The Modelling and Optimisation of the Vector Logistics Distribution Network

BPJ 420

Final Project Report

Name: Rita Jose

Student Number: 11034522

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Study Leader: Ms Yajna Maharaj

Executive Summary

Supply chain networks are constantly facing numerous challenges and need to find solutions to overcome them. It needs to ensure that it remains competitive and generates a profit whilst meeting company and customer requirements.

Vector Logistics is a 3PL service provider that is experiencing complexity within its distribution network. This paper explores the complexity rationale and literature by looking at the challenges faced by supply chains. The paper goes on to discuss a solution in the form of supply chain network design with the aid of an evaluation framework. In order to apply this tool correctly, existing frameworks and optimisation tools are investigated.

The paper then goes onto look at the generation of conceptual solutions. It is determined, with the use of a decision matrix, that Supply Chain Guru would be the most suitable software to perform this network optimisation. The Vector Logistics PSD network is then modelled, scenarios determined and a framework is established to evaluate the outputs that are generated by the scenarios. The outputs include aspects such as logistical costs, throughput rates and the flow of units. Due to confidentiality reasons, index systems, and not the actual values, have been used to compare values from the different scenarios.

The framework is applied to the results obtained and it is established that the best possible solution for Vector Logistics is to move to a distribution network that has 5 hubs and cross docks. This solution will result in decreasing the network complexity, maximised profits and have the ability to manage constraints currently placed on the network.

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1. Introduction

Outsourcing initiatives performed by companies is a growing trend that has been seen over recent decades and this has led to the development of 3rd Party Logistics (3PL) service providers. A 3PL provider refers to an external firm that executes a certain amount or all of a company's logistics activities. 3PL's became popular as technology started improving and globalisation began to affect companies (Green, et al., 2008). Greater demand was now being placed on various enterprises and competitiveness increased among them. Companies realised that in order to increase their market share, an improvement in efficiency is essential. This steered businesses to outsourcing supply chain activities to 3PL's and the demand for these logistics companies grew.

For any 3PL to remain competitive within its market, it is essential that it has ample resources and capacity to meet the requirements of their customers. The uncertainty in supply and demand and customer needs causes distribution networks to become more complex. The ability to manage these networks to meet all the requirements, while still generating a profit over a long term horizon, is a difficult task. According to Chopra (2003), distribution is said to be the overall profitability driver of a firm because it impacts both the supply chain cost and customer experience.

Vector Logistics is a 3PL service provider in South Africa that is currently experiencing the side effects of an increase in the complexity of their distribution network. The firm's overall objective is to overcome these challenges by designing an optimal network using a framework to evaluate the applicable criteria.

1.1. Background

Vector Logistics stores and distributes both frozen and chilled food products to the retail, wholesale and food service sectors in Southern Africa. It was originally a distribution division of I&J, but went on to becoming a subsidiary company of RCL Foods. Currently Vector Logistics have 19 storage and distribution facilities located across South Africa and Namibia and manage a fleet of approximately 401 vehicles.

Their services include the following:

- Bulk Cold Storage
- Refrigerated Primary Transport
- Multi-temperature Warehousing and Distribution
- Sales and Merchandising
- Debtors Management
- Information Management

Vector Logistics is made up of a number of business types that perform the functions stated above. Figure 1 lists them and briefly gives details relating to each type.

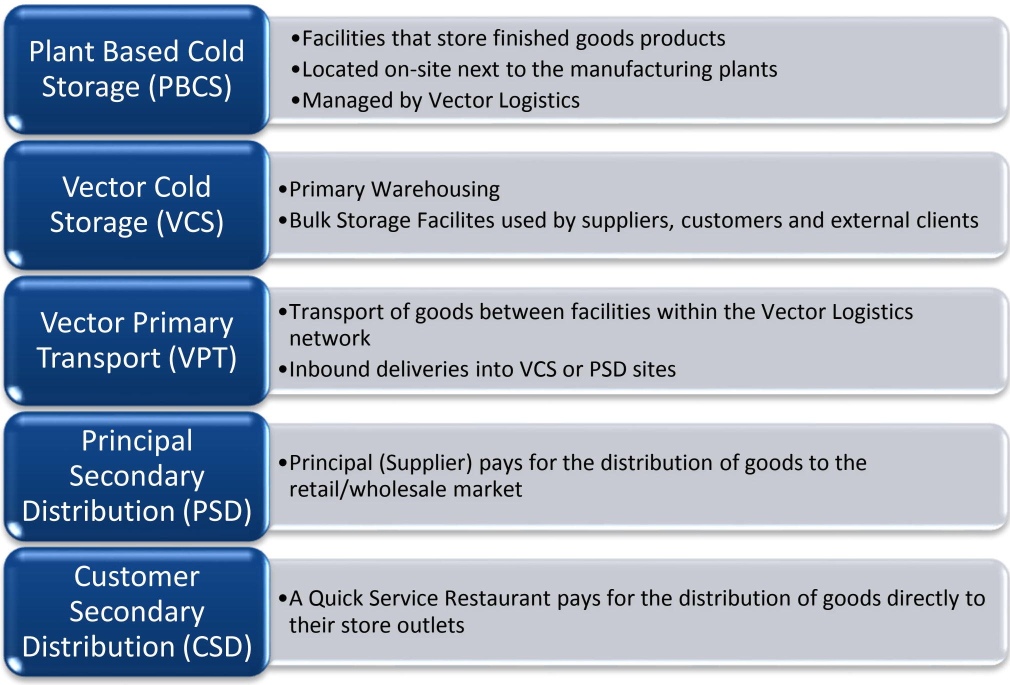

Figure 1: Vector Logistics Business Types

Examples of principals are Rainbow Chicken, I&J and Sea Harvest while customers include Spur, Burger King and Nandos.

As it can be seen in Figure 1, Vector Logistics performs multiple key functions within various companies' supply chains and this causes it to face many challenges. An example of this would be that as the number of Stock Keeping Units (SKU) increase, irrespective of the volume, the firm has to be able to manage the increase in product complexity. Furthermore, the products are mainly perishable and require cold storage which places more constraints on the company. In the last six months, Vector Logistics has taken on business from three new principals which demonstrate the example of the increase in SKU's. As the product complexity increases, the company faces problems such as capacity constraints which may lead to a loss of prospective customers in the future. As Vector Logistics continues to provide all these services, they need to establish a network that is able to handle all the aspects that make it more complex.

1.2. Project Rationale

As previously discussed in the Background, Vector Logistics is facing an increase in the complexity of their distribution network. This segment aims to analyse this further by focusing on the Principal Secondary Distribution (PSD) sector within the company and data relating to it.

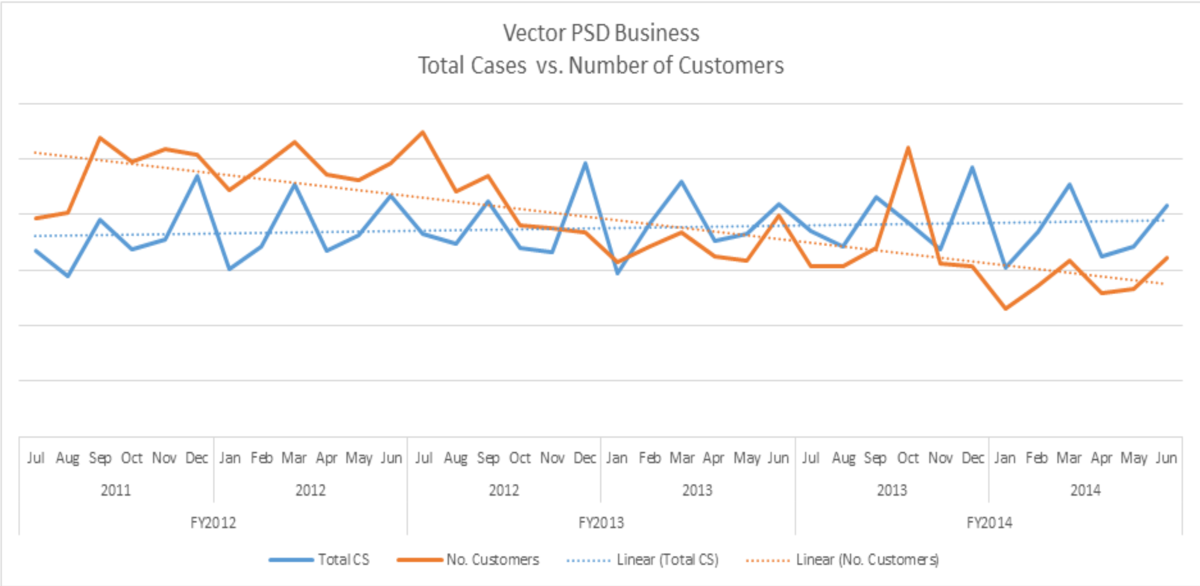

Figure 2: Total Cases vs Number of Customers

Figure 2 depicts how the volume of cases distributed has increased while the number of customers has decreased significantly over the period of 2011 to 2014 by approximately 8.9 percent. The increase in volume of 3.5 percent over the three year period indicates a growth in demand. This graph leads to the question of whether Vector Logistics has the warehouse capacity and the optimal amount of vehicles to support their network should the demand continue to grow. An optimal distribution network should be able to react to uncertain demand and provide the means to ensure that no losses are experienced.

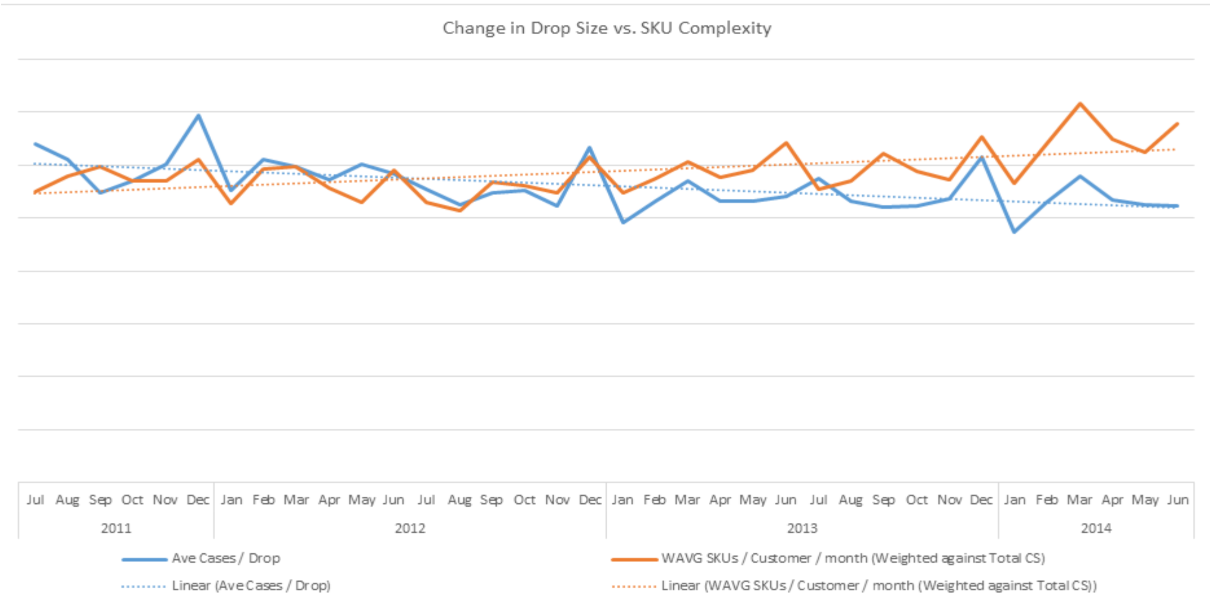

Figure 3: Change in Drop Size vs SKU Complexity

In terms of the vehicles and fleet size, the decrease in the number of customers would indicate that there is a sufficient amount of vehicles available. However, the required size of the vehicles has changed since the drop size has decreased. In other words, instead of possibly requiring vehicles with a capacity of fourteen tonnes, only vehicles with a capacity of eight tonnes may now be needed. Figure 3 illustrates this concept. It can also be seen that even though the drop size decreased by 10 percent, the number of SKU's by 8.2 percent.

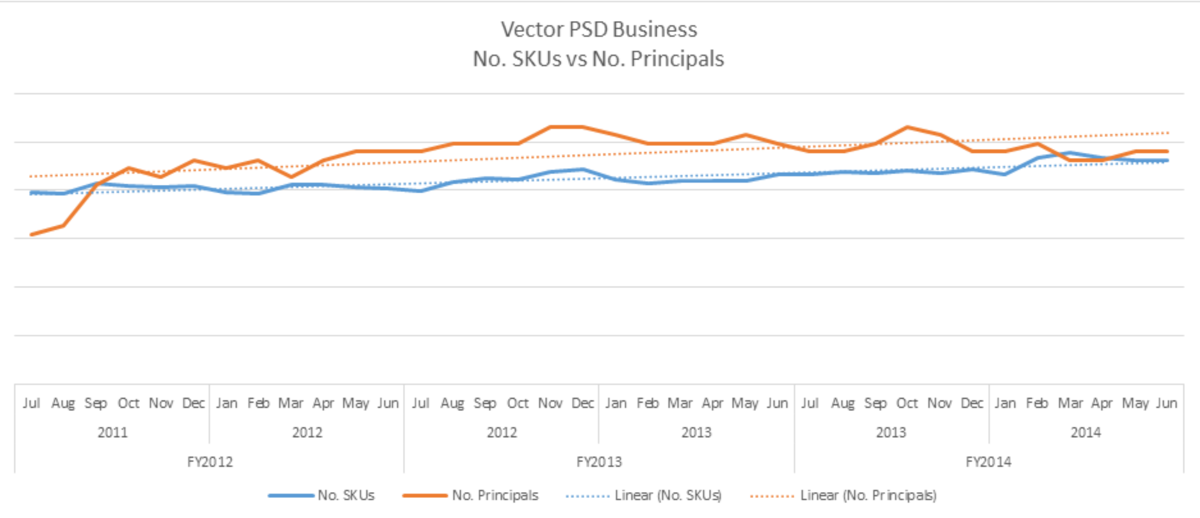

Figure 4: Number of SKU's vs Number of Principals

Figure 4 starts to show how both the number of Stock Keeping Units (SKU's) is increasing over the three year period as well as the number of suppliers. The SKU's increased by 11.1 percent while the number of suppliers grew by 13.7 percent. This indicates that Vector Logistics was starting to deal with a greater number of products and suppliers. The graph starts to show that the collection of products is becoming more complex as it all has its own set of unique requirements. This consequently places more constraints on the distribution network as the number of suppliers is increasing.

