:19

Figure 29: Existing product demand vs new product demand

Source: Gebhardt, Olivier & Visser 2011:19

Figure 30: Supply and demand rates overview



Source: Gebhardt, Olivier & Visser 2011:20

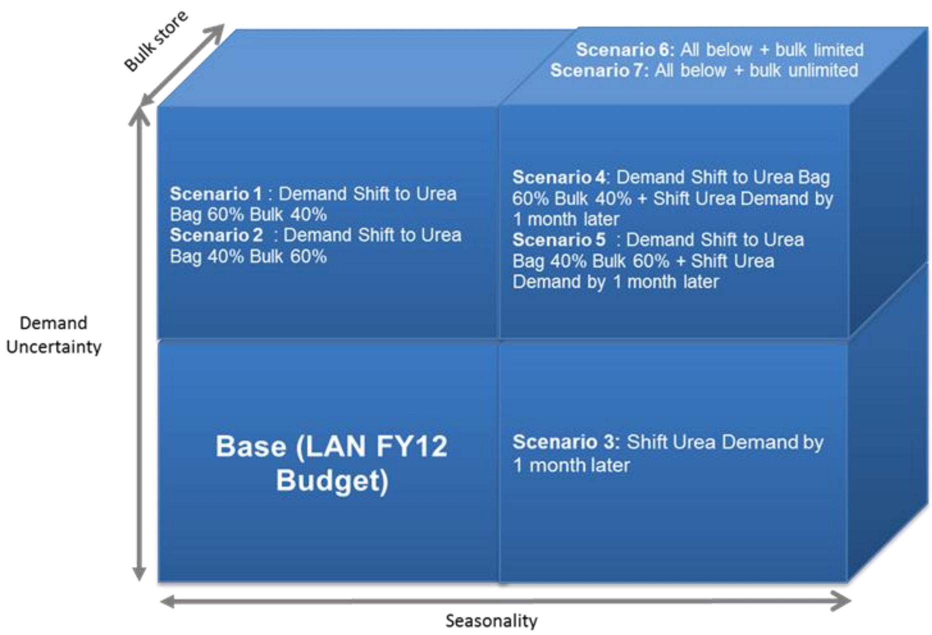
5.2.5.2 **Scenario analysis**

Various different scenarios were tested in order to represent realistic events that might influence the supply chain and in effect the storage requirements of bulk and bagged product. The scenarios are based both on expert experience and future expectations given the product's market and its customer base. (Gebhardt, Olivier & Visser 2011:22)

5.2.5.3 **Supply and demand scenarios**

Figure 31 below illustrated the different supply and demand scenarios tested. Scenarios included high bag (60% of total production sold as bagged product), high bulk (60% of total production sold as bulk product), demand shifting with 1 month for each of the above mentioned scenarios and also having a limited bulk storage versus having unlimited bulk storage for all the mentioned scenarios. It was determined that should the bulk store be limited to a certain size, the network model is not optimal compared to when the bulk store's size is not limited. All scenarios were therefore by default testing with the underlying assumption that scenario 7 was applicable. Scenario 4 and 5 furthermore was deemed to be more realistic than scenario 3 and therefore, scenario 3 was not used further. (Gebhardt, Olivier & Visser 2011:20-22)

Figure 31: Supply and demand scenarios tested



Source: Gebhardt, Olivier & Visser 2011:21

The results obtained from the supply and demand sensitivity analysis can be seen below in Table 9 and Table 10.

5.2.5.3.1 Silo bulk outloading:

If only market shifts were catered for (scenario 1 and 2), the bulk store would have to had to have enough capacity for 24 458 tons of product. If seasonality changes are taken into account additional to market shifts (scenario 4 and 5), the bulk store will need to have enough capacity for approximately 30 445 tons of product. The 30 000 ton bulk store mark is however only surpassed one week a year and therefore, by catering for space for 30 000 tons of product, sufficient space will be available 98% of the year. The silo bulk outloading design's bag store is unconstrained. A minimum size of 3 500 tons is required by business, and as such, the model's result is 3500 tons as well. The design lastly makes use of a silo with a 500 ton capacity. (Gebhardt, Olivier & Visser 2011:23)

5.2.5.3.2 Traditional bulk outloading:

If only market shifts were catered for (scenario 1 and 2), the bulk store would have to had to have enough capacity for 28 458 tons of product. If seasonality changes are taken into account additional to market shifts (scenario 4 and 5), the bulk store will need to have enough capacity for approximately 30 945 tons of product. The 30 000 ton bulk store mark is however only surpassed one week a year and therefore, by catering for space for 30 000 tons of product, sufficient space will be available 98% of the year. The traditional bulk outloading design's bag store requires a 5 000 ton bagged product store in order to have enough space 94% of the year. (Gebhardt, Olivier & Visser 2011:21-23)

In order to ensure that stores do not overflow, stock levels will have to be monitored and actively managed as is currently the practice.

Table 9: Silo bulk outloading design network model results

	Results				
	Silo bulk outloading			Bulk Store	
Scenario Tested	Bulk Storage	Silo Storage	Bag Storage	No of weeks when inventory will exceed 28000 tons	No of weeks when inventory will exceed 30000 tons
Scenario 1: High Bag	23458	500	3500	0	0
Scenario 2: High Bulk	24458	500	3500	0	0
Scenario 4: High Bag + 1 Month Shift	30445	500	3500	2	1
Scenario 5: High Bulk + 1 Month Shift	28782	500	3500	2	0

Source: Gebhardt, Olivier & Visser 2011:22

Table 10: Traditional bulk outloading network model results

	Results					
	Traditional bulk outloading		Bulk Store		Bag Store	
Scenario Tested	Bulk Storage	Bag Storage	No of weeks when inventory will exceed 28000 tons	No of weeks when inventory will exceed 30000 tons	No of weeks when inventory will exceed 4500 tons	No of weeks when inventory will exceed 5000 tons
Scenario 1: High Bag	27958	5560	0	0	5	3
Scenario 2: High Bulk	28458	4834	1	0	2	0
Scenario 4: High Bag + 1 Month Shift	30445	5265	2	1	4	2
Scenario 5: High Bulk + 1 Month Shift	30945	4407	2	1	0	0

Source: Gebhardt, Olivier & Visser 2011:22

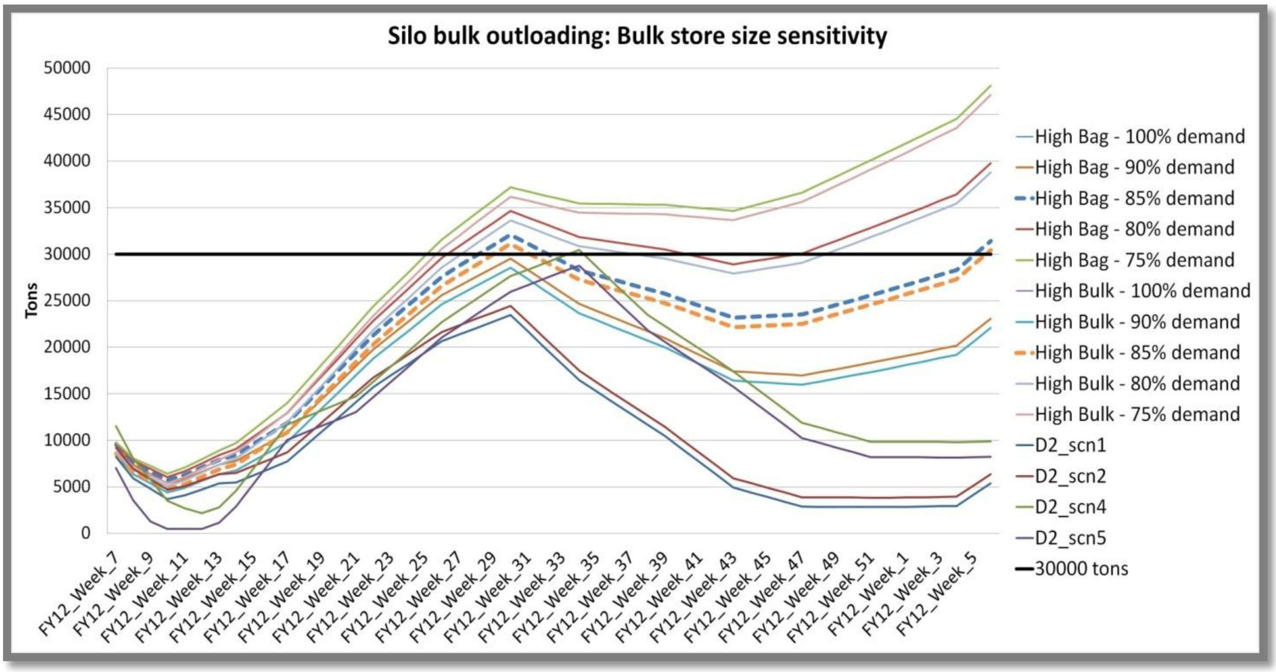
5.2.5.4 **Demand sensitivity**

Sensitivity analyses were conducted to assess how the network model and therefore the network model's results will react to changes in product demand. Because the warehouses act as a buffer against the variance of demand, product demand has the single biggest influence on the final size chosen by the network model

The warehouses in both designs act as a buffer against the variance of demand. Product demand therefore has the single biggest influence on the final size chosen by the network model. By dropping the demand by 10%, 15%, 20% and 25% respectively, the effect of demand on the required bulk and bagged product storage space could be singled out and determined. A business decision would need to be made to decide for which level of risk, drop in demand, the supply chain would have to cater for. For this study, the assumption was made that the supply chain would cater for up to 15% drop in demand. It was found that an increase in demand lowered the required stock levels as the instantaneous bagging capacity is sufficiently high to bag just in time. The low stock level resulted in a smaller warehouse, and as such, was not considered in detail. (Gebhardt, Olivier & Visser 2011:23-24)

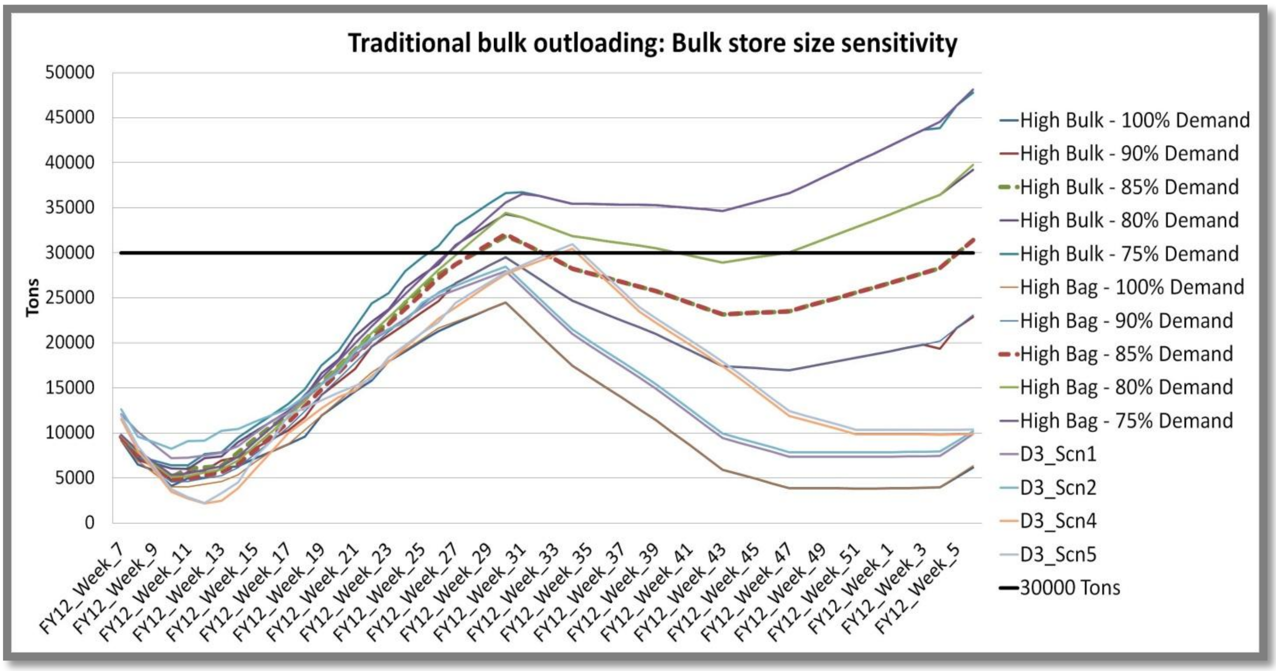
From Figure 32 and Figure 33 below, it can be seen that both design's supply chains would be able to handle a 15% drop in demand 90% of the year if the bulk store was able to store 30 000 tons bulk product. The same results can be seen in tabular form in Table 11 and Table 12 below. (Gebhardt, Olivier & Visser 2011:23)

Figure 32: Silo bulk outloading: Bulk store's sensitivity to demand drop



Source: Gebhardt, Olivier & Visser 2011:23

Figure 33: Traditional bulk outloading: Bulk store's sensitivity to demand drop



Source: Gebhardt, Olivier & Visser 2011:23

The results further more indicate that even if demand drops by 15%, the silo bulk outloading design would be able to cater for bagged product demand with a 3 500 ton bagged product store. The traditional bulk outloading design would be able to cater for bagged product demand 94% of the year with a 5 000 ton bagged product store.

Table 11: Silo bulk outloading network model results tested for sensitivity

	Sensitivity analysis Silo bulk outloading - High Bulk			Bulk Store	
% of full demand	Bulk Storage	Silo Storage	Bag Storage	No of weeks when inventory will exceed 28000 tons	No of weeks when inventory will exceed 30000 tons
90.00%	28550	500	3500	1	0
85.00%	31095	500	3500	8	3
80.00%	38775	500	3500	32	20
75.00%	47125	500	3500	34	33

	Sensitivity analysis Silo bulk outloading - High Bag			Bulk Store	
% of full demand	Bulk Storage	Silo Storage	Bag Storage	No of weeks when inventory will exceed 28000 tons	No of weeks when inventory will exceed 30000 tons
90.00%	29550	500	3500	3	0
85.00%	32095	500	3500	11	5
80.00%	39775	500	3500	33	26
75.00%	48125	500	3500	34	33

Source: Gebhardt, Olivier & Visser 2011:24

Table 12: Traditional bulk outloading network model results tested for sensitivity

	Sensitivity analysis Traditional bulk outloading - High Bulk		Bulk Store		Bag Store	
% of full demand	Bulk Storage	Bag Storage	No of weeks when inventory will exceed 28000 tons	No of weeks when inventory will exceed 30000 tons	No of weeks when inventory will exceed 4500 tons	No of weeks when inventory will exceed 5000 tons
90.00%	29512	4508	3	0	1	0
85.00%	31822	5048	11	5	1	1
80.00%	39199	4473	33	26	0	0
75.00%	47791	4746	37	35	3	0

	Sensitivity analysis Traditional bulk outloading - High Bag		Bulk Store		Bag Store	
% of full demand	Bulk Storage	Bag Storage	No of weeks when inventory will exceed 28000 tons	No of weeks when inventory will exceed 30000 tons	No of weeks when inventory will exceed 4500 tons	No of weeks when inventory will exceed 5000 tons
90.00%	29550	5598	0	0	7	3
85.00%	32095	5765	11	5	18	3
80.00%	39775	5932	34	33	22	11
75.00%	48125	6099	34	33	23	20