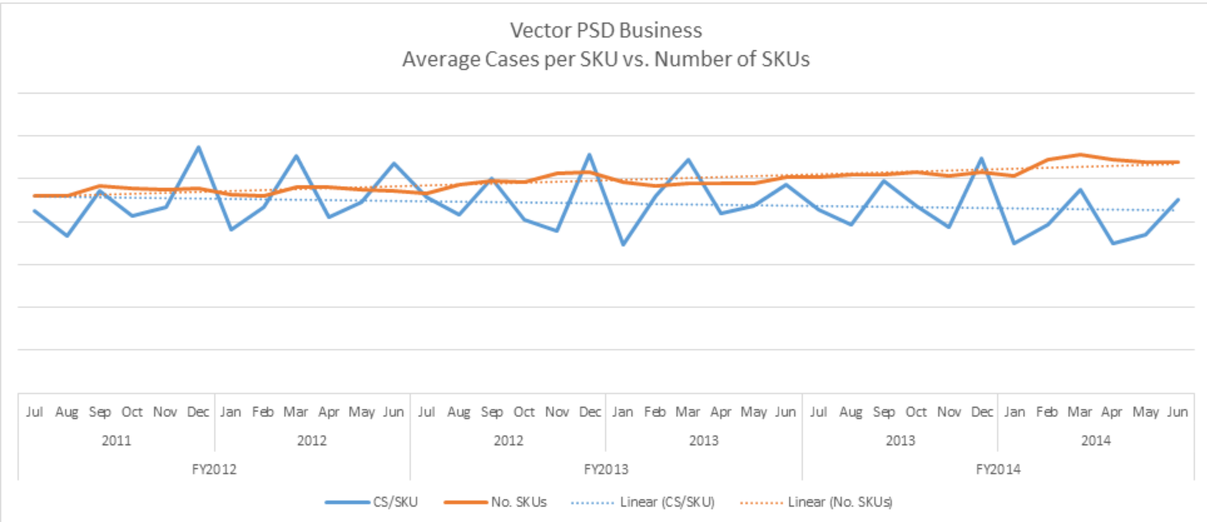

Figure 5: Average Cases per SKU vs Number of SKU's

Figure 5 is considered the most important indication of the increase in complexity of the Vector Logistics network. The figure shows how the volume per SKU has decreased by 6.7 percent while the number of SKU's has experienced a positive growth rate of approximately 4 percent over the 36 months. As indicated in the paragraph above, the increase in the SKU's shows an increase in product complexity. The decline in volume per SKU demonstrates that the percentage of utilisation of resources have decreased over the three year period even though the number of SKU's have increased. A greater amount of constraints have been placed on the system as Vector Logistics needs to adapt to the changes in order to obtain a competitive advantage.

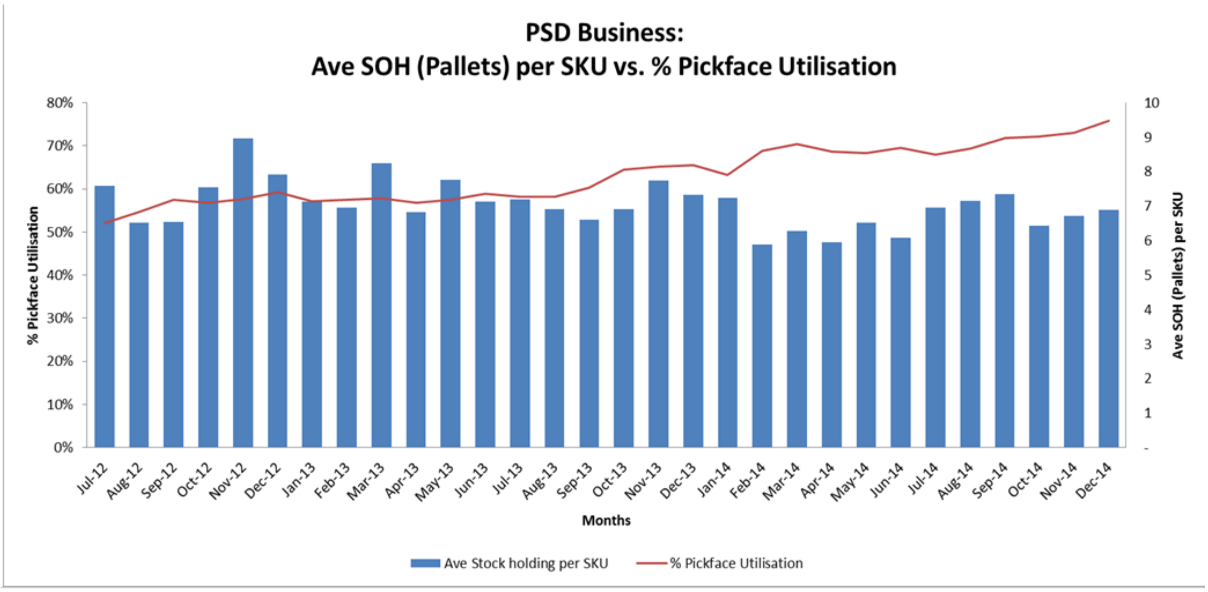

Figure 6: Average stock on hand per SKU vs % Pickface Utilisation

Figure 6 is another important indicator of the complexity within the Vector Logistics distribution network. The graph refers to data concerning stock being held in PSD warehouses while pickfaces are pick bins, where one product will have at least one pick bin. The average stock on hand has decreased by 7 percent over the time period being addressed. This is a positive aspect as stock on hand usually has a large carrying cost associated with it. The Pickface Utilisation percentage increases steadily over the same period by 26 percent and is currently very high. According to data provided by Vector Logistics, the current average of pickface utilisation is close to 70 percent of the design capacity. By taking the graphs that show an increase in SKU's into consideration, pickfacing will be placed under immense pressure if the number of SKU's increase.

1.3. Problem Statement

As technology and globalisation have driven major strategic decisions in various supply chain networks, a great demand has been placed on Third Party Logistics service providers to be efficient and effective. Vector Logistics is such a company and the effects of the demand are causing their distribution network to become more complex. This is due to factors that affect supply chains all across South Africa such as transportation costs and strikes and issues specific to Vector Logistics. Matters of concern particular to the business include the SKU proliferation and high pickface utilisation. If Vector Logistics aims to handle a rise in the number of suppliers and customers, flourish as a company and achieve an increase in profitability, these aspects need to be addressed.

1.4. Project Aim

The aim of this project is to design an optimal network, using supply chain design, for the Principal Secondary Distribution (PSD) area of Vector Logistics. A modelling and optimisation software will be used that will be determined based on a decision matrix. An optimal scenario will be chosen, with the help of a framework that will be developed using a Multi Criteria Decision Method, to help in obtaining an ideal solution.

The framework will be relevant to the South African environment and will act as an accurate aid in decision making. It will help to evaluate multiple scenarios in the effort to determine the optimal distribution network design. The new optimal design should be able to decrease the network complexity and handle all constraints placed on it currently and in the near future. This will result in Vector Logistics maximising resources.

1.5. Project Deliverables

The main deliverables, in order to achieve the above stated aim, are:

- Application of Supply Chain Design
- A framework for evaluation using Multi Criteria Decision methods to identify key criteria that will establish the optimal network design
- A baseline model of the Vector Logistics PSD area modelled in the selected optimisation software
- A number of scenarios, modelled in optimisation software, of the Vector Logistics PSD distribution network where the framework will be applied and possible solutions are achieved.
- An analysis of the results obtained from the modelled scenarios

1.6. Research Methodology

In order to execute this project effectively, a more comprehensive literature review is done in Chapter 2 on supply chain network design and the factors affecting it, supply chain tools available for decision analysis and on the modelling and optimisation software. The reason for the review is to identify tools and appropriate factors that will be used to develop the framework.

Once the literature review is complete, the strategic objectives and constraints of Vector Logistics need to be determined and data will be gathered and analysed through supply chain analysis techniques to understand the current network. At this point, it must be made known that assumptions may need to be made depending on the type of data made available.

An optimisation software, once selected, will then be used to model the current distribution network in its AS-IS state. A framework will then be developed using a supply chain decision making tool that is chosen based on the literature review. The created model will be a baseline to verify the developed framework and an aid to further understand the network. Finally, multiple scenarios will be modelled and analysed in the selected program to see the possible solutions that can be reached with the influence of the evaluation framework.

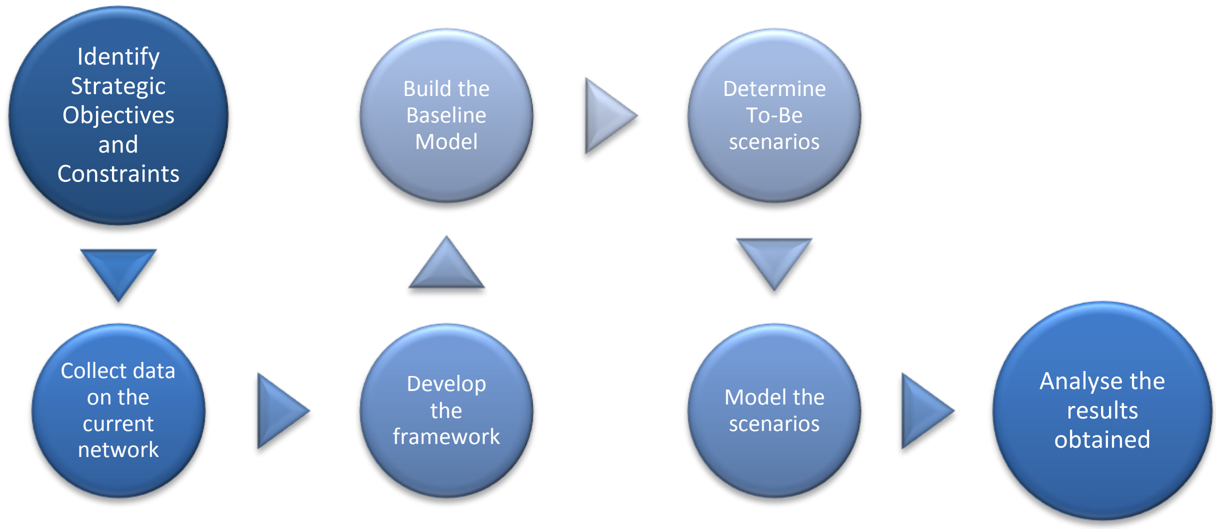

Figure 7: Research Methodology Flow Chart Adapted from: (Fortna, n.d.)

1.7. Document Structure

A detailed literature review is presented in the 2nd chapter of this document. It examines the factors that affect the problem as stated in the problem statement from a macro perspective. Supply chain network design is discussed after which current applicable frameworks are considered. Finally multi criteria decision methods and optimisation tools are analysed. Chapter 3 addresses the conceptual solution development which includes generation of a decision matrix, baseline model and the evaluation framework to be applied.

2. Literature Review

2.1. Problem Investigation

This problem investigation aims to create awareness and further state the need to have an optimal network design by looking at literature that discusses the challenges that South African supply chains experience.

2.1.1. Supply Chain challenges experienced in South Africa

Imperial Logistics, Council for Scientific and Industrial Research, University of Stellenbosch: Department of Logistics (2014) talks about the concept of Supply Chain maturity and mentions how South African supply chains have progressed from survival to being optimised, but achieving the sustainable mode has been delayed due to various challenges.

Figure 8 gives a graphical representation of this concept (Imperial Logistics, Council for Scientific and Industrial Research, University of Stellenbosch: Department of Logistics, 2014).

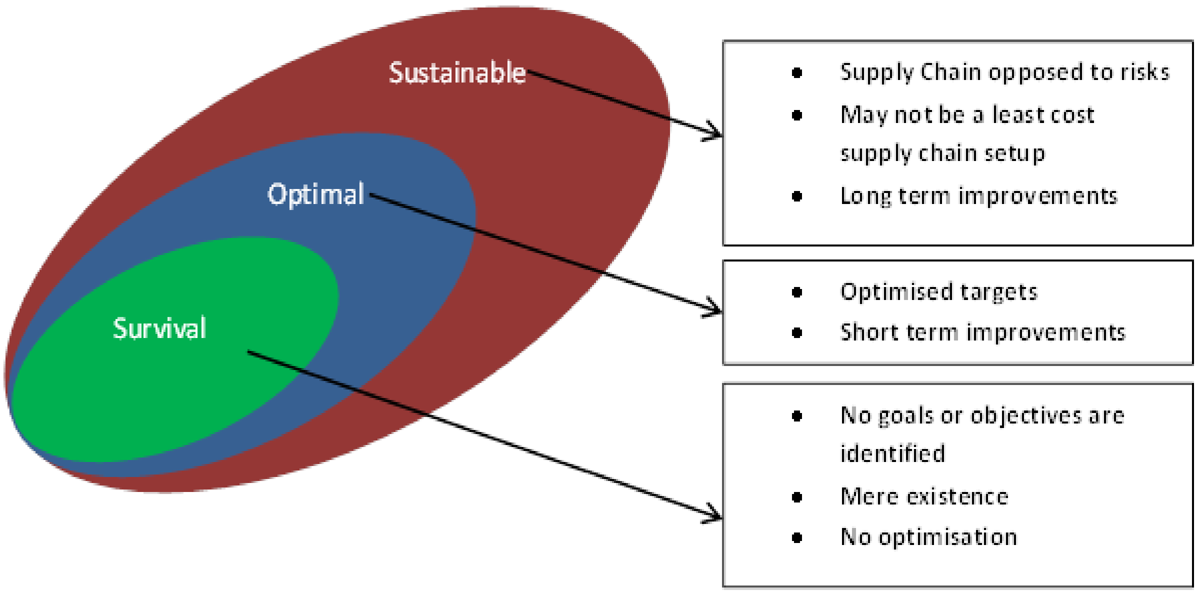

Figure 8: Supply Chain Maturity Levels. Source: 10th Annual State of Logistics Survey for South Africa

In order to reach the status of an optimal and sustainable distribution network, companies are pursuing ultimate customer satisfaction. In order to achieve this, it is imperative to identify the challenges that a logistics company faces, especially in its own country. Within South Africa, numerous factors contribute towards the reason for logistics firms not performing at their best.

According to Badenhorst-Weiss & Waugh (2014), supply chain management will only be able to alleviate risks and develop approaches to neutralise constraints if they have knowledge and understand the importance of it. Identifying the constraints can lead to the business recognising possible areas of opportunity and economic growth. Badenhorst-Weiss & Waugh (2014) conducted a study within South Africa to identify the biggest problem areas experienced by South African logistics service providers. These factors are inhibiting supply chains' abilities and generally have a negative impact on them. After a quantitative and qualitative survey was performed, key problem areas were established, namely operational inefficiencies, transportation issues such as the unpredictable fuel price and labour relations aspects including strikes occurring within the industry. In Table 1 below, a few of the other matters of concern are stated as taken from Badenhorst-Weiss & Waugh (2014):

Factors of concern within the logistics industry
Infrastructure quality in South Africa
Operational issues in South Africa
Human resources problems
Shortage of skilled and experienced supply chain staff
Increasing transportation costs
Road vs rail options
Introduction of carbon tax
Increasing toll roads and e-tolling
Lack of law enforcement
Corruption in logistics activities in supply chains in South Africa
Labour relations in industry

Table 1: Factors of Concern

Badenhorst-Weiss & Waugh (2014) proceeds to elaborate on the factors listed in Table 1. A key aspect mentioned is where infrastructure is said to be of a good standard in South Africa, but it lacks the capacity to meet the growing demands placed on it. This has led to transportation costs increasing and roads being severely damaged.

Badenhorst-Weiss & Waugh (2014) only looks at challenges experienced within South Africa and does not actually compare South African supply chains to that of other countries. Since the long term aim of numerous businesses is to achieve profitability on a global scale, it is necessary to determine where South African supply chains stand globally. Kumar (2013) elaborates on this topic and additionally provides a quantitative perspective on certain aspects. South African supply chains are performing well compared to other African countries and BRICS nations, but transport related issues are once again highlighted as in the previous referenced article. Distribution by road is the most utilised mode of transport with lead time being approximately 30 days as compared to 13 days in other developing countries. This may be due to the fact that only 9 to 52 kilometres per 1000 kilometres^2 of road is actually used for transportation of goods. Figure 9 taken from the 10th Annual Logistics Survey in South Africa shows that transportation related aspects are the principal costs for all the provinces in South Africa. The cost includes factors such as the increasing fuel price, E-tolls and driver wages. In six out of the 9 provinces, inventory carrying cost was the second largest cost which is due to attempts at satisfying demand and costs associated with safety stock levels.

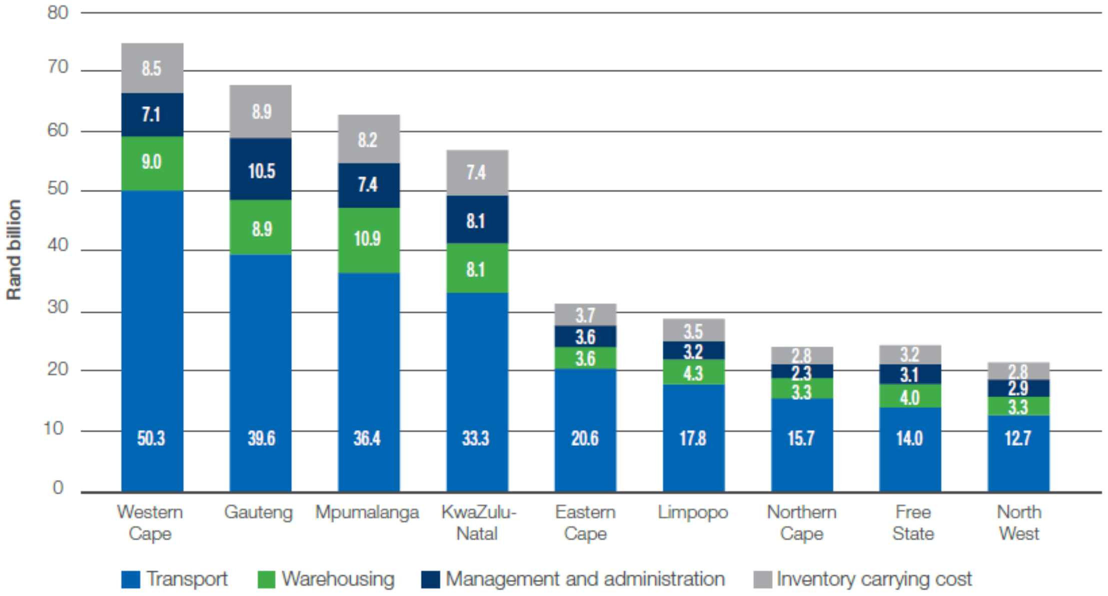

Figure 9: Logistics costs in 2012 per province (Imperial Logistics, Council for Scientific and Industrial Research, University of Stellenbosch: Department of Logistics, 2014)

Kumar (2013) also goes on to mention that South African supply chains are under-skilled when compared to other BRICS countries. The lack of skills and supply chain knowledge of employees hinders companies' from operating as efficiently as possible. The 10th Annual State of Logistics Survey for South Africa agrees with this account (Imperial Logistics, Council for Scientific and Industrial Research, University of Stellenbosch: Department of Logistics, 2014). Employees are equipped with the fundamental skills that may have sufficed in a supply chain in the survival level of maturity, but this is not considered sufficient in a supply chain that aims to improve in performance and mature in terms of supply chain maturity levels.

From the information discussed from the 10th Annual State of Logistics Survey for South Africa, Badenhorst-Weiss & Waugh and Kumar, it can be seen that there are connections between the challenges faced as the rise of one leads to another. An increase in customer satisfaction leads to an increase in demand. Products are transported more frequently to meet the increasing demand since companies do not have the capacity for storage, and finally, the insufficient capacity leads to operational inefficiencies and higher logistical costs. In summary, the main challenges experienced by a supply chain company in South Africa are increasing logistics costs, inability to handle fluctuations in demand and process inefficiencies. The aspect of a shortage of skills is one due to gaps in supply chain education within South Africa. This challenge is the responsibility of the education sector and is therefore outside the scope of this project. Obtaining solutions to the challenges summarised above, specifically for Vector Logistics, will be dealt with in the development of the framework and modelling of scenarios as mentioned in the research methodology.

The challenges discussed in the articles by Badenhorst-Weiss & Waugh and Kumar, form the basis of the problem statement from a macro perspective. A company in South Africa, like Vector Logistics, is unable to perform at its optimal level due to these factors and the increase in complexity of their network only makes these challenges more evident. By establishing these problem areas in the beginning of the project, solving them will lead to greater benefits for Vector Logistics in terms of optimal functionality of the distribution network and an increase in the ability to handle more customers.

2.2. Supply Chain Network Design

In order to make network design decisions, one needs to first determine the importance of supply chain network design, when companies need to consider applying it and factors that need to be studied.

2.2.1. Reasons for conducting Network Design

Ozkarahan & Selim (2008), explain network design as one of the most in depth strategic decision issues that can lead to a long term successful supply chain. Network design is the technique of evaluating features of a supply chain to maximise profitability and improve the performance of the supply chain sections (Francas & Simon, 2011). Watson, et al (2012) discusses that 80% of supply chain costs are related to the location of facilities and determination of the optimal flows. Successful firms thus place great importance on strategic planning related to these aspects. There are many factors that go into the design of a good network, especially a distribution network. As the complexity of the network increases, it becomes even more essential to understand the requirements of the company in terms of cost and performance. A business that manages to identify the factors that affect their supply chain and take them into consideration when designing their network will improve key performance measures such as order lead time, total cycle time, flexibility to meet customer needs and effectiveness of distribution planning schedule (Gunasekaran, et al., 2004). This will better aid them in achieving their strategic objectives.

According to Francas & Simon (2011), fundamental challenges faced include:

- Increasing cost pressures
- Developing of risks and market volatility
- Increasing service requirements
- Greater focus on sustainability

These factors, together with those mentioned Section 2.1 summarise the challenges faced by a South African supply chain.

If the aforementioned challenges are addressed and a network design is executed correctly, the performance of the supply chain, in the following areas, will improve (Francas & Simon, 2011):

- Greater return on assets
- Lower supply chain costs
- Reduced exposure to supply and demand risks
- Higher customer service

From these points, it is understood that decisions made from a strategic level affect both the operational and tactical levels of any supply chain. This would include improved inventory management, a decrease in logistical costs such as those related to transport, and improvement in operational efficiency levels.

Since the importance of network optimisation design analysis has been established, what would trigger the need to perform it? Or how frequently should it be done? Previously, businesses would only need to perform this redesign once every few years since not many changes were experienced in that time. Nowadays, businesses complete the analysis due to reasons that include mergers, product characteristic changes, demand uncertainty and other socio-economic factors or challenges experienced. The current trend is for network design to be done frequently due to business demographics changing faster and the growth of the global supply chain. (Watson, et al., 2012).

Since Vector Logistics is a subsidiary company of RCL Foods, the need for the network design analysis became apparent as the complexity of the whole company increased. The need arose to study the current distribution network and redesign it to take current changes, such as increasing SKU's, into consideration to lower costs and in turn increase profitability and improve company growth.

2.2.2. Network Design Decisions

A well-planned network design can only lead to the correct answers provided that the applicable questions and requirements are established. In the supply chain industry, this refers to network design decisions. The decisions are specific, depending on the objective of the business, and can lead to accurate results tailored for the company situation. Figure 10 gives the example of decisions to address that are specific to the subsystem within the supply chain.

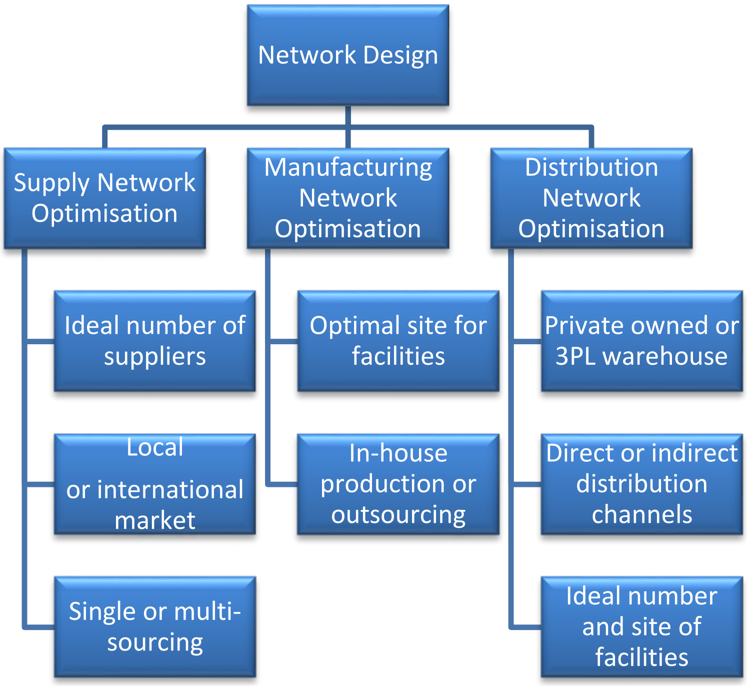

Figure 10: Network specific optimisation aspects to consider (Francas & Simon, 2011)

Francas & Simon (2011), mention that it is imperative that decisions concerning the network design are driven by the company's strategic direction. In most companies, four primary strategic dimensions establish the direction, namely cost, time, agility and service. As mentioned above, performance improvement is an objective of supply chain design, but high performance in all four dimensions cannot be considered as economically feasible. Essentially, Francas & Simon (2011) do not explain what performance includes, especially that of a distribution network. Chopra (2003) fills this gap by stating that performance of a distribution network should be assessed based on two aspects of customer service; namely meeting customer needs and the costs associated with meeting them. The measures that make up customer service include response time, product variety and its availability, customer experience, order visibility and return ability. Businesses need to prioritise these main dimensions and customer service factors and then perform the trade-offs to find the correct combination. This will lead to the alignment of company objectives and customer requirements being satisfied. For example, one business may find a low response time to be more important than a high product variety while another may opt for the opposite situation.

In order to measure performance, numerous approaches are available. The Supply Chain Operations Reference (SCOR) model provides a method to assess the overall performance of the supply chain by connecting the processes, best practices and skills. It looks at four categories of metrics which are cycle time, cost, service quality and asset metrics (Lapide, 2000). The Balanced Scorecard integrates non-financial measures with financial measures to provide a more balanced overview of the supply chain performance. It provides a financial, customer, internal business and learning perspective on a business. The Balanced Scorecard method is used to assess supply chain control while the SCOR model is applied when measuring performance of an integrated mapped out supply chain. (Butilcă & Ilieş, 2011).

Melo, et al (2008) goes into detail concerning the actual decisions that need to be addressed in a distribution facility. All these decisions will eventually lead to finding an optimal network design that satisfies demand and generates a profit for a company. Examples of these decisions are (Melo, et al., 2008):

- The role of facilities within the network needs to be analysed in terms of the number, type and location of the facilities
- The customer markets that each facility services
- The amount of inventory that can and should be transported to satisfy demand
- Capacity decisions that determine whether existing facilities should be expanded or reduced.

All these aspects further highlight the fact that an optimal distribution network is essential to gain a competitive advantage, but one needs to know what the relationship is between the cost dimension, performance factors and network design decisions. Chopra (2003) once again fills this void through graphical methods. Figure 11 demonstrates that the number of facilities within a distribution network will have a significant effect on the response time. A higher number of facilities closer to various markets will ensure that customers receive their goods in a shorter span of time whereas if there was only one distribution facility, it will take a greater amount of time. Increasing the number of facilities to decrease response time will lead to businesses requiring a large initial investment for such a project so it would be an opportunity for them to perform a trade-off analysis to determine which factor holds greater importance. Figure 12 depicts a similar scenario, but in this case the number of facilities has different effects on the different logistics costs. Figure 13 finally shows the combined effect of the number of facilities on the response time and logistics costs. The aim of any supply chain company is find the optimal point that satisfies all 3 aspects.

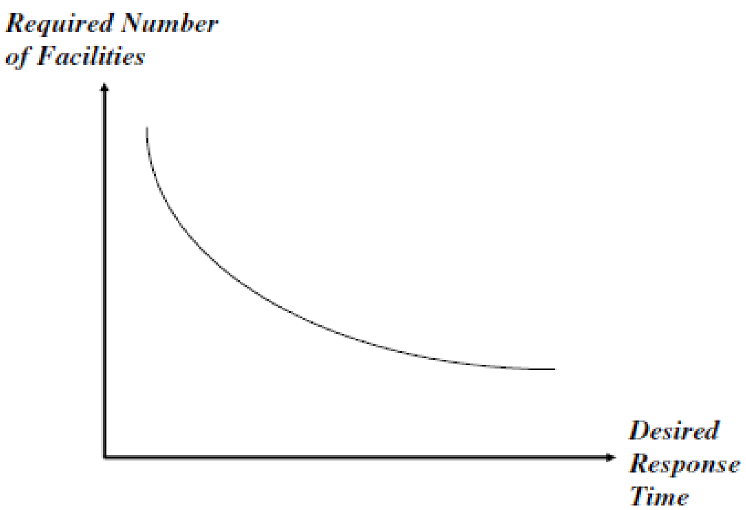

Figure 11: Response time vs number of facilities. Source: (Chopra, 2003)

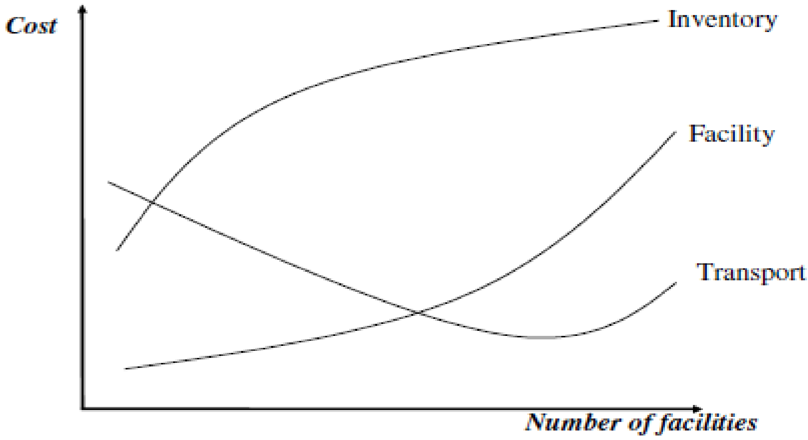

Figure 12: Number of facilities vs logistics costs. Source: (Chopra, 2003)

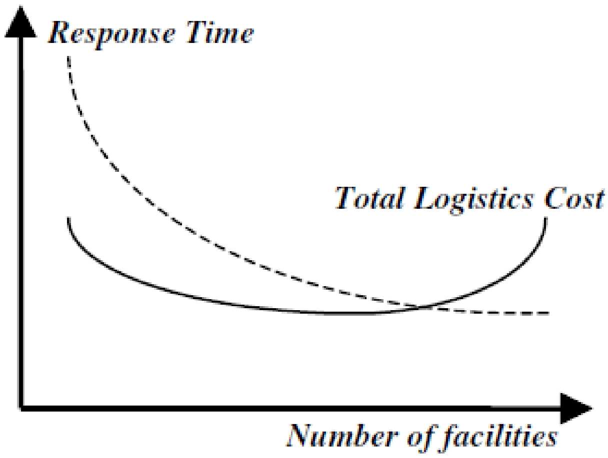

Figure 13: Number of facilities vs response time and total logistics cost. Source: (Chopra, 2003)

The network design decisions for Vector Logistics is based on the relationships discussed between the decisions given by Melo, et al. (2008) and the challenges mentioned in Sections 2.1 and 2.2.1. The company aims to optimise and address the following network design aspects based on its strategic objectives:

- The number and type of facilities such as hubs and cross docks
- The flow path and quantity that products will follow
- The customers that each facility will service
- The capacity of the facilities

The decision relating to the mode of transport will not affect this project since road is the chosen mode of transport. The study of deciding on the feasibility of other modes of transport, such as rail, is outside the scope of this project.