Source: Gebhardt, Olivier & Visser 2011:24

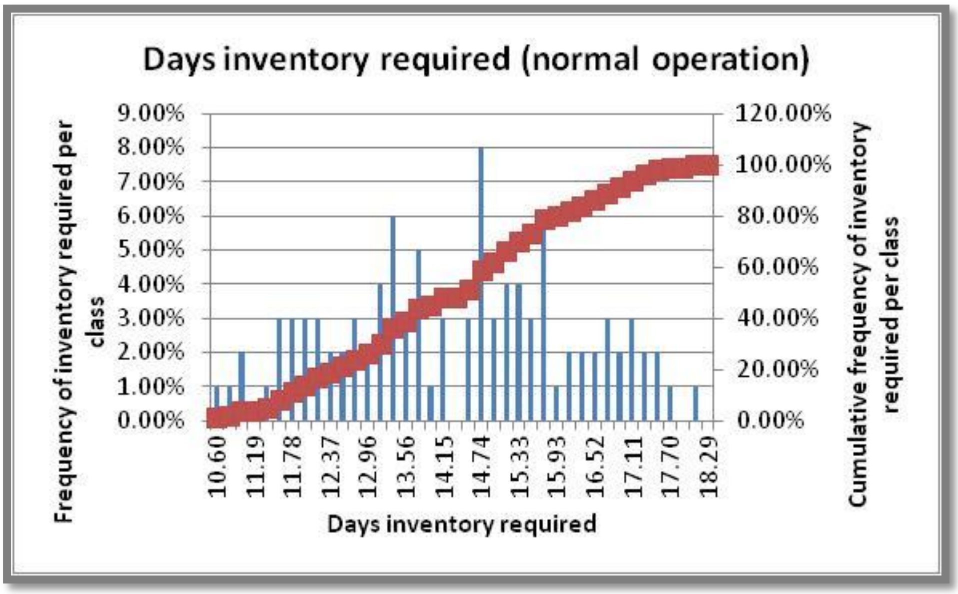
5.2.5.5 **Other analysis**

5.2.5.5.1 Inbound Supply Chain:

5.2.5.5.1.1 Process Chemicals

UFC-85, a chemical that contains Formaldehyde which is used in Urea production, is the only process material used. Approximately 1 390 ton/year UFC-85 will be required, and is readily available from local suppliers. The results of the statistical model indicate that a tanks size of at least 50 m^3, space for approximately 17 days' inventory, will be required which will cater for the 8.66 days turnaround time and a further buffer of 8.4 days which is to cater for variability and supply chain disruptions. The model's output can be seen in Figure 36 below. (Gebhardt, Olivier & Visser 2011:38-42)

Figure 34: UFC-85 tank size statistical model



Source: Gebhardt, Olivier & Visser 2011:43

5.2.5.5.1.2 Packaging Material

New block bottom bags must be introduced due to size restrictions of pallets. A supplier was found already registered on Sasol's vendor list. Unit cost per bag is 10% more expensive than bags currently used to bag the existing product. As block bottom bag technology needs to be confirmed for Project Spud's use, traditional bagging equipment costs, which is more expensive, was used to determine the capital estimate. Bagging Material opex is expected to be ~R6.6 million/ year. Semi-bulk product is to be bagged in the same bags as is currently used by LAN. Bagging support material is to be procured from existing suppliers. (Gebhardt, Olivier & Visser 2011:43)

5.2.5.5.1.3 Pallets

Pallets will be procured from current suppliers. An initial nine month supply will be needed to build a pool of pallets, after which pallets will be replaced as required. This once off cost will be approximately R7.2 million while opex is expected to be ~R2.9 million/year**.** (Gebhardt, Olivier & Visser 2011:43)

5.2.5.5.1.4 MRO Material

MRO material will be managed and stored utilising the central warehousing infrastructure of Shared Services. A potential risk identified is the requirement for equipment to a large extent to be constructed of stainless steel due to the corrosive nature of the product. This could have an impact on the cost and availability of spares. Two year's spares are to be procured before the plant is commissioned. (Gebhardt, Olivier & Visser 2011:44)

5.2.5.5.2 On-site Logistics and Infrastructure:

5.2.5.5.2.1 Traffic flow

The south gate and weighbridge, close to the site, is to be used by customers for both incoming and outgoing traffic. Trucks will be scheduled using Renaissance as operated by the logistical operation centre (LOC). (Gebhardt, Olivier & Visser 2011:44)

5.2.5.5.2.2 Bag/Bulk/Semi-Bulk loads

Both block stacking and pallet racking were investigated by this study. Pallet racking is the preferred option. Existing pallets will be used which supports Sasol's site-wide pallet uniformity. Pallets can however only be stacked with 1.5 tons product because of pallet rack height restrictions and therefore stacks will be smaller. Since trucks load in 1.5 ton multiples, trucks will at a maximum be able to load 33 tons instead of 34 tons. The increased number of pallets will still fit on a truck, with the load spread over a larger area. The new product's density is furthermore higher than the current product, necessitating special bags and bagging equipment in order for bags to fit on the existing pallets. The special bags, block bottom bags, and machine are currently used in Sasol, and according to literature and suppliers can be used for the new product, but will need to be tested by Sasol. Since the technology has not yet been confirmed, the EPC's cost estimate for the bagging machine, palletizer and wrapper was used in the SC cost estimate. A last potential option identified is to utilize existing bagging technology used within Nitro, and by making certain adjustments, convert the equipment to bag block bottom bags. A trial study will need to be conducted to test the effectiveness and operability of such a system, which according to the equipment supplier is completely possible. Bulk product and semi-bulk product will be handled similar to the current product. (Gebhardt, Olivier & Visser 2011:44-45)

5.2.5.5.2.3 Site Layout

Physical space restrictions, space requirements, underground mining activity, traffic flow and warehouse best practices were taken into account to determine the optimal site layout. (Gebhardt, Olivier & Visser 2011:45)

5.2.5.5.2.4 Material Handling Equipment

Front end loaders (FEL), used at the bulk store, will be owned and maintained by Sasol, but operated by the LOC. One front end loader and four drivers will be required to operate a 24 hour operation at the bulk warehouse. (Gebhardt, Olivier & Visser 2011:45)

5.2.5.5.2.5 Outbound Supply Chain:

The analysis of the SC did not include a delivery model as the assumption was made to sell ex works like the existing product. The outbound logistics that have been catered for by the study include analysis of traffic flow, turning circles, vehicle sizes and scheduling. (Gebhardt, Olivier & Visser 2011:45)

5.2.5.5.2.6 Off Streams

Of the three off streams, process condensate, 35% AN solutions and cooling tower purge, both process condensate and 35% AN solution will be recycled in the production process with only cooling tower purge supplied to Sasol Waste Water treatment plant via pipe. (Gebhardt, Olivier & Visser 2011:45)

5.2.5.5.2.7 Supply Chain Enablers:

The current Sasol functional operating model is to be followed; while a product SC specific functional delivery model was developed. The LOC will be responsible for a large part of the material handling functions, while Sasol shared services will conduct procurement management, supply and demand management, master data management, MRO inventory management, and MRO warehouse management. (Gebhardt, Olivier & Visser 2011:45)

5.2.5.5.2.8 Risk Management:

Major applicable regulatory and legal standards have been identified. The new product is not classified as a hazardous material and does not pose any environmental risk. It can therefore be handled according to the standard current handling and safety procedures. The new product should however not to be stored with existing products as spillage and contamination can lead to an explosion. Urea Formaldehyde Concentrate (UFC-85), a feedstock in the production process, is a combustible liquid that poses health risks if exposed to and should be handled appropriately. Formaldehyde, a component of UFC-85, is regarded very hazardous. Containment measures, by means of bund walls and vapour recovery lines, are required. (Gebhardt, Olivier & Visser 2011:45)

5.3 Results of Study

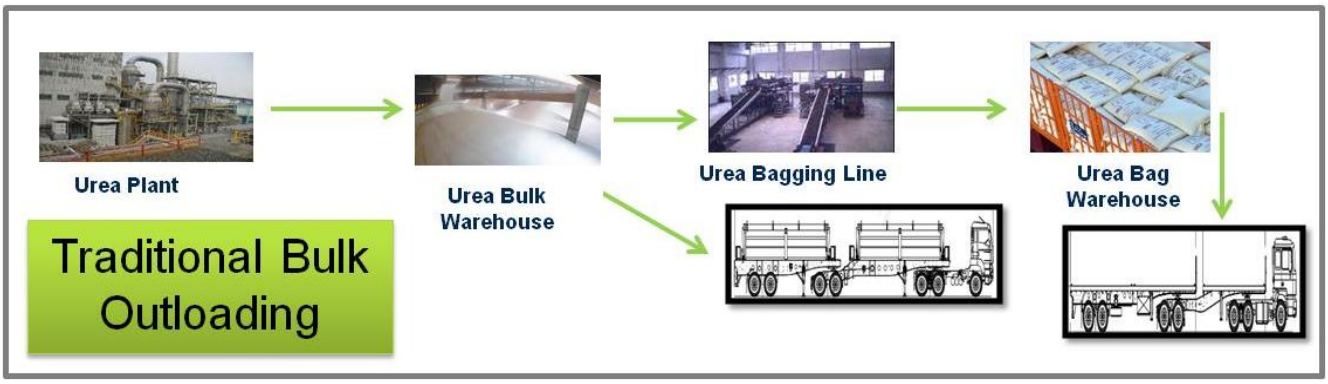
Even by having more capacity, the model showed a reduction, as shown in Figure 36, of 44.5% in the total CAPEX cost of the SC compared to the engineering consultant's initial designs and a reduction in OPEX cost because the stock is kept in the bulk form until bagged product is needed. There were also determined that some major areas were over looked. The process chemicals needed tanks to be stored in due to the delivery lead time and the quantities required, also the engineering house did not cater for packaging material store. All these costs were included in the study's cost. A benchmarking study was also conducted to determine unit rates normally used in the warehousing industry for the same order of accuracy cost estimates. As can be seen in figures 35 and 36, using industry unit rates has the potential to decrease the direct SC capital estimate by a further 3%.

5.3.1 Proposed direct supply chain design

It was identified during a late stage of the project that the silo bulk outloading design will not be feasible due to technical constraints. The product will exit the production plant at approximately 50 °C and would need to cool down before it can either be loaded into a silo or bagged. This cool down period is necessary to ensure that the product granules do not form lumps (also known as caking). Since allowing the product to cool in the bulk store before being moved to a silo would entail double handling, it would counteract the silo's objective of reducing material handling.

The direct supply chain design using traditional bulk outloading methods are therefore the proposed design. The traditional bulk outloading design with its specific requirements can again be seen below in Figure 35:

Figure 35: Proposed direct supply chain design

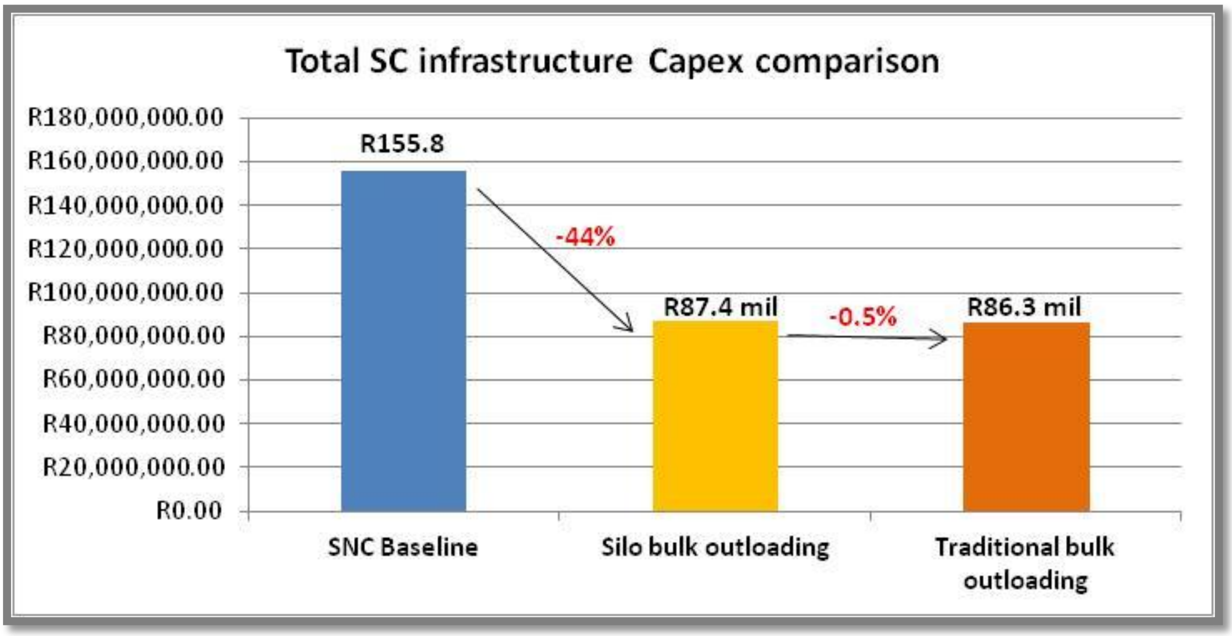


Source: Gebhardt, Olivier & Visser 2011:32

- Bulk Store: 30 000 tons
- Bag Store: 50 00tons
- Semi-Bulk Store: 500 tons
- Total Direct Supply Chain Infrastructure Capex: ~R86.3 million

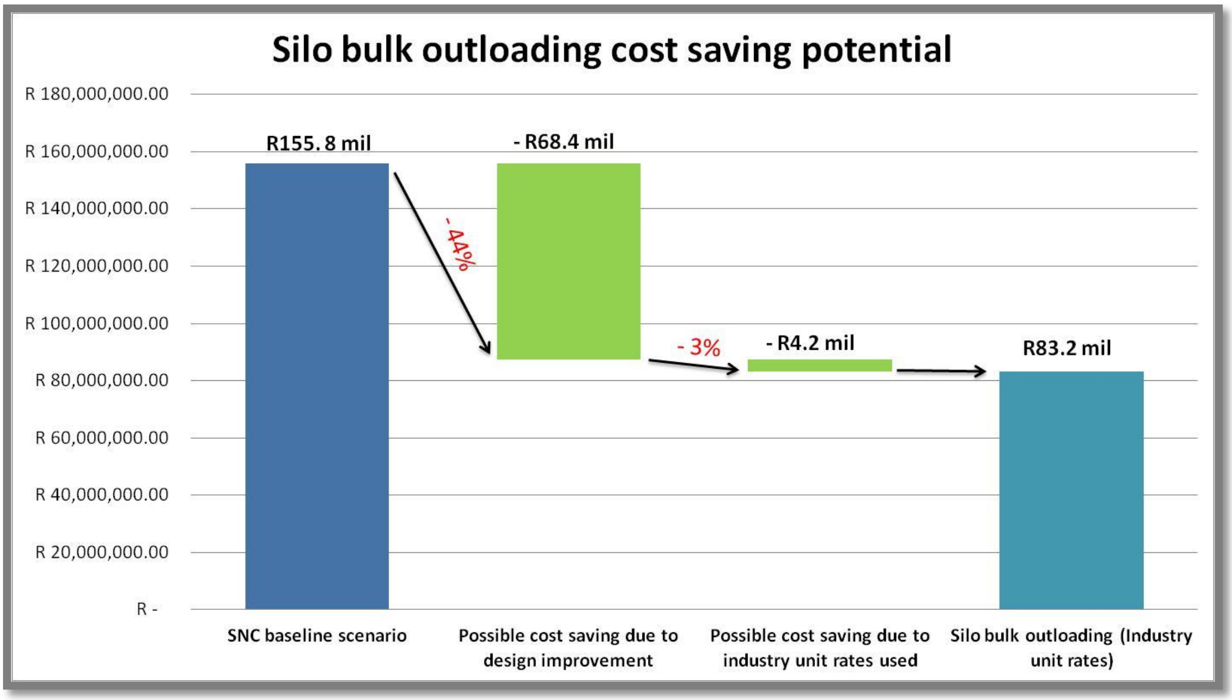
This study confirmed that by doing proper strategic planning, integrated supply chain design and by incorporating multiple forecasts by linear programming models, not only capital and operational expenditure can be reduced but also the right capacities for the supply chain's needs can be determined and to create a flexible and reliable supply chain suiting the objectives.