All the aspects, obtained and discussed from literature in this section, are relevant to achieve the Vector Logistics strategic objectives which include decreasing supply chain costs and risks and increasing reliability, agility, asset efficiency and visibility across the supply chain. An improvement in these factors will help the company in the strategic alignment process.

2.3. Framework Models for Supply Chain Network Design

Over the years, numerous studies have been completed that examines the relationships between characteristics that make up a good supply chain network and customised frameworks have been created to apply these relationships optimally. These frameworks ensure that the correct network design decisions are considered, provide guidance in choosing objectives and determine the right scope for the network design (Francas & Simon, 2011).

2.3.1. Network Design Principles Framework

According to Francas & Simon (2011), companies are advised to follow the framework model given in Figure 14 to select the applicable objectives and identifying the right scope for the network design.

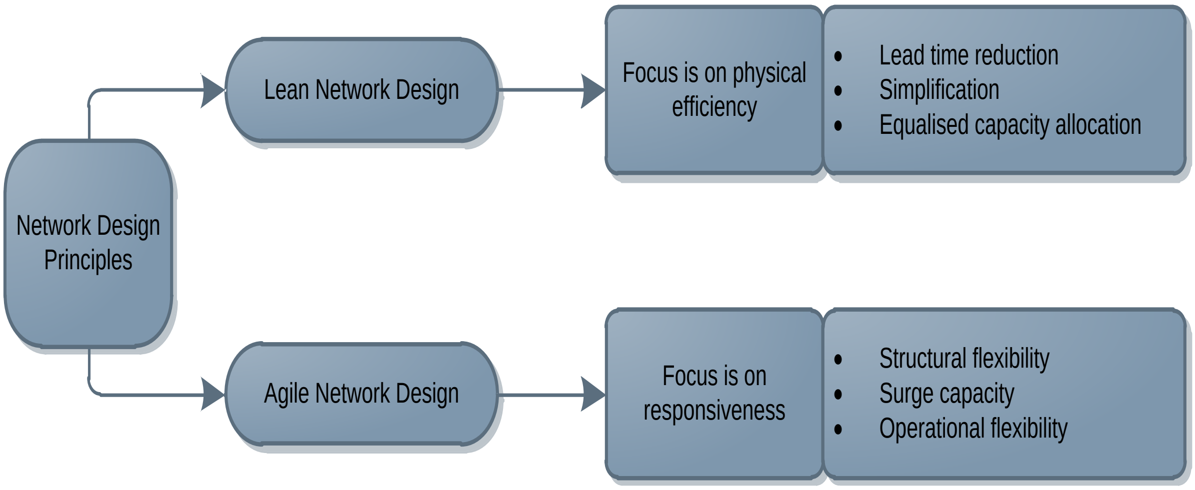

Figure 14: Framework model for network design (Francas & Simon, 2011)

Lean Network Design focuses on decreasing throughput times, simplifying processes and eliminating unused capacity. Agile Network Design focusses on bringing about changes quickly and cost efficiently. This framework may be a starting point, but it cannot be considered detailed enough and does not specifically take into account challenges faced in a distribution network or for that matter, challenges experienced in South Africa. In order to use such a framework, the main objective of a company needs to be either aiming for a lean design or an agile design. Most companies would see the two as sub sections to consider with an assigned priority given to each aspect.

2.3.2. Integrated Planning Support Framework

Evers & Joseph (1996) looks specifically at designing a framework for a distribution network. Generally, when looking at network design decisions, the issues at hand overlap which makes it difficult to establish a clear strategy. Various evaluations and trade-off analysis will be required, but this may be extremely complex and may take a significant amount of time. Unlike Francas & Simon, that only paid attention to initial objectives of a company, Evers & Joseph propose establishing small models. These models would make up the total design of the supply chain that, when applied, will take less time and effort, but will still result in an optimal supply chain. This methodology results in the Integrated Planning Support Framework (IPSF) (Evers & Joseph, 1996). The framework consists of four stages with each stage addressing its own issues. The stages are (Evers & Joseph, 1996):

- Arrangement stage: At this stage the required number, location and size of facilities are established as well as the customer markets that each facility will service.
- Deployment stage: The optimal distribution of inventory and final assembly activities are established at this stage while various product types and its stock levels are allocated to facilities.
- Flow stage: This is where the necessary inventory levels, batch sizes, order frequency and safety stock levels are calculated.
- Operations stage: Matters related to controlling the functioning of the supply chain are addressed at this stage, which include features such as ordering procedures, detailed vehicle routing algorithms etc.

Since the results obtained in one stage are used in the next, it is essential that results are verified otherwise the end results may be inaccurate. Table 2 provides the framework as discussed and Figure 15 depicts the interaction between the various models and the answers it provides. In terms of applying this to Vector Logistics business areas and this project, the main focus would be on the arrangement stage which looks at supply chain strategy. The deployment, flow and operational stages would be applied when focusing on an operational level by looking at supply and demand planning within the company and route and sales and operations planning.

Model	Input	Output	Assumptions
Arrangement Model	• Customers and distribution centres with their demand, assortments and capacity restrictions • Product information	• Location and size of distribution centres • Assignment of customers to distribution centres	• Network deployment • Aggregate flow • Operational characteristics
Deployment Model	• Network arrangement • Additional information such as order frequencies, safety stock levels	• Logistical functions of each product • Inventory and final assembly	• Flow and aggregate operational characteristics
Flow Model	• Network arrangement and deployment • Additional information such as service levels, capacity types, production batch sizes	• Delivery frequencies to customers and distribution centres • Batch sizes, utilisation rates, stock levels	• Network operations
Operations Model	• Network arrangement • Deployment and flows	• Replenishment and transport lad times	• Vehicle failure rates • Stochastic variations

	• Operational aspects	• Procedure to schedule shipments and replenish stocks • Protocols for communicating demand	of demand

Table 2: Summary of the IPSF. Source: (Evers & Joseph, 1996)

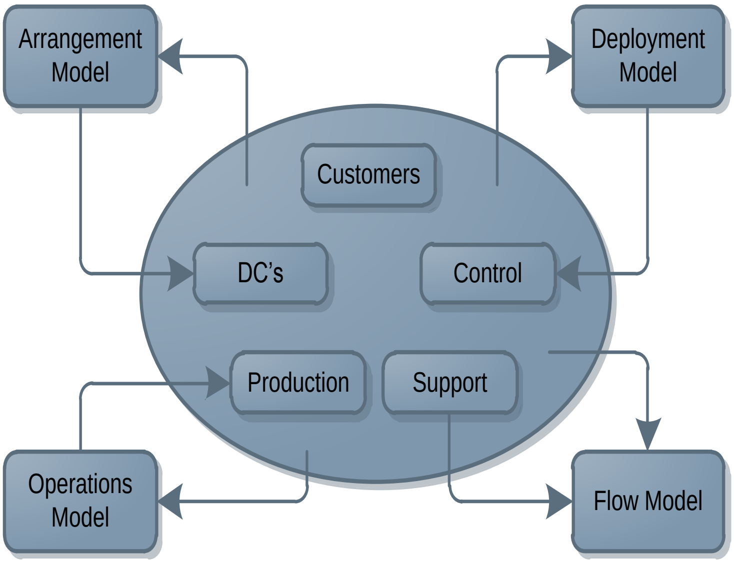

Figure 15: Interaction between models that make up the IPSF

The advantages of this IPSF are that one does not have to deal with a large complicated network design all at once. The framework allows special attention to be paid to small models that will eventually lead to the optimal answer. On the other hand, there is a gap in the research of the framework as it does not accommodate constraints such as those mentioned in Table 1.

Vector Logistics needs an evaluation framework that will determine the optimal network design aspects as mentioned in Section 2.2.2. Both frameworks discussed in sections 2.3.1 and 2.3.2 do not address challenges experienced by a supply chain network, but rather the actual design decisions. The IPSF gives more detail and can be considered more relevant and applicable for Vector Logistics since its systematic approach will ensure that attention to detail is provided. It should be noted that the main focus of this project is on a strategic level and not on the tactical or operational level. The framework will need to be adapted to include the challenges and ensure that the company's strategic objectives are addressed. This will increase the accuracy of the framework and make it more relevant to the project.

2.4. Decision-making Tools

Network design is a complex process where many dimensions, objectives and constraints have to be considered on an operational, tactical and strategic level. This gives rise to the need for network design to be supported by decision making tools that will help ensure that the framework developed, incorporates and addresses all relevant factors. In order to execute this, the most applicable decision making tool needs to be selected. In this section, three different methods are discussed.

2.4.1. Multi-Attribute Utility Theory

According to Velasquez & Hester (2013), this method is seen to be the most commonly used. It is a more demanding methodology on how to include risk preferences and uncertainty into multi criteria (Velasquez & Hester, 2013). The method decides on the most suitable decision by assigning a utility to every possible result and calculating the most ideal situation. The method takes uncertainty into account, but it requires a large amount of data that may not always be available. The theory would only be used if the governing factor is to consider uncertainty. An example of such a scenario was selecting a country to situate a manufacturing plant. Such a situation is risky due to its complexity, and uncertainty plays a dominant role since it involves international aspects (Canbolat, et al., 2007). The MAUT method allowed the decision maker to identify weaknesses in the alternatives and establish whether investing in an alternative would be worth it.

2.4.2. Simple Additive Weighting Method

Sharma (2013) suggests this weighting method to be a simple technique. The method calculates an assessment tally for each option by multiplying the scaled value given to it with the weight of relative importance (Sharma, 2013). In the study that Sharma (2013) performed, it was noted that this method was used by management for decisions related to supplier, facility location and other selections, but it is not as popular as other methods. This is due to the fact that all values in the criteria need to be positive. The answers that this method produces may be illogical and may not represent the real life situation, but have been used in financial and business management problems (Velasquez & Hester, 2013). Abdullah & Adawiyah (2014) believe that the SAW method is too intuitive for reaching an agreement for group decisions. They elaborate on this statement by mentioning an application example. The technique was applied to a personnel selection problem, but Abdullah & Adawiyah noticed a void where fuzziness of judgement, for the duration of the decision making process, was not taken into consideration. This leads to results that are not optimal for the problem at hand.

2.4.3. Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

This method is a multiple criteria method to recognise probable answers from a fixed set of options. (Sharma, 2013). The fundamental principle behind this method is that the selected choice should have the minimum distance from the positive optimal solution and the maximum distance from the negative optimal solution (Sharma, 2013). TOPSIS is considered simple to apply, but its disadvantages outweigh its simplicity. The use of Euclidean Distance does not take the relationship between attributes into account and maintaining consistency is considered difficult. The fact that the method is easy to use is the reason that various industries apply it (Velasquez & Hester, 2013). In most cases, this methodology is used to confirm and compare results obtained by using another multi criteria decision method.

2.4.4. Analytical Hierarchy Process

The fourth and final method is a pairwise comparison method that arranges the criteria into a hierarchy. The relative weights are compared against each other to establish the final rankings of the alternatives. The steps for applying this method are as follows (Sharma, 2013):

- Determine the goals and objectives
- Establish the criteria
- Select the applicable options
- Determine the hierarchy
- Establish the pair-wise comparison
- Compute the Eigen value and Eigen Vector
- Complete the Consistency Test
- Calculate the weights
- Establish the pair-wise comparison of the alternatives with respect to each criteria
- Calculate the geometric mean
- Compute the Eigen value and Eigen Vector
- Complete the Consistency Test
- Calculate the overall weights

AHP is one of the most popular decision making methods due to its simplicity and ability to handle problems of varying sizes. The negative aspect of the method is that interdependence between alternatives does not allow the strengths and weaknesses of one alternative to be assessed alone. It is considered as the ideal method to compare performance between alternatives.

From this discussion of all the Multi-Criteria Decision Making methods, the Analytical Hierarchy Process would be the best suited since a number of factors need to be considered and the hierarchy method provides further structure and order. The TOPSIS and SAW methods would not provide an accurate answer due to the disadvantages listed in each section. The MAUT method is considered to be similar to AHP, but in the case of Vector Logistics, uncertainties of challenges are not considered as the most important aspect.

2.5. Optimisation Tools

Network optimisation tools aid significantly in the analysis of a supply chain in its current state by providing detailed statistics and visualisation functions. It also simplifies the design, supports the evaluation of supply chain network scenarios and aids the designer in determining the most optimal supply chain network. The main challenge in this phase of network design would be to determine the optimisation tool that is best suited to the company and the scenario.

The optimisation tools use the fundamentals of Operations Research methods in the form of mathematical algorithms and maximised or minimised objectives in order to establish optimal answers. Basic programs such as Excel can be used for simple models, but complex scenarios require software built for optimisation and simulation (Francas & Simon, 2011). As mentioned before, it is essential that the most applicable optimisation tool is chosen for the network design. Figure 16 shows how network optimisation tools are most useful for strategic decisions and design, while tools for transport and inventory optimisation are most apt for tactical design (Francas & Simon, 2011). This section discusses possible options of optimisation software that can be used for the modelling of the Vector Logistics distribution network. The aim of using such optimisation software is to allow a business to examine and study various possible real-life scenarios and the effects that different factors have on the distribution network.