Figure 36: Supply chain design cost using i2 vs EPCM costs



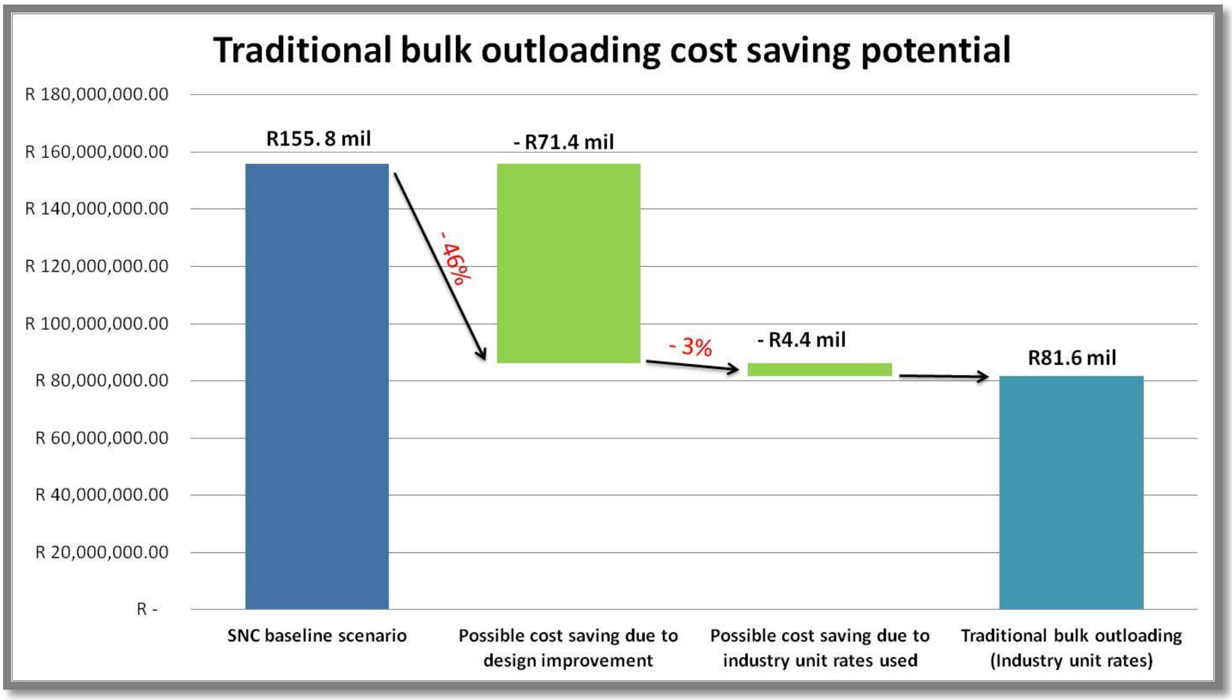
Source: Gebhardt, Olivier & Visser 2011:30

Figure 37: Model results scenario 1



Source: Gebhardt, Olivier & Visser 2011:31

Figure 38: Model results scenario 2



Source: Gebhardt, Olivier & Visser 2011:31

5.4 Applying the theory from the study on a practical example: Brownfield case study

The second case study that the study will be looking at required a totally different approach due to it being a brownfield project. Yet the same supply chain design principles, from the study, will be demonstrated to be flexible enough to cater for both types of projects. This study that will be used as a case study was initiated by the Research and Technology (R&T) business unit in Sasol. They were facing supply chain problems due to the increasing pressures to render a service to the ever expanding Sasol group of companies. Their logistical infrastructure was designed on the basis of rendering a service to the Sasol group of companies across two Sasol production sites. In recent years this has expanded to eight production sites across a large geographical region. This resulted in high storage cost, over procurement, slow customer response times and decreased profit margins. (Gebhardt, Buis & Ratsibe 2013:2)

The supply chain project was redesigned with the scope being; having an optimal supply chain that will enable research to be done quicker, reduce the supply chain costs and to free up time of scientists involved in supply chain processes. (Gebhardt, Buis & Ratsibe 2013:2)

5.4.1 Supply chain design parameters

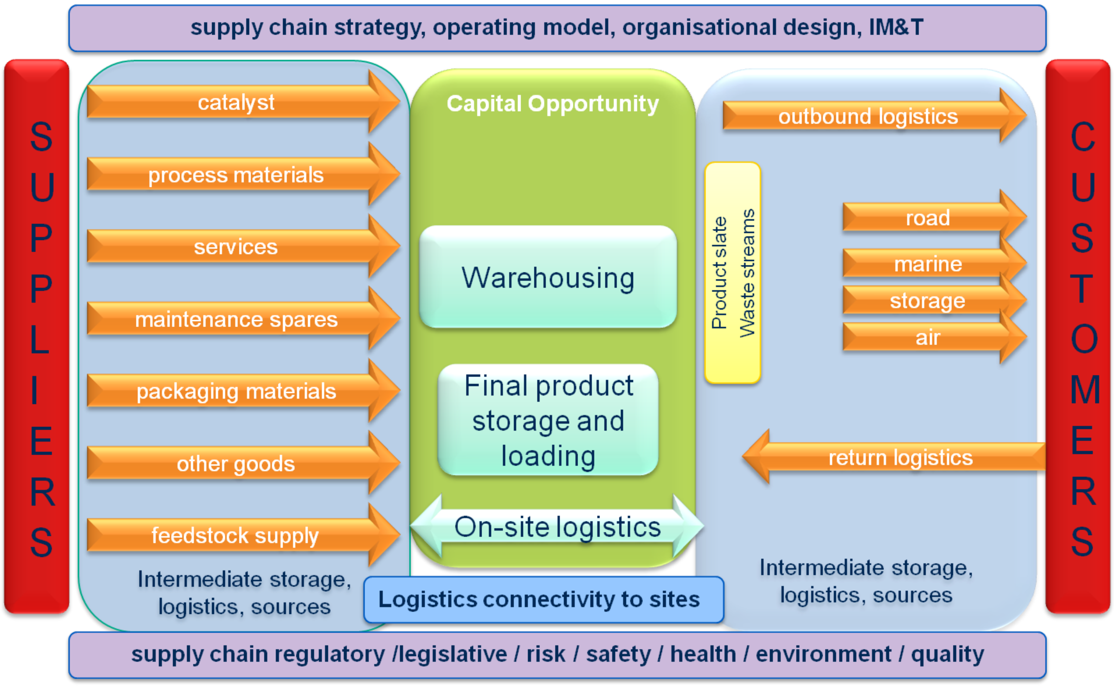
5.4.1.1 Supply chain design objectives

The supply chain redesign objectives were to gain an in-depth understanding of the R & T supply chain in order to identify improvement opportunities that will enable the business.

- Enable R&T supply chain to ensure the business can function optimally.
- Develop supply chain strategy for R&T
- Enable an effective and efficient supply chain.
- Ensure sufficient inventory levels to support the business needs.
- Optimise investments in inventory.
- Identifying critical products to the business.
- Conform to statutory requirements and align to group guidelines.
- Safety regulations in handling, storage and transportation of chemical and hazardous products.
- Identify Supply Chain risk areas.

The integrated supply chain shown in Figure 39 was included in the scope. Inbound, outbound and other supply chain related activities will be used to understand and identify possible improvements.

Figure 39: Integrated generic supply chain



Source: Gebhardt, Buis & Ratsibe (2013:4)

5.4.1.2 **Approach followed:**

Firstly the supply chain strategies were derived from the business strategy. Because of the unique and dynamic environment of all the different areas in R&T it was decided to create supply chain strategies based on the different business areas. Three supply chain strategies were created, a reliable on for the production area, a flexible on for the labs, due to nature of their work, and an agile supply chain for the fuels research business. Because of the extremely vague objectives that were given, a series of interviews was needed to be scheduled with key stakeholders to understand the current challenges and to compile a list of all challenges in R&T supply chain to be addressed throughout the project. The information gathering phase took three weeks in which multiple interviews were conducted with all key stakeholders and a list of all problems experienced were compiled. (Gebhardt, Buis & Ratsibe 2013:6)

Interviews were conducted with senior management, middle management and their subordinates. This helped to compile a detailed list of what the real challenges and the perceived challenges are. Questions were formulated in order to understand the as-is situation, the previous operating model before a redesign done in 2008 left the business in a bad state and also what the desired outcome should look like. Individual interviews as well as group interviews were done to stimulate conversations and to be able to get into the real problem. The group interviews were split into sessions with middle management and separate sessions for their subordinates. This was done as the information received from initial discussions, where middle management and their subordinates were present, was very superficial and the real issues were not being addressed. One-on-one interviews were mainly done with senior management. All the issues were captured and then grouped according to supply chain streams. The root cause analysis were done whereby the results were prioritised to ensure that the key issues be addressed first. After prioritising the root causes to these problems, a list of possible improvements were identified and divided into different streams for the project. The streams that came out of the project were business processes, master data, procurement, inventory, planning and logistics. The different streams were then staggered in order to execute them as efficiently and effectively as possible. (Gebhardt, Buis & Ratsibe 2013:8)

5.4.1.2.1 Master data

Then a data analysis was done on the previous financial year's ERP data in order to gain more insight into what exactly each of the streams' deliverables should be. Problems found were very poor quality data due to the lack of little or no master data; material -, service - and vendor masters not existing. Transactional data were also very poor due to; the lack of training of the end users on how to work on SAP, not understanding the business processes, not understanding the procure to pay process, KPIs in performance agreements not ensuring optimal data quality etc. This prompted the master data stream to investigate and improve the material -, service – and vendor masters through cataloguing. (Gebhardt, Buis & Ratsibe 2013:10)

5.4.1.2.2 Warehousing/Inventory

What was found from the data analysis, after looking at all reservations, from the previous financial year with regards to inventory, high level of stock-outs occurring when reservations are placed against items from a shared service warehouse. This was happening because the relevant stock levels were incorrect due to the business having stock in decentralised stores which functioned outside the ERP system. Also a system issues were discovered between the different SAP instances, causing a delay of 48 hours after reservation is placed before it reserving the stock on the other SAP instance. After the interviews, with the operational teams, a lot of decentralised stores were found containing similar inventory to than that from the shared services stores but no visibility of the stock were available due to stock being kept outside SAP. The inventory team were then tasked to look at all items in the stores and identify critical items to business as well as all redundant items. They will then sell off all redundant items and take the rest of the decentralised inventory back up in inventory, moving the common items found in the shared services stores back to those stores. (Gebhardt, Buis & Ratsibe 2013:11)

5.4.1.2.3 Planning/Procurement

A disturbing discovery was made that there does not exist any form of planning on the short medium or long term. This means that from operational to strategic levels no planning occurred which made it clear why so many problems exist. The number of people creating purchase requisions (PR) was also alarming sitting at 159. The purchasing stream was then tasked to come up with an idea to optimise the purchasing. Business process had to be relooked in order to align with all the improvements. Possible contract benefits were identified to the amount of R25 million. (Gebhardt, Buis & Ratsibe 2013:11)

5.4.2 Improvements implemented from each stream

5.4.2.1 Master data

- More than 12 000 material masters were created after walk downs of all labs and decentralised stores and cataloguing everything.
- More than 7 000 service masters were created after looking at all services purchase requisitions for the last financial year.
- Vendor masters were cleaned up and new applicable vendors added.

5.4.2.2 **Procurement**

- A centralised purchase requisition team were established and trained that would create PRs for the whole of R&T going forward.
- Dedicated planners were trained and the planning function created and embedded in the R&T community.
- All relevant contracts were created and all material and service master were linked to the contracts via the ERP system.
- SRM procurement channels were established and started to be used for high volume low value items.
- R17 Million in benefits were achieved after new contracts were implemented.

5.4.2.3 **Inventory**

- After the master data team catalogued all the items in the decentralised stores, the stock was taken back into inventory. All stock that were found to be duplicated, in the decentralised store due to shared services' store keeping stock, were sold back to shared services and the inventory reorder points were adjusted.
- All redundant items were sold off and the profits from the sale of items were given back to the business.
- All items in store that were not identified as business critical were set as non-stock items and some items were identified to be vendor held stock.
- A central receiving function was created at the stores in order for non-stock items and consumables to be redistributed/cross-docked directly to the end users without having to stock these items.

5.4.2.4 **Business processes**

- All relevant business processes were update and aligned to the improvements.

5.4.2.5 **Forecasting**

- A linear program i2 model was built to determine the optimal supply chain design by combing different forecasts. As per the objective of this study to have an integrated supply chain design everything needed to be included in the model from raw materials to finished products.

- Three separate models were built due to the different nature of the business. The split was for research and development (R&D) pilot plants, R&D labs and for fuels technology the third leg in forming R&T.
- For the pilot plant operations a normal production approach was taken. Raw materials as the input, operations turning it into finished goods and outbound logistics transporting it to the clients. Based on the current operations a model was developed to calculate the optimal inbound and outbound warehouse sizes. By optimising the procurement channels and current inventory and by changing the stock holding strategies to vendor held for non-critical items, the warehouse footprint was decreased significantly freeing up extra space. Most of the decentralised stores could be closed down and stock visibility was created in SAP by taking the decentralised stock back in to the system.
- For R&D labs a different approach was needed. They procure items required for research, consume the items during experiments and deliver knowledge as a output. Due to this reason mentioned above only the inbound materials were analysed. A centralised procurement team help to reduce the amount of items procured across the labs. This lead to lower stock due to a just-in-time (JIT) approach implemented. Critical items were identified and based on consumption patterns optimal stock levels could be identified.
- Fuels technology model looked at how to gain market share by strategically placing stock across the globe to decrease lead time to customers. Fuels technology do special blends of fuels so they operate in a very niche market. Four areas were identified based on customer locations. A hub in Sasolburg for Africa, a Hub in Germany for the European Market, a hub in North America to cater for the American markets and finally a hub in Singapore to cater for the Asian Market. Stock levels were increased enable a more responsive supply chain and to improve customer service.

5.4.3 Results due to the redesign of the supply chain

The result that was achieved was quite surprising. The overall improvement of the supply chain performance exceeded all expectations. By first fixing the fundamental problems before trying to optimise using software the business was able to show real benefit from this process. On contract spend went up from 14% to 55% for material and service spend in the first 6 months after the implementation. Free text material and service procurement came down from 99% to 45% during the first 8 months after implementation and will continue to go do as work continues. Stock outs came down from 76% to 25% and stock levels are more accurate and so is the user behaviour. The inventory investment went from R13.5 million to R87 million after all stock were taking back into SAP. The forecasted figure show that this will end on R17 million when redundant stock is sold off and stock level decreased by consuming excessive stock on hand. Three of the decentralised stores could be cleaned up and space opened up so much so that the business now rent out those stores to other businesses. Through collaboration, between the business and other research facilities and labs, implementation of optimised strategic sourcing strategies, synergies from procurement, using same suppliers, storage, distribution and handling could be found through making use of excel and LP models. (Gebhardt, Buis & Ratsibe 2013:20-43)

5.4.3.1 **Supply chain design attributing to success**

By redesigning the supply chains benefits ranging from lower inventory levels, shorter lead times, higher customer response times, better utilisation of warehouse space and better management and distribution of stock could be achieved. This confirms that by having a supply chain designs that incorporates planning, forecasting and sound design principles superior results can be achieved. The supply chain design objectives were all achieve. The R&T business is now delivering an superior service to its growing customer base, whilst overall operational cost have decreased, inventory space were optimised, time of scientists have been freed up and costs was recover from the sale of redundant items. The planning function have been established to look at short term/operational procurement needs, from a tactical or medium term at contracts required, sourcing strategies and synergies that could be found and finally in the long term or strategically at possible changes in the bigger Sasol group that could influence the R&T environment. (Gebhardt, Buis & Ratsibe 2013:43)

6 Conclusion

This chapter will review and summarize the research from this study by identifying the methods that were used, discuss their implications and make recommendations to be implemented.