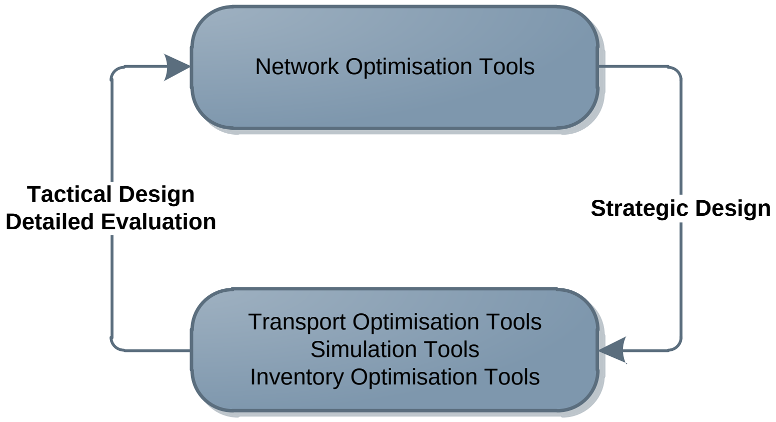

Figure 16: Optimisation tools (Francas & Simon, 2011)

2.5.1. LLamasoft: Supply Chain Guru

This is a LLamasoft product that takes the whole supply chain into consideration by looking at the process from suppliers to customers. The program combines optimisation and simulation tools into one software and can handle tactical activities as well as strategic planning. The program also allows constraint modelling that allows a model to be built depicting real life situations. A key advantage of this software is that it allows multi-objective optimisation and generates and compares multiple scenarios against each other to obtain optimal answers. In terms of the appearance, the software uses the Geographical Information System (GIS) which is not only aesthetically pleasing to the eye, but also adds accuracy to modelling routes, travel time and distance. (LLamasoft Inc, 2015)

2.5.2. JDA: Supply Chain Strategist

Supply Chain Strategist is a JDA product that performs optimisation and network design. The software has the ability to model the whole supply chain and time periods, inventory levels and demand requirements amongst others can be fed into the software as inputs. The software mainly addresses network design, sourcing optimisation and capacity optimisation. A disadvantage of the program is that only one scenario can actually be modelled at a time. Therefore various scenarios cannot be compared against each other. (JDA Inc, 2014)

2.5.3. Operations Research Approach

Operations Research uses a systematic approach and techniques to establish optimal solutions as set out by the objectives of the problem at hand. Figure 17 illustrates this procedure. In summary, the process identifies the problem that needs to be solved and based on the data and objectives; the model is formulated using decision variables and an objective function and constraints are established. The problem is formulated in mathematical software such as LINGO or MATLAB in order to determine optimal values for the decision variables. Finally, the solution needs to be verified and if so, is implemented (Rajgopal, 2001).

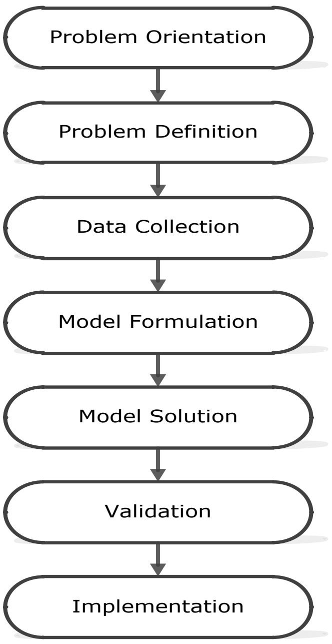

Figure 17: Operations Research Approach

This approach of operations research provides a mathematical solution but it is not able to execute supply chain network design as well as the two optimisation programs mentioned in section 2.5.1 and 2.5.2. This method requires one to build the mathematical models whereas programs such as those in the aforementioned sections have this functionality built in already which allows for more room for analysis. The mathematical software will not be able to compare different scenarios simultaneously and mapping facilities on mathematical modelling software will not be as user friendly as Supply Chain Guru and Supply Chain Strategist. The two programs also allow visual modelling which is essential when trying to understand a supply chain model. An operations research approach would be able to model all quantitative data accurately, but challenges would be experienced in modelling qualitative data. This distribution network design project for Vector Logistics includes qualitative data such as the importance of risk and the networks ability to adapt to change; therefore this option of modelling to obtain solutions is not viable.

Both Supply Chain Guru and Supply Chain Strategist have their advantages and disadvantages and in order to decide on the best applicable software, a conceptual design of the decision matrix will be developed in the next chapter.

2.6. Conclusion

The literature review revealed how most supply chains are undergoing the same challenges and that further reiterates the need for accurate supply chain network design. The IPSF, together with the Analytical Hierarchy Process will be applied and formulated when the current state of the supply chain is modelled. Chapter 3 looks at the development of the solution by first determining the ideal software to use between three different options.

3. Conceptual Solution Development

The aim of a conceptual solution phase is to determine and execute a design that ensures that the problem at hand is attended to correctly. This is done by firstly setting out the preliminary design. Thereafter, this section discusses the steps that were taken to execute and evaluate the modelled distribution network.

3.1. Preliminary design

In the Project Rationale, data concerning the Principal Secondary Distribution (PSD) sector was analysed and it was concluded that if the Stock Keeping Units kept increasing, pickface utilisation would become constrained. The 24 percent increase in pickface utilisation is a strong indicator that the distribution network is becoming more complex. Consequently, the Industrial Engineering tools, in the form of supply chain network design and multi criteria decision methods will be used to obtain an optimal solution to conquer the changing dynamic of the Vector Logistics PSD network.

The redesigned network needs to address this challenge while meeting the objectives mentioned in Network Design Decisions, namely decreasing supply chain costs and risks and increasing reliability, agility, asset efficiency and visibility across the supply chain.

In order to solve this problem, the current state of the Vector Logistics network will be mapped. The decision matrix generated in the next section will identify the ideal software to perform this task. This decision making technique is used to ensure that the most applicable optimisation software, which aligns with the needs of the company, is chosen. Based on findings made in the literature review, it is imperative that the correct network design decisions are addressed. Therefore, mapping the AS-IS state of the PSD division will aid in understanding the network and identifying improvement opportunities and cost savings.

A supply chain is made up of numerous components hence using the framework mechanism ensures that all features are dealt with. The application of an accurate framework, in this case an adaption of the IPSF, is chosen because it will ensure that all the reasons for the increase in complexity of the network are addressed in a structured manner. The use of the Analytical Hierarchy Process (AHP) is ideal for this scenario since pair-wise comparisons of qualitative data can be computed. The method results in a hierarchy which helps in determining the relative importance of alternatives.

This strategic planning method will help in determining TO-BE states of the network and understanding the costs and risks that are associated with the possible solutions that are established. The optimal network will be determined using these tools to aid Vector Logistics to maximise resources, meet company objectives and obtain a profit.

3.2. Decision Matrix

The decision matrix developed in this section includes categories or characteristics that will help make an informed decision on the most appropriate software to use. In many instances, companies do consider the possibility of outsourcing such a project. This would mean that the business, such as Vector Logistics, would not need to purchase new software, but only receive a once-off solution. Conducting the project within the company may entail purchasing software, but it would also allow continuous analysis for future gains.

Data that is used to create the matrix has been obtained from the respective software websites and Vector Logistics. It should be noted that Microsoft Excel has been added as an alternative since Vector Logistics currently uses this. Weightages of the characteristics are assigned based on data provided by Vector Logistics.

In Table 3 below, the criteria has been broken down into three main sections, namely functionality, integration and use and finally cost. In modelling, one aims to use software that has the most applicable features for the situation in which it will be used. Without this, the exercise would be futile. It is for this reason that functionality of the software has the greatest weightage. Integration and use looks at the ability of the software to accommodate change. The move from certain software to another should be a smooth transition; otherwise a large amount of money and time will be wasted unnecessarily. Finally, cost is a major driver for any company and it is no different for Vector Logistics as the weight of it shows this.

Main Attributes	Criteria	Weight
Functionality	Model end-to-end elements of the supply chain	14
	Ability to model different inventory options	12
	Ability to model different transportation options	12
	Multiple Scenario Generation	8
	Visual Modelling	10
	Sub-total	**56**
Integration and Use	Ability to import and export data	10
	Data Verification	6
	Ease of modelling and use	4
	Training and support	2
	Sub-total	**22**
Cost	Total Cost of Software	22
	Sub-total	**22**
	Total	**100**

Table 3: Criteria Weight Values

In order to rate the different software choices, a simple rating scale of 1 to 5 has been created with 1 being the most unfavourable rating and 5 being the most favourable.

Rating	Description
5	Exceptional performance
4	Performance beyond expectations
3	Satisfactory performance
2	Below average performance
1	Fails performance expectations

Table 4: 1-5 Rating Scale

In Table 5, rating values have been allocated to Supply Chain Strategist, Supply Chain Guru and Excel. These values have been assigned based on information made available and experience of the three programs. Supply Chain Strategist and Supply Chain Guru are similar since the main functions of both programs are related to network design and optimisation, but Supply Chain Guru has the added advantage that one can model various scenarios at the same time. This aids in the analysis of results of the models developed. Microsoft Excel is a very powerful tool that has multiple functions, but it is mainly advantageous for data handling and manipulation. When compared to the other two programs in question, Excel underperforms as it is not as user friendly and obtaining an optimal result will take a greater amount of time.

Table 6 finally sums up the total weightages of the three programs. A higher total score indicates a more suitable program to use for the purpose of this project. Therefore, it can be seen that, based on the criteria developed, Supply Chain Guru would be the ideal program to use to model the Vector Logistics Network as it scored 77.2 points compared to the 64.4 points of Supply Chain Strategist and the 45.6 points scored by Microsoft Excel.

Main Attributes	Criteria	JDA Supply Chain Strategist Score	Supply Chain Guru Score	Microsoft Excel Score
Functionality	Model all elements of the supply chain	4	4	2
	Ability to model different inventory options	3	4	1
	Ability to model different transportation options	3	4	1
	Multiple Scenario Generation	2	5	1
	Visual Modelling	3	5	1
Integration and Use	Ability to import and export data	3	3	3
	Data Verification	2	4	4
	Ease of modelling and use	3	4	2
	Training and support	3	4	4

Cost	Total Cost of Software	4	3	4

Table 5: Software Scores

Main Attributes	Criteria	Weight	Supply Chain Strategist Weight	Supply Chain Guru Weight	Microsoft Excel Weight
Functionality	Model end-to-end elements of the supply chain	14	11.2	11.2	5.6
	Ability to model different inventory options	12	7.2	9.6	2.4
	Ability to model different transportation options	12	7.2	9.6	2.4
	Multiple Scenario Generation	8	3.2	8	1.6
	Visual Modelling	10	6	10	2
Integration and Use	Ability to import and export data	10	6	6	6
	Data Verification	6	2.4	4.8	4.8
	Ease of modelling and use	4	2.4	3.2	1.6
	Training and support	2	1.2	1.6	1.6
Cost	Total Cost of Software	22	17.6	13.2	17.6
		100	**64.4**	**77.2**	**45.6**

Table 6: Total Software Scores

4. Framework

4.1. Framework Features

In order to effectively evaluate the scenarios that will be generated, a framework that is applicable to the Vector Logistics distribution network is being developed. The Literature Review, together with the Project Rationale, extensively discusses the challenges that a 3PL like Vector Logistics face. The framework is established based on those aspects and it will be applied to the results of all three alternatives to directly compare the outputs of the scenarios that are generated.

In order to create an applicable framework, the main features listed below was established based on information obtained from the literature study and features that Vector Logistics considered important. Figure 18 provides a summary of the aspects that are to be evaluated. It is fundamentally based on the sections that make up the IPSF which were the arrangement, deployment and flow stages of the framework. By studying the IPSF, the various factors that make up this framework were addressed to ensure that no integral factor was left out. Although the IPSF is used for determining the criteria, it will not be used for the diagrammatic representation of the framework.

Finally, in order to make the framework more applicable, current problems experienced by South African supply chains is placed under the Risk section as these are unpredictable qualitative attributes.

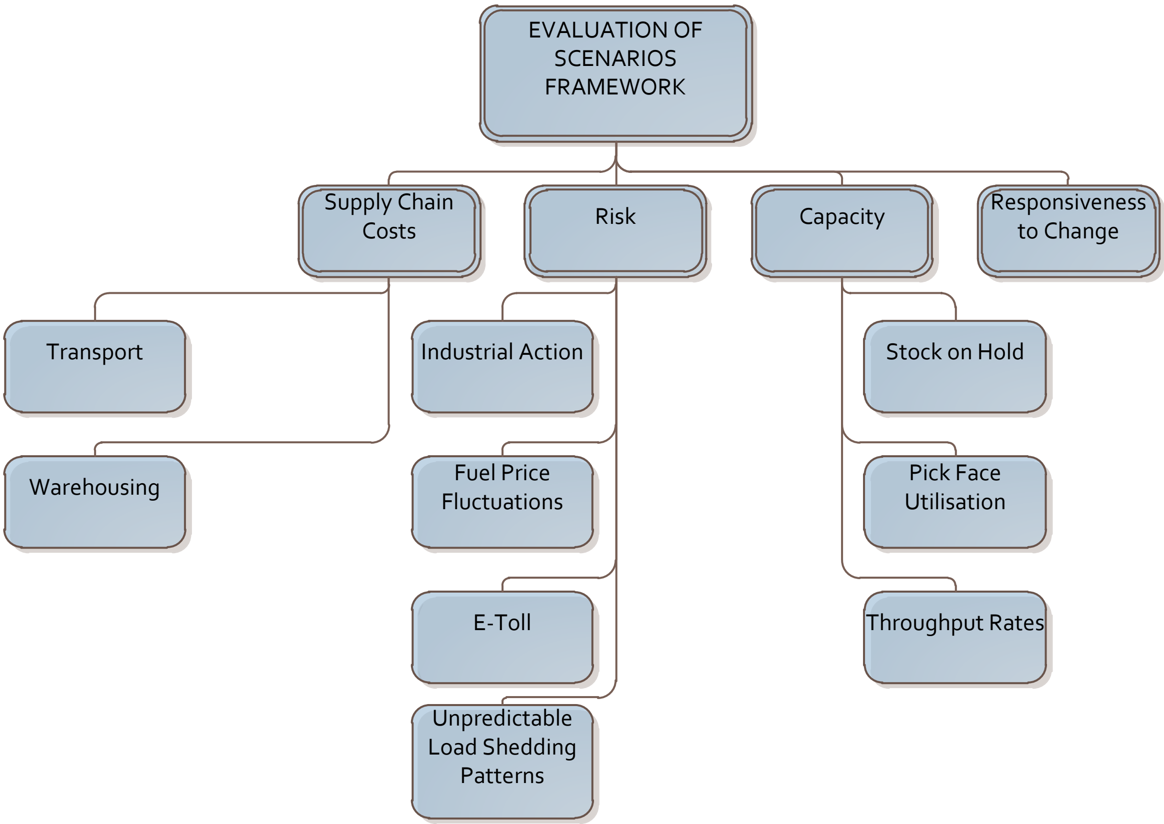

Figure 18: Evaluation of Scenarios Framework

In order to accurately determine the importance of each aspect when applied to the scenarios, it is first necessary to give a brief idea of the features that make up this framework. The table below explains this:

Framework Feature	Explanation
Transport Costs	Vendors to Distribution Centres: Costs are calculated based on the quantity transported per unit distance.
	PBCS to Distribution Centres: Costs to transport goods are fixed values based on the average cost and shipment size.
	Distribution Centres to Customers: Costs are based on the shipment size and the distance from the DC to the customer.
Warehousing Costs	The warehousing cost looks at the outbound cost which is the monetary value associated with moving one unit of a product from inventory to preparing it for shipping.
Industrial Action	As per Table 2.1 in the literature study, labour relations are a significant concern in the logistics industry. Industrial action at Vector Logistics can lead to inventory not being picked and ready for shipment on time.
Fuel Price Fluctuations	Since one of Vector Logistics main functions is transportation, fuel price fluctuations play an integral role as it has an impact on transportation costs.

E-Toll	The E-Toll system in South Africa requires vehicles to pay a certain amount every time certain roads are used, namely the national highways, especially in Gauteng.
Unpredictable Load Shedding Patterns	Vector Logistics stores mainly frozen and chilled products. Load shedding leads to the need of a generator and possible loss of quality of products.

Table 7: Framework Features

4.2. Framework Development using AHP

The Analytical Hierarchy Process is a decision making tool that will aid in this project by determining the varying importance of the features that make up the framework. For instance, if a scenario shows that there are low transportation costs, but the impact of a strike is high, one needs to decide which feature will be the deciding factor. Therefore the steps stated in Section 2.4.4 of the Literature Study will be used to execute this.

In order to determine the pair-wise comparison, the following table, as created by Thomas L. Saaty, is used to assign values:

AHP Scale	Value	Reciprocal
Equal importance	1	1.0000
Equal to moderate importance	2	0.5000
Moderate importance	3	0.3333
Moderate to strong importance	4	0.2500
Strong importance	5	0.2000
Strongly to very strong importance	6	0.1667
Very strong importance	7	0.1429
Very strong to extreme importance	8	0.1250
Extreme importance	9	0.1111

Table 8: AHP Scale (Saaty, 2008)

The main comparison shall be done according to the following diagram. Thereafter, the features that make up the main factors shall be compared as seen in Figure 20, Figure 21 and Figure 22.

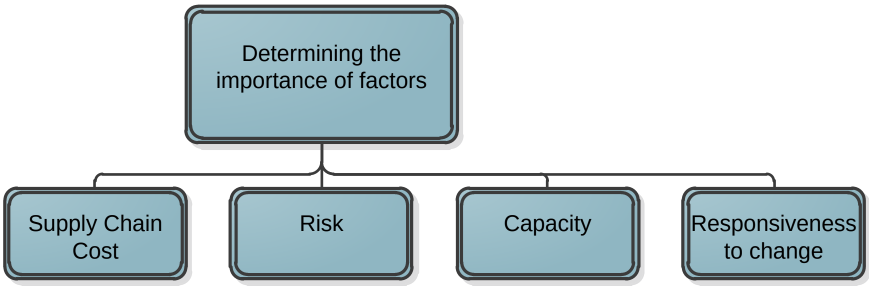

Figure 19: Hierarchy of main attributes to be considered

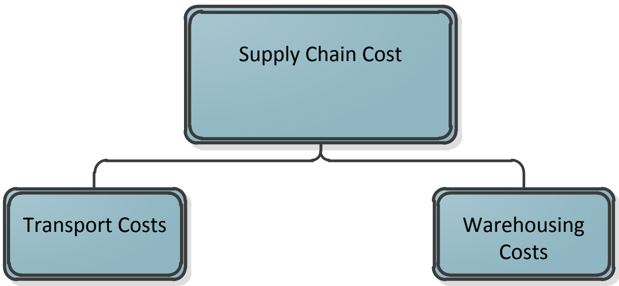

Figure 20: Supply Chain Cost Hierarchy

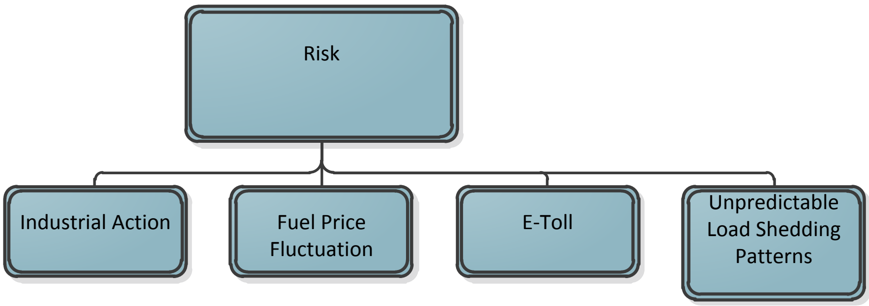

Figure 21: Risk Hierarchy

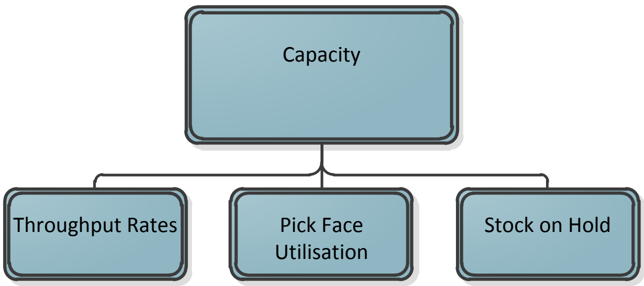

Figure 22: Capacity Hierarchy

Since the various hierarchies have been established, the next step is to determine the pair-wise comparison. This process is done by calculating the Eigen vectors of each hierarchy using the values in Table 8. The various matrices are calculated and squared. Thereafter, two iterations are completed in order to determine the Eigen Vectors accurately. The feature with the highest Eigen Vector value has the greatest importance and the feature with the lowest value can be considered the least when making decisions.

	Supply Chain Cost	Risk	Capacity	Responsiveness to change
Supply Chain Cost	1.0000	4.0000	2.0000	7.0000
Risk	0.2500	1.0000	0.2000	6.0000
Capacity	0.5000	5.0000	1.0000	6.0000
Responsiveness to change	0.1429	0.1667	0.1667	1.0000

Table 9: Relative importance of main criteria

Squared Matrix				Sum of each Row	Eigen Vector
4.0003	19.1669	5.9669	50	79.1341	0.455182
1.4574	4	1.9002	14.95	22.3076	0.128314
3.1074	13	4	45.5	65.6074	0.377376
0.4108	1.7385	0.6525	4.0007	6.8025	0.039128
				173.8516	

Table 10: Main criteria matrix squared

Squared Matrix				Sum of each row	Eigen Vector
83.0178	317.832	116.7791	958.0891	1475.718	0.467622
23.7058	94.6257	33.6518	278.9395	430.9228	0.13655
62.4977	242.6582	88.9303	713.7516	1107.8378	0.351049
7.848	30.2651	10.9748	92.2249	141.3128	0.044779
				3155.7914	

Table 11: Second iteration of the main criteria matrix

Since the difference between the Eigen Vector values in Table 10 and Table 11 are minimal, there is no need for further iterations. From this pair-wise comparison, it can be seen that Supply Chain Cost has the greatest importance and is followed by Capacity, Risk and Responsiveness to Change, in that particular order.

The next step in establishing the framework more accurately is to conduct the pairwise-comparison of the sub-criteria involved.

	Transport Costs	Warehousing Costs
Transport Costs	1	2
Warehousing Costs	0.5	1

Table 12: Relative importance of Supply Chain Cost criteria

Squared Matrix		Sum of each row	Eigen Vector
2	4	6	0.66666667
1	2	3	0.33333333
		9	

Table 13: Supply Chain Cost criteria matrix squared

Squared Matrix		Sum of each row	Eigen Vector
8	16	24	0.66666667
4	8	12	0.33333333
		36	

Table 14: Second iteration of the Supply Chain Cost criteria matrix

In terms of supply chain cost, transportation costs have greater importance than the warehousing costs. This is due to the fact that transportation is a main function of Vector Logistics and has a greater number of factors affecting it such as the risk factors to be discussed in the next pair-wise comparison. Without the function of transporting a product to a customer, the business would not function.

	Industrial Action	Fuel Price Fluctuation	E-Toll	Unpredictable Load Shedding Patterns
Industrial Action	1	0.5	3	2
Fuel Price Fluctuation	2	1	2	4
E-Toll	0.333333333	0.5	1	0.5
Unpredictable Load Shedding Patterns	0.5	0.25	2	1

Table 15: Relative importance of the Risk criteria

Squared Matrix				Sum of each row	Eigen Vector
4	3	11	7.5	25.5	0.2773
6.6666	4	18	13	41.6666	0.453104
1.9166	1.2917	4	3.6666	10.8749	0.118259
2.1666	1.75	6	4	13.9166	0.151336
				91.9581	

Table 16: Risk criteria matrix squared

Squared Matrix				Sum of each row	Eigen Vector
73.3319	51.3337	187	139.3326	450.9982	0.280014
115.9974	82.0004	295.3326	219.9983	713.3287	0.442889
31.8881	22.4999	82.3328	60.4993	197.2201	0.122449
40.4989	28.25	103.3326	76.9991	249.0806	0.154648
				1610.6276	

Table 17: Second iteration of the Risk criteria matrix

According to the calculations of the importance of the various sub-criteria that make up risk, fuel price fluctuation holds the greatest importance followed by Industrial Action, Unpredictable Load Shedding Patterns and finally the E-Tolls.

This feature relates to transportation costs being the most important to consider when looking at Supply Chain Costs. The fuel price has a large impact on the price that Vector Logistics demands from its Vendors and Customers. A great fluctuation in fuel cost will require Vector Logistics to forecast a price to make sure that they do not experience a loss whilst in partnership with a company. Since Industrial Action is currently a large problem in South Africa, it has the second highest importance. This factor of risk can stop the whole distribution network from functioning. Finally, unpredictable load shedding and E-tolls are the bottom two factors in terms of relative importance. Load shedding can be dealt with the use of generators and E-Tolls are something constant that will not change, therefore the risk factor is low.

	Throughput Rates	Pick face Utilisation	Stock on Hold
Throughput Rates	1	0.5	2
Pick face Utilisation	2	1	2
Stock on Hold	0.5	0.5	1

Table 18: Relative importance of capacity criteria

Squared Matrix			Sum of each row	Eigen Vector
3	2	5	10	0.310078
5	3	8	16	0.496124
2	1.25	3	6.25	0.193798
			32.25	

Table 19: Capacity criteria matrix squared

Squared Matrix			Sum of each row	Eigen Vector
29	18.25	46	93.25	0.310833
46	29	73	148	0.493333
18.25	11.5	29	58.75	0.195833
			300	

Table 20: Second iteration of the capacity criteria matrix

As it was mentioned previously in the document, capacity is a large problem that the company is attempting to manage; therefore Pickface Utilisation has the greatest importance as it needs to be managed efficiently. It affects both Stock on Hold and Throughput Rates immensely.

4.3. Vector Logistics Framework for Decision Making

Based on the information collected and determined in this section, the following framework will be used for decision making and consideration by Vector Logistics. If the situation arises where a certain factor does not need to be considered in a scenario, it may be ignored.

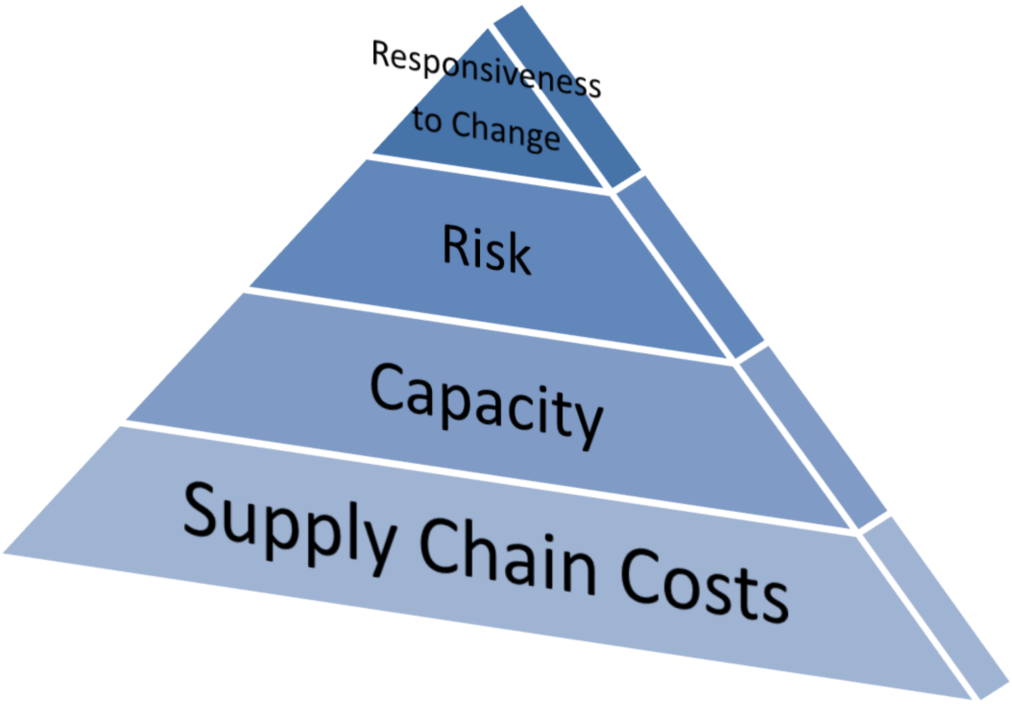

Figure 23: Main Criteria Framework

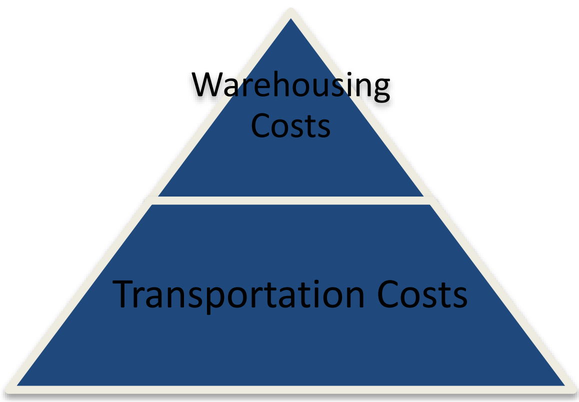

Figure 24: Supply Chain Costs Sub-criteria Framework

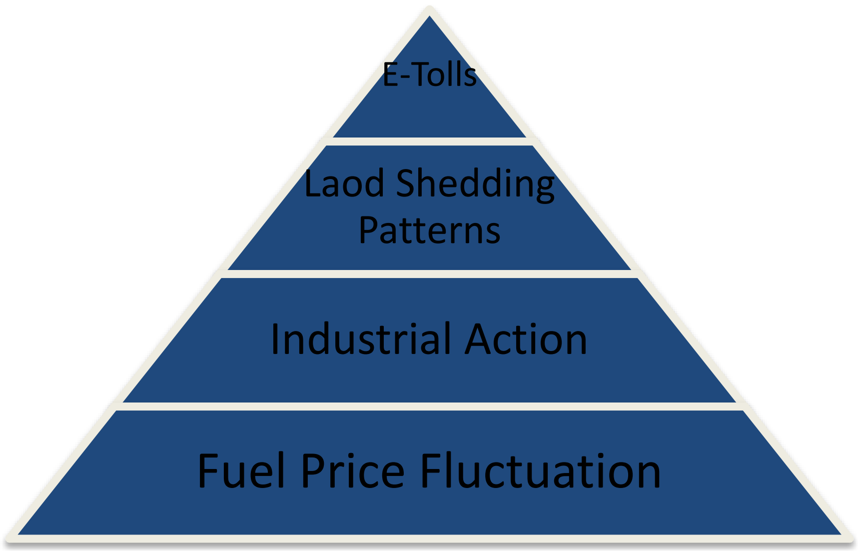

Figure 25: Risk Sub-criteria Framework

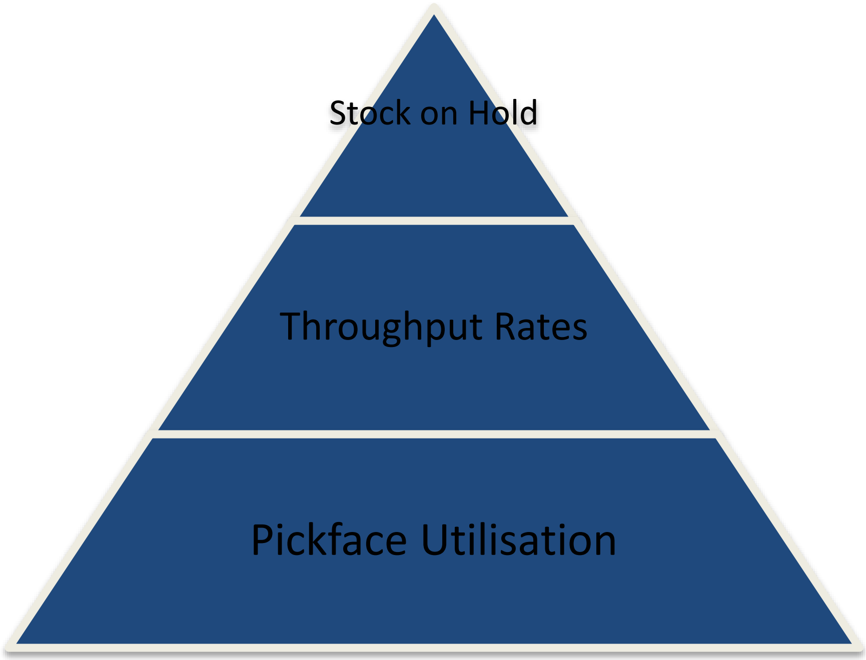

Figure 26: Capacity Sub-criteria Framework

The diagrammatic representation of the framework is fairly simple with the concept of the base of the pyramids being the most important factors to consider. As one travels up the levels, the importance of the factors decreases.

5. Model Development in Supply Chain Guru

5.1. Basic Data for the Distribution Network

In order to model the Vector Logistics distribution network accurately, a baseline model is developed in Supply Chain Guru based on the current network. The baseline model is beneficial as it allows one to directly validate, assess and compare the performance of scenarios to that of the current network.

As mentioned in the Background, Vector Logistics has six different business types, but due to limitations and the scope, this project is focusing on the Principal Secondary Distribution sector. The sector in this case study is made up of ten products and one hundred sites. The ten products are sourced from six different vendors and are classified according to storage temperatures. The one hundred sites are made up of the different vendor locations, existing distribution centres and eighty customer locations. The flow of the products is such that five out of the six vendors have the responsibility to transport its products to the Vector Logistics distribution centre. From that point onwards, it is the responsibility of Vector Logistics to deliver the products to the customers. In the case of Rainbow Farms products, the 3PL is responsible for the distribution of its goods from the Plant Based Cold Storage (PBCS) location to the distribution centre and finally to the customer. The customers are situated across South Africa and are made up of major chain store groups. Table 21, Table 22 and Table 23, summarise these details.

Vendors	Products
RAINBOW FARMS (PTY)	Chilled
	Frozen
	Quick Frozen
	Fresh
IRVIN & JOHNSON LTD	Frozen
PIEMANS PANTRY	Frozen
WILLOWTON GROUP CAPE	Chilled
NATURES GARDEN (PTY)	Frozen
SUPREME POULTRY (PTY)	Frozen
	Quick Frozen

Table 21: Vendors and products

Major Customer Groups
Checkers Hyper
Makro
Pick n Pay Hyper
Spar

Table 22: Customer groups

Distribution Centres
Bloemfontein
George
Midrand
Nelspruit

Newcastle
Peninsula
Polokwane
Port Elizabeth
Thekwini

Table 23: Distribution Centre Locations

5.2. General Sourcing, Transportation and Inventory Policies

Using the Geocoding function in Supply Chain Guru, the various sites are modelled using physical addresses and geographical co-ordinates. The sites are distinguished from each other based on their function in the distribution network, that is to say the customers, distribution centres, vendors and Plant Based Cold Storage locations. Figure 28 depicts the spread of the sites across South Africa. Since the customers are major stores as mentioned previously, it can be seen that customer sites are located in major metropolitan areas of South Africa, namely the Western Cape and Gauteng, but there are a few scattered elsewhere.

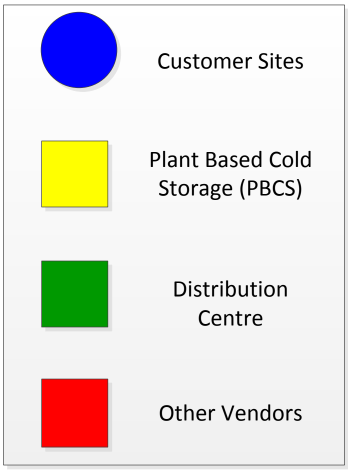

Figure 27: Key for site location

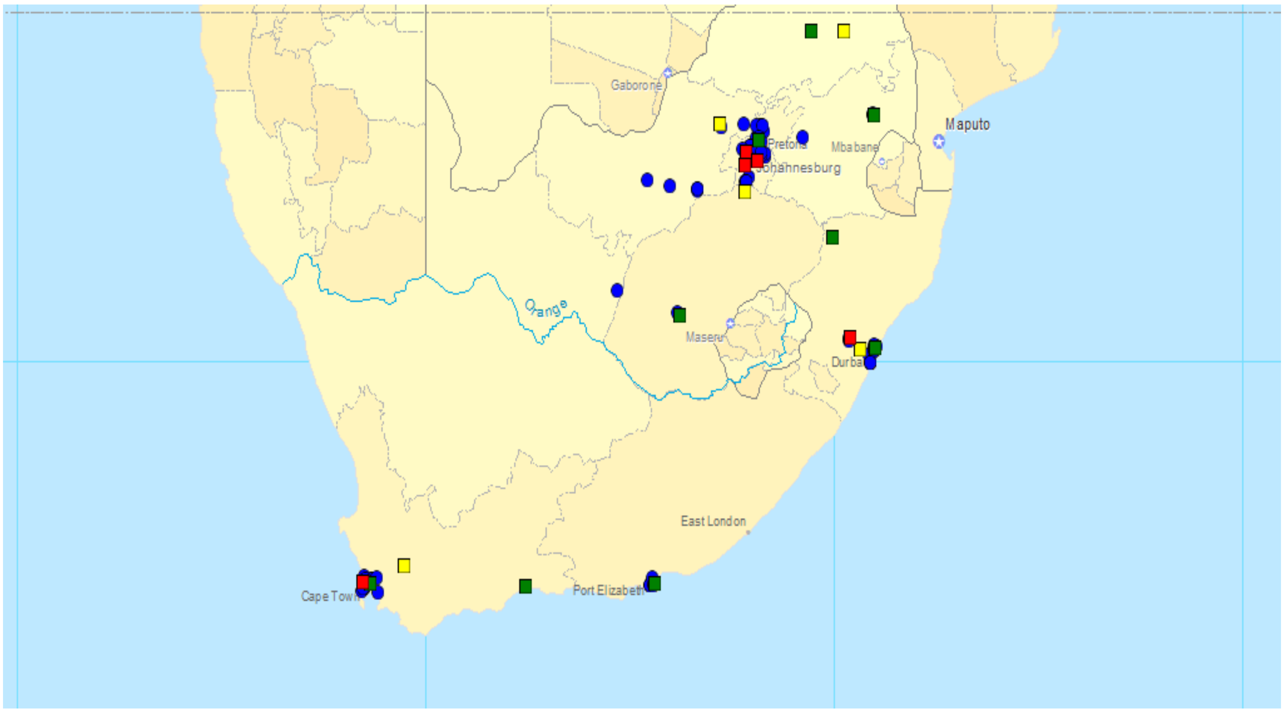

Figure 28: Current site locations

Once all the sites had been created, general sourcing policies needed to be applied. Sourcing policies allows one to model from which sites products can be sourced to the distribution centre or customer. For Vector Logistics, the sourcing policies were modelled such that:

- Vendors act as sources that make the product, which includes Rainbow Farms (Pty).
- The distribution centres then source the products from the vendors and send it to either other distribution centres or customers.
- Customers source their required products from the distribution centres.

Figure 29 depicts the sourcing flows between the various sites.

After the general sourcing policies had been established, transportation policies were implemented. Transportation policies model all routes that products must travel through, the mode of transport, shipment sizes and costs associated with these activities. Due to Supply Chain Guru's geocoding abilities, the model uses actual roads rather than the straight line method where possible. This leads to greater accuracy when the model is optimised. Figure 30 depicts all the routes that the general transportation policies implemented. The transportation policies are modelled as follows:

- Goods are transported from the vendor or PBCS to the distribution centre with the average cost based on quantity-distance. In other words, the cost to transport one unit, one kilometre. The cost to transport from a vendor to a distribution centre is zero since it is the vendors' responsibility.
- The goods are then modelled to be transported between distribution centres. The average cost of this section of the network is fixed based on the shipment size and distance covered.

- Finally goods are transported to the customer with the average cost calculated per kilometre travelled.

Finally, the inventory policies specify how inventory needs to be managed at the sites which, in the case of Vector Logistics, are at the nine distribution centres. In the case of this model, the inventory policy specifies the outbound costs of the various products from the numerous distribution centres. The outbound cost is the amount it costs to move one unit of inventory in stock to preparing it for shipment.

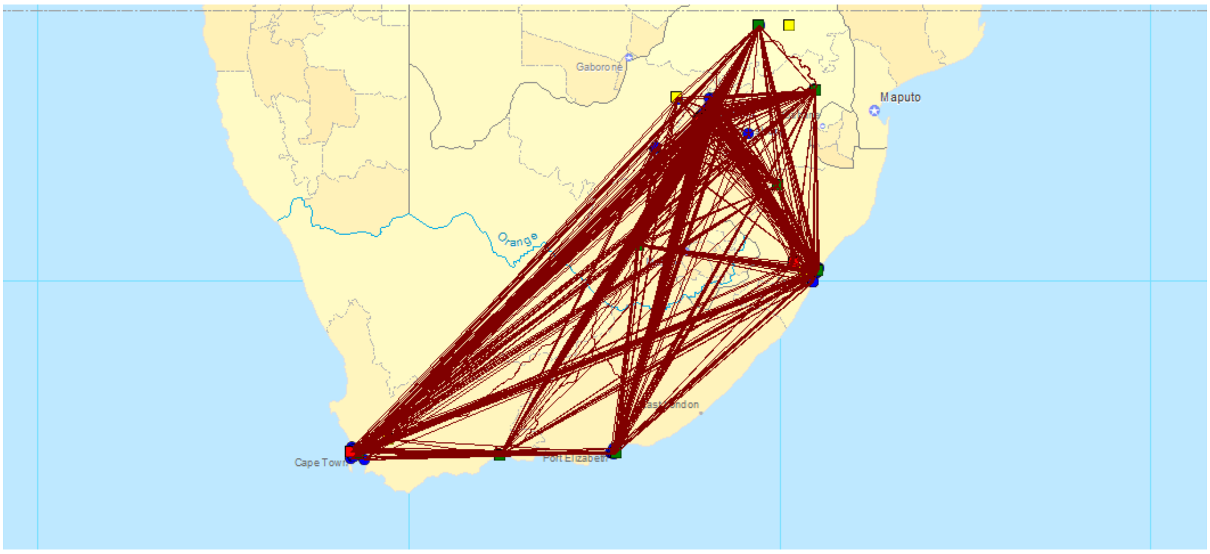

Figure 29: General Sourcing Policies

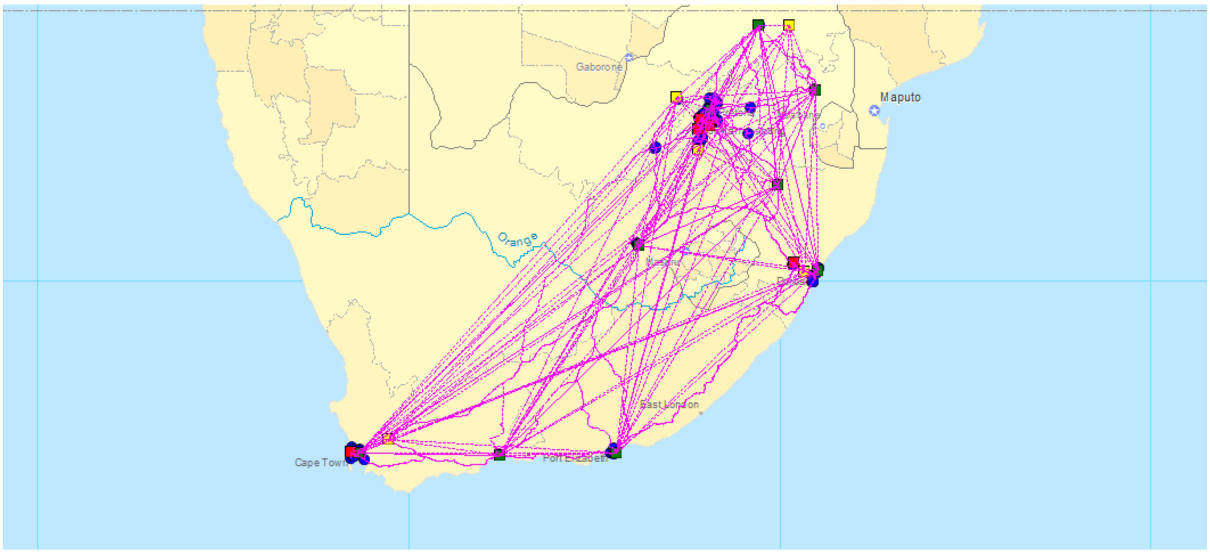

Figure 30: General Transportation Policies

5.3. Specific Sourcing and Transportation Constraints

Initially, sourcing and transportation policies were set up such that all vendors could deliver to all the distribution centres and all customers could be serviced by all distribution centres, but these policies were modelled so that they can be used in the process of creating scenarios for comparison purposes later in the project. In reality, this is not the case as distribution centres are serviced by certain vendors depending on the location and volume required. The following are the sourcing and transportation constraints modelled in the baseline:

- Rainbow Farms (Pty) can only produce an X amount of each product at each PBCS facility. Initially, the general sourcing policy was chosen such that a distribution centre was serviced by the vendor source that had the most inventory of a product on hand. The specific constraint seen below in Table 24 required the sourcing policy to now be based on probability proportions.

PBCS Facility	Product Type	Proportion
PBCS_Worcester	Chilled	0.00
PBCS_Rustenburg	Chilled	0.31
PBCS_Hammarsdale	Chilled	0.54
PBCS_Wolwehoek	Chilled	0.15
PBCS_Worcester	Frozen	0.08
PBCS_Rustenburg	Frozen	0.32
PBCS_Hammarsdale	Frozen	0.60
PBCS_Worcester	Quick Frozen	0.10
PBCS_Rustenburg	Quick Frozen	0.61
PBCS_Hammarsdale	Quick Frozen	0.29
PBCS_Worcester	Fresh	0.57
PBCS_Hammarsdale	Fresh	0.43

Table 24: Proportion of products produced at different PBCS facilities

- Rainbow Farms, Willowton Group and Piemans Pantry can deliver products to all distribution centres.
- Irvin & Johnson Ltd (I&J) can deliver products to all distribution centres except George, Newcastle, Nelspruit and Polokwane.
- Natures Garden can deliver products to distribution centres in Midrand, Peninsula and Thekwini.
- Supreme Poultry can deliver products to all the distribution centres except Nelspruit and Polokwane.
- Pick n Pay Hyper customers can only be serviced by distribution centres in George, Midrand, Peninsula, Newcastle, Port Elizabeth and Thekwini.
- A customer can only be serviced by one distribution centre. This alleviates the need for more than one delivery being made to a customer which leads to fewer costs.
- All distribution centres can deliver to all distribution centres with the Vector Logistics distribution network.

The above stated constraints can be modelled mathematically using the Operations Research approach discussed in the Literature Review, but Supply Chain Guru has these functions built into the program therefore alleviating the need for mathematical programming.

5.4. Alternative Modelled Solutions

5.4.1. Modelled Scenarios

As mentioned in the Project Aim, the purpose of this project is to design an optimal network that will be able to deal with constraints on capacity and find solutions to aid Vector Logistics to grow as a 3PL. In order to do this, a number of possible solutions need to be considered.

The company has decided that four different scenarios will be developed, namely:

- The baseline will be optimised to see if a feasible solution can be reached by running it the way that it currently is.
- Five hub scenario where only five distribution centres will be running and the other 4 shall act as satellite facilities.
- Five hub and a Cross Dock scenario where there shall be cross docks for vendors and PBCS to compensate for the decrease in distribution centres.
- Five hub and a Cross Dock scenario where there are no flow constraints in place. This is to see the impact that flow constraints have as compared to the previous scenario discussed.

All four of these scenarios tie into network design decisions that need to be considered. In Figure 10, which looks at network specific aspects to consider, one needs to contemplate whether to use direct or indirect distribution routes and the ideal number and location of sites. The four scenarios stated above will address these aspects and other network design issues as discussed in the Literature Review, namely:

- The number and type of facilities such as hubs and cross docks
- The flow path and quantity that products will follow
- The customers that each facility will service
- The capacity of the facilities

The scenarios, as listed above, will produce outputs in the form of capacity values, inter-facility flows and supply chain costs that will be evaluated, against each other and the current distribution network, to see which scenario solves the problem in the best manner.

5.4.2. Optimised Baseline Scenario

The following constraints were applied to optimise the baseline model:

- The general transportation policy that allows all distribution centres to deliver all products to all customers is switched off and excluded from the model.
- The flow constraint that requires a specific distribution centre to deliver an X amount of a certain product to a customer is switched off and excluded from the model.

- The transportation policy that requires Pick n Pay Hyper customers to be serviced by distribution centres in George, Midrand, Peninsula, Newcastle, Port Elizabeth and Thekwini is switched on and included in the model.
- The flow count constraint is included and switched on in the model that states that a customer can only be serviced by one distribution centre.

The baseline model has been optimised in this way to allow for more realistic constraints.

5.4.3. 5 Hub Scenario

For this scenario, the exact same constraints were applied as was done for the optimised baseline, but there was one more constraint which was the following:

Distribution centres in the following sites were switched off and excluded from the model, namely:

- George
- Newcastle
- Polokwane
- Nelspruit

Therefore the 5 hubs are:

- Midrand
- Port Elizabeth
- Peninsula
- Thekwini
- Bloemfontein

These 5 hubs were chosen as they are considered to be in central areas when compared to the locations of the numerous customers.

5.4.4. 5 Hub and Cross Dock Scenario

Once again, this scenario also required that the constraints as specified for the optimised baseline be applied. The following constraints are added to this scenario:

- The sourcing policy whereby the PBCS delivers to the various distribution centres, based on probability proportions, is turned off and excluded.
- To compensate the above constraint, another constraint has been modelled that requires the various PBCS to deliver only to the specified 5 hubs with the probability proportions as stated earlier.
- Vendors Supreme Poultry, Piemans Pantry and Willowton Group cannot deliver to all distribution centres.
- The above stated three vendors can now only deliver to the 5 hubs as listed previously.

Constraints relating to the vendors and the PBCS are changed to create the cross dock scenario.

5.4.5. 5 Hub and Cross Dock with no Flow Constraints

This scenario includes the constraints as mentioned in the 5 Hub and Cross Dock scenario, but does not include the flow constraints as listed in the optimised baseline scenario. Therefore the only constraints applicable to this scenario are the following:

- The sourcing policy whereby the PBCS delivers to the various distribution centres, based on probability proportions, is turned off and excluded.
- To compensate the above constraint, another constraint has been modelled that requires the various PBCS to deliver only to the specified 5 hubs with the probability proportions as stated earlier.
- Vendors Supreme Poultry, Piemans Pantry and Willowton Group cannot deliver to all distribution centres.
- The above stated three vendors can now only deliver to the 5 hubs as listed previously.

The diagram on the following page shows the above discussed scenarios as modelled in Supply Chain Guru.

Name	Table	Column		Value	Filter
1. Baseline Optimised (1 sub-scenarios)					
Turn off DC to STP Baseline Constraints	TransportationPolicies	TransportationPolicyStatus	=	Exclude	([SourceSite] LIKE 'DC%') AND ([DestinationSite] LIKE 'All[_]Customers%')
Turn on DC to STP Optimisation Constraints	TransportationPolicies	TransportationPolicyStatus	=	Include	([TransportationPolicyStatus] LIKE 'Exclude%') AND ([SourceSite] LIKE 'DC%')
Turn off DC to STP Flow Constraints	AggregateFlowConstraints	AggregateFlowConstraintSta...	=	Exclude	([SourceSite] LIKE 'DC%') AND ([DestinationSite] LIKE 'STP%')
Turn on DC to STP Flow Count Constraints	AggregateFlowCountConstr...	AggregateFlowCountConstr...	=	Include	([SourceSite] LIKE 'All[_]DC%')
2. 5 Hub Scenario (1 sub-scenarios)					
Turn off DC to STP Baselines Constraints 5 Hub	TransportationPolicies	TransportationPolicyStatus	=	Exclude	([SourceSite] LIKE 'DC%') AND ([DestinationSite] LIKE 'All[_]Customers%')
Turn on DC to STP Optimisation Constraints 5 Hub	TransportationPolicies	TransportationPolicyStatus	=	Include	([TransportationPolicyStatus] LIKE 'Exclude%') AND ([SourceSite] LIKE 'DC%')
Turn off DC to STP Flow Constraints 5 Hub	AggregateFlowConstraints	AggregateFlowConstraintSta...	=	Exclude	([SourceSite] LIKE 'DC%') AND ([DestinationSite] LIKE 'STP%')
Turn on DC to STP Flow Count Contraints 5 Hub	AggregateFlowCountConstr...	AggregateFlowCountConstr...	=	Include	([SourceSite] LIKE '%DC%')
Exclude sites except 5 Hubs	Sites	SiteStatus	=	Exclude	([SiteName] LIKE 'DC[_]George%' OR [SiteName] LIKE 'DC[_]Newcastle%' OR [SiteName] LIKE 'DC[_]Polokwan...
3. 5 Hub and Cross Dock Optimised (1 sub-scenarios)					
Turn off PBCS to DC Sourcing Policy	SourcingPolicies	SourcingPolicyStatus	=	Exclude	([SourceName] LIKE '%PBCS%') AND ([SiteName] LIKE '%All[_]DC%')
Turn on PBCS to 5 Hub DC Sourcing Policy	SourcingPolicies	SourcingPolicyStatus	=	Include	([SourceName] LIKE '%PBCS%') AND ([SiteName] LIKE '%5 Hub%')
Turn off DC to STP Baseline Constraints 5 Hub an...	TransportationPolicies	TransportationPolicyStatus	=	Exclude	([SourceSite] LIKE 'DC%') AND ([DestinationSite] LIKE 'All[_]Customers%')
Turn on DC to STP Optimisation Constraints 5 Hu...	TransportationPolicies	TransportationPolicyStatus	=	Include	([SourceSite] LIKE 'DC%') AND ([DestinationSite] LIKE '%PNP%')
Turn off DC to STP Flow Constraints 5 Hub and Cr...	AggregateFlowConstraints	AggregateFlowConstraintSta...	=	Exclude	([SourceSite] LIKE 'DC%') AND ([DestinationSite] LIKE 'STP%')
Turn on DC to STP Flow Count Constraints 5 Hub...	AggregateFlowCountConstr...	AggregateFlowCountConstr...	=	Include	([SourceSite] LIKE 'All[_]DC%')
Turn off Vendor to DC	TransportationPolicies	TransportationPolicyStatus	=	Exclude	([SourceSite] LIKE '%VEN%') AND ([TransportationPolicyStatus] LIKE 'Include%') AND ([DestinationSite] NOT LI...
Turn on Vendor to DC 5 Hub and Cross Dock	TransportationPolicies	TransportationPolicyStatus	=	Include	([SourceSite] LIKE '%VEN%') AND ([DestinationSite] LIKE '%5 Hub%')
4. 5 Hub and Cross Dock without Flow Constraints (1 sub-scenarios)					
Turn off PBCS to DC Sourcing	SourcingPolicies	SourcingPolicyStatus	=	Exclude	([SourceName] LIKE '%PBCS%') AND ([SiteName] LIKE 'All[_]DCs%')
Turn on PBCS to DC Cross Dock	SourcingPolicies	SourcingPolicyStatus	=	Include	([SourceName] LIKE '%PBCS%') AND ([SiteName] LIKE '%DCs[_]5 Hub%')
Turn off Vendor to DC Specific	TransportationPolicies	TransportationPolicyStatus	=	Exclude	([SourceSite] LIKE '%VEN%') AND ([TransportationPolicyStatus] LIKE 'Include%') AND ([DestinationSite] NOT LI...
Turn on Vendor to DC	TransportationPolicies	TransportationPolicyStatus	=	Include	([SourceSite] LIKE '%VEN%') AND ([DestinationSite] LIKE '%5 Hub%')

Figure 31: Scenarios modelled in Supply Chain Guru

5.5. Validation of the Model

In order to ensure that the distribution network modelled is accurate, it was necessary to validate the baseline model. This was done by comparisons with the data made available by Vector Logistics. A similar project was being conducted at the company therefore all applicable information was compared and validated to be correct.

6. Results and Application

6.1. Scenario Results

Due to confidentiality reasons, actual monetary and inventory values are not given in the results below, but rather an index system is used to indicate the relative differences between values with the total baseline values equal to 1.

Scenario	Source	Flow Units	Transportation Cost	In transit Inventory Holding Cost
5 Hub and Cross Dock Optimised	PBCS_Hammarsdale	0.44	0.38	0.44
	PBCS_Rustenburg	0.42	0.32	0.32
	PBCS_Wolwehoek	0.04	0.06	0.03
	PBCS_Worcester	0.10	0.19	0.21
5 Hub and Cross Dock Optimised Total		**1.00**	**0.95**	**0.99**
5 Hub and Cross Dock without Flow Constraints	PBCS_Hammarsdale	0.44	0.38	0.44
	PBCS_Rustenburg	0.42	0.32	0.32
	PBCS_Wolwehoek	0.04	0.06	0.03
	PBCS_Worcester	0.10	0.19	0.21
5 Hub and Cross Dock without Flow Constraints Total		**1.00**	**0.94**	**0.99**
5 Hub Scenario	PBCS_Hammarsdale	0.44	0.38	0.44
	PBCS_Rustenburg	0.42	0.32	0.32
	PBCS_Wolwehoek	0.04	0.06	0.03
	PBCS_Worcester	0.10	0.19	0.21
5 Hub Scenario Total		**1.00**	**0.95**	**0.99**
Baseline	PBCS_Hammarsdale	0.44	0.41	0.44
	PBCS_Rustenburg	0.42	0.32	0.32
	PBCS_Wolwehoek	0.04	0.07	0.03
	PBCS_Worcester	0.10	0.20	0.21
Baseline Total		**1.00**	**1.00**	**1.00**
Baseline Optimised	PBCS_Hammarsdale	0.44	0.41	0.44
	PBCS_Rustenburg	0.42	0.33	0.32
	PBCS_Wolwehoek	0.04	0.07	0.03
	PBCS_Worcester	0.10	0.20	0.21
Baseline Optimised Total		**1.00**	**1.01**	**1.00**

Table 25: Inter facility PBCS to DC flow

Table 25 looks at the flow of products from the PBCS to the various distribution centres. From the total index values obtained from each scenario, it can be seen that the number of units flowing does not change. In terms of transportation cost, the 5 Hub and Cross Dock without any flow constraints obtain the lowest index value. This is due to the fact that the hubs are close to the areas in which the PBCS's are located. Inventory holding cost remains approximately the same through all scenarios.

Scenario	Source	Flow Units	Outbound Warehousing Cost	In transit Inventory Holding Cost	In Transit Inventory	Transportation Cost	Total Cost
5 Hub and Cross Dock Optimised	DC_Midrand D	1.97	3.04	1.73	1.56	1.62	1.97
	DC_Peninsula	0.19	0.10	0.28	0.34	0.30	0.25
	DC_Thekwini	0.16	0.03	0.22	0.26	0.19	0.15
5 Hub and Cross Dock Optimised Total		**2.32**	**3.18**	**2.23**	**2.16**	**2.12**	**2.38**
5 Hub and Cross Dock without Flow Constraints