The study was set out to explore the advantages to Sasol's business/competitiveness if the supply chain planning, design and forecasting were improved. The focus for this study was narrowed to see how Sasol's competitiveness can be optimised by using supply chain planning, design and forecasting techniques to improve investments in logistical infrastructure and ultimately optimising supply chains. The second question that was addressed was if this methodology is flexible enough for both greenfield projects and brownfields project.

With rising costs and decreasing profits during and after the recession Sasol were forced to look at other ways, initiatives and ideas to be more competitive. Sasol had to increase efficiency and effectiveness by optimising capital spend, reduce operating costs, increase outputs, and reduce unnecessary fat in the supply chain. This is why the study was done to help improve the competitiveness of Sasol by focusing on optimised logistical infrastructure spending and optimal supply chains. Without logistical infrastructure capacity being created in the right location within the supply chain and focused on as being an integrated part of the supply chain the forecast will not be successful and Sasol could suffer significant losses in the process.

This study explore how forecasting techniques can be combined in linear programming (LP) as a tool to optimise the parameters of forecasting methods in order to ensure sufficient capacity of logistic infrastructure exist for future growth. The methodology followed in the study was to firstly look at previous literature studies on logistical infrastructure and how to create sufficient capacity. Secondly, understandings of supply chain planning principles in general as well as supply chain planning in context of Sasol were investigated. Thirdly, different forecasting methods like; qualitative include judgemental, life cycle, Delphi method, market research and quantitative methods including time series and causal methodologies had been investigated. Fourthly, decision making tools to incorporate multiple forecasts were investigated to understand why Sasol decided to use i2 supply chain strategist. Fifthly, the current capital project approach in Sasol had been investigated to fully understand where room for improvements would possible exist. Finally the theory from the study was applied on two different projects in Sasol, one greenfield and one brownfield project.

The results found that by using sound supply chain planning methodologies, sound supply chain design principles and multiple forecasts being combined by using LP decision making tools a better decision can be made with regards to logistical infrastructure investment as well as ensuring sufficient logistical infrastructure capacity. The greenfield project case study showed the difference in using the current methodology used in Sasol compared to the new proposed one from the study. The current methodology relied heavily on expert forecasting techniques and designing a supply chain based on engineering principles. After applying the methodology of the study the design was not only improved based on CAPEX, but also improved based on OPEX. This was mainly due to understanding what the business requirements were and aligning the supply chain to support the business strategy. Secondly, by using a combination of forecasts and combining it in i2 the result could be optimised. This resulted in a lower logistical infrastructure spend and also decreased the maintenance cost of running such a supply chain. This ultimately translated into a higher ROI, higher customer satisfaction, lower inventory holding cost and higher competitiveness.

The brownfield project case study proved that by redesigning the supply chain by incorporating planning, forecasting and the use of sound design principles superior results can be achieved like; lower inventory levels, shorter lead times, higher customer response times, better utilisation of warehouse space and better management and distribution of stock. The R&T business is now delivering an superior service to its growing customer base, whilst overall operational cost have decreased, inventory space were optimised, time of scientists have been freed up and costs was recover from the sale of redundant items. The planning function have been established and the contract benefit of R17 million was achieved.

After the completion of this study, the recommendation to Sasol is that all small to medium, green- and brownfield projects should be done using this methodology. The two case studies have shown that this approach is flexible enough, apart from a few minor changes and can be adopted for both scenarios and that great results can be achieved. Logistical infrastructure can be optimised due to collaboration and the overall costs and performance of a supply chain improved. Further research can be done on large capital projects that will have an impact on logistical infrastructure like the construction of a new plant or production site. Continual research should also be conducted to ensure the optimal forecasting, planning and supply chain design techniques for Sasol is constantly used as this is a dynamic and constant evolving environment.

In spite of the recession leading to decreasing profit margins, optimal investments in logistical infrastructure lead to optimal supply chains that ultimately increase the competitiveness of Sasol. This confirms the statement by Shah (2004:929) that profit margins are being eroded and robust infrastructure investment decision and efficient capacity utilisation plans are required to increase profit margins and competitiveness.

7 Appendix A

Major Projects Table - Transport

Project Name	Sector	Value (US $mn)	Capacity/ Length	Companies	Timeframe	Status
Cape Town International Airport runway realignment	Airports	19		na	-2014	Feasibility studies/EIA underway (construction expected to begin in 2014)
OR Tambo International Airport (Johannesburg) upgrade and expansion	Airports	263		Airports Company of South Africa Limited	2006-2016	Under construction (Departures hall completed - work ongoing)
Port Elizabeth Airport departure terminal upgrade	Airports			Airports Company of South Africa Limited	2009	Completed (completed)
Greefspan PV Power Plant	Airports	na	10 MW	na	2012	Project selected among preferred bidders (December 2011)
Refurbishing equipment at Richards Bay Port	Ports	94		Transnet	2009	At planning stage (Project planning underway)
Cape Town Container Terminal	Ports	617	1400000 TEU	Transnet	2011-2016	Project finance closure (Loan secured from AFD)
Construction of a deepwater port, Ngqura	Ports	1090		na	-2011	Delayed (Project delayed)
Port of Durban reconstruction	Ports	14340		Transnet	2015-2019	Project finance closure (Loan secured from JBIC, At April 2012 - Advisor and project consultant tenders launched)
Export facility at Richards Bay Port	Ports		91000 '000 tonnes	Durban Bulk Connections		At planning stage (Project planning underway)
Cape Town Port Expansion	Ports		1400000 TEU	Civil and Coastal Construction Pty Ltd, Transnet, WHBO Constructions, Rohde Nielson	2008-2012	Under construction (At 2011 - project under construction)
Freight railway serving Ngqura port	Rail			Transnet Freight Rail (TFR)	-2010	Completed (Expansion planned)
Motherwell-Coega Industrial Zone rail link	Rail		35 km	Prasa		Announced
Cape Town International Airport rail link	Rail	274	4.6 km	Prasa		Delayed (as on June 2010)
High speed rail	Rail	30000	500 km	China Railway Group		Delayed (Accusations of government corruption places project in jeopardy in May 2011)

Table - Continue

Project Name	Sector	Value (US $mn)	Capacity/ Length	Companies	Timeframe	Status
Two port rail corridors, Kwa-Zulu Natal	Rail	5000	na	na	2011-2016	Plans announced February 2011
Gauteng Nerve Center (GNC) (signalling project)	Rail	132	na	Siemens	-2016	Contract awarded by Prasa
Railway line to Richards Bay Coal Terminal (RBCT)	Rail	1500-1950	140km	NTransnet, Swaziland Rail	2013-2016	Agreement over the construction reached (January 2012)
Majuba railway	Rail	636	68km	Eskom, Transnet Freight Rail	2012-2015	Prequalification tender launched (May 2012)
Majuba railway project	Rail	626	68km	Eskom	2012-2014	Awaiting Tender Launch
Bridge City Rail Link (BCRL)	Rail	154.24	3.5km	Prasa	-2013 (March)	Under Construction
Durban roads N2 intersection upgrades	Roads & Bridges	9	12.8km	Sanral	2011-2014	Project announced
R55 expansion	Roads & Bridges	24	na	na	2008-2012	Project announced
Gauteng Freeway Improvement Project	Roads & Bridges	2860	185km	Sanral	2008	First phase to be completed April 2010
Upgrading R21 and N17 - GFIP	Roads & Bridges	na	na	Sanral	2010	First phase complete February 2011 - 560km Total project coverage
Toll road bypass, Knysna	Roads & Bridges	na	650km	Sanral	2010	Plan approved - 30th July 2011
S'hamba Sonke secondary road upgrade programme	Roads & Bridges	3300	na	na	2011-2014	Planning phase (March 2011)
Tshwane bus rapid transit network (BRT)	Roads & Bridges	312.92	80km, 3 depots, 51 stations	na	2012 - 2015	Construction started
freeway expansion project Phase II	Roads & Bridges	137				tender launched
N5 highway upgrade (Vaalpensspruit -Winburg section)	Roads & Bridges	31.5	33.4	Basil Read	2013-2015	Contract awarded (January 2013)
Stafford' Posts Interchange On N2 Highway	Roads & Bridges	14.1		Group Five	December 2014	Construction Started April 2013

Energy And Utilities Infrastructure – Outlook And Overview

	2011	2012e	2013f	2014f	2015f	2016f
Energy and Utilities Infrastructure Industry Value As % Of Total Infrastructure	52.0	47.0	46.4	45.6	44.8	44.4
Energy And Utilities Infrastructure Industry Value, ZARbn	28.6	26.5	29.4	31.3	33.3	36.0
Energy and Utilities Infrastructure Industry Value, US $bn	3.9	3.2	3.3	3.5	3.7	4.0
Energy and Utilities Infrastructure Industry Value Real Growth (%)	-16.6	-17.6	0.8	1.2	1.4	3.2
Energy and Utilities Infrastructure Industry Value As Percent Of Total Construction (%)	28.6	23.5	23.3	23.0	22.5	22.5
Power Plants and Transmission Grids Infrastructure Industry Value As % Of Total Energy and Utilities	90.0	89.0	89.1	88.7	88.3	88.1
Power Plants and Transmission Grids Infrastructure Industry Value, ZARbn	25.7	23.6	26.1	27.7	29.4	31.7
Power Plants and Transmission Grids Infrastructure Industry Value,US$bn	3.5	2.9	2.9	3.1	3.3	3.5
Power Plants and Transmission Grids Infrastructure Industry Value Real Growth (%)	-18.6	-18.6	0.8	0.8	1.0	3.0
Power Plants and Transmission Grids Infrastructure Industry Value As % of Total Infrastructure	46.8	41.8	41.4	40.5	39.5	39.1
Power Plants and Transmission Grids Infrastructure Industry Value As % of Total Construction	25.7	20.9	20.7	20.4	19.9	19.8
Oil and Gas Pipelines Infrastructure Industry Value As % Of Total Energy and Utilities	3.0	2.0	2.0	2.0	2.1	2.1
Oil and Gas Pipelines Infrastructure Industry Value, ZARbn	0.9	0.5	0.6	0.6	0.7	0.8
Oil and Gas Pipelines Infrastructure Industry Value, US$bn	0.1	0.1	0.1	0.1	0.1	0.1
Oil and Gas Pipelines Infrastructure Industry Value Real Growth (%)	-53.3	-48.4	-0.2	4.8	4.5	4.5
Oil and Gas Pipelines Infrastructure Industry As % of Total Infrastructure	1.6	0.9	0.9	0.9	0.9	0.9
Oil and Gas Pipelines Infrastructure Industry As % of Total Construction	0.9	0.5	0.5	0.5	0.5	0.5
Water Infrastructure Industry Value As % Of Total Energy and Utilities	7.0	9.0	9.0	9.3	9.6	9.7
Water Infrastructure Industry Value, ZARbn	2.0	2.4	2.6	2.9	3.2	3.5
Water Infrastructure Industry Value, US$bn	0.3	0.3	0.3	0.3	0.4	0.4
Water Infrastructure Industry Value Real Growth (%)	105.6	8.9	0.3	4.8	5.0	5.0
Water Infrastructure Industry As % of Total Infrastructure	3.6	4.2	4.2	4.2	4.3	4.3
Water Infrastructure Industry As % of Total Construction	2.0	2.1	2.1	2.1	2.2	2.2

Table - Continue

	2017f	2018f	2019f	2020f	2021f	2022f
Energy and Utilities Infrastructure Industry Value As % Of Total Infrastructure	43.8	42.9	42.4	42.0	41.7	41.4
Energy And Utilities Infrastructure Industry Value, ZARbn	38.6	41.1	44.1	47.6	51.4	55.6
Energy and Utilities Infrastructure Industry Value, US $bn	4.3	4.6	4.9	5.3	5.7	6.2
Energy and Utilities Infrastructure Industry Value Real Growth (%)	2.3	1.4	2.2	3.1	3.1	3.1
Energy and Utilities Infrastructure Industry Value As Percent Of Total Construction (%)	22.1	21.5	21.1	20.9	20.7	20.6
Power Plants and Transmission Grids Infrastructure Industry Value As % Of Total Energy and Utilities	87.9	87.6	87.4	87.4	87.3	87.3
Power Plants and Transmission Grids Infrastructure Industry Value, ZARbn	34.0	36.0	38.5	41.6	44.9	48.5
Power Plants and Transmission Grids Infrastructure Industry Value,US$bn	3.8	4.0	4.3	4.6	5.0	5.4
Power Plants and Transmission Grids Infrastructure Industry Value Real Growth (%)	2.0	1.0	2.0	3.0	3.0	3.0
Power Plants and Transmission Grids Infrastructure Industry Value As % of Total Infrastructure	38.5	37.6	37.0	36.7	36.4	36.1
Power Plants and Transmission Grids Infrastructure Industry Value As % of Total Construction	19.4	18.8	18.5	18.3	18.1	18.0
Oil and Gas Pipelines Infrastructure Industry Value As % Of Total Energy and Utilities	2.2	2.2	2.2	2.3	2.3	2.3
Oil and Gas Pipelines Infrastructure Industry Value, ZARbn	0.8	0.9	1.0	1.1	1.2	1.3
Oil and Gas Pipelines Infrastructure Industry Value, US$bn	0.1	0.1	0.1	0.1	0.1	0.1
Oil and Gas Pipelines Infrastructure Industry Value Real Growth (%)	4.0	4.0	3.5	3.5	3.4	3.3
Oil and Gas Pipelines Infrastructure Industry As % of Total Infrastructure	0.9	1.0	1.0	0.9	0.9	0.9
Oil and Gas Pipelines Infrastructure Industry As % of Total Construction	0.5	0.5	0.5	0.5	0.5	0.5
Water Infrastructure Industry Value As % Of Total Energy and Utilities	9.9	10.2	10.3	10.4	10.4	10.5
Water Infrastructure Industry Value, ZARbn	3.8	4.2	4.6	4.9	5.4	5.8
Water Infrastructure Industry Value, US$bn	0.4	0.5	0.5	0.5	0.6	0.6
Water Infrastructure Industry Value Real Growth (%)	4.5	4.0	4.0	3.5	3.5	3.5
Water Infrastructure Industry As % of Total Infrastructure	4.3	4.4	4.4	4.4	4.3	4.3
Oil and Gas Pipelines Infrastructure Industry Value Real Growth (%)	4.0	4.0	3.5	3.5	3.4	3.3
Oil and Gas Pipelines Infrastructure Industry As % of Total Infrastructure	0.9	1.0	1.0	0.9	0.9	0.9
Oil and Gas Pipelines Infrastructure Industry As % of Total Construction	0.5	0.5	0.5	0.5	0.5	0.5
Water Infrastructure Industry Value As % Of Total Energy and Utilities	9.9	10.2	10.3	10.4	10.4	10.5
Water Infrastructure Industry Value, ZARbn	3.8	4.2	4.6	4.9	5.4	5.8
Water Infrastructure Industry Value, US$bn	0.4	0.5	0.5	0.5	0.6	0.6
Water Infrastructure Industry Value Real Growth (%)	4.5	4.0	4.0	3.5	3.5	3.5
Water Infrastructure Industry As % of Total Infrastructure	4.3	4.4	4.4	4.4	4.3	4.3
Water Infrastructure Industry As % of Total Construction	2.2	2.2	2.2	2.2	2.2	2.2

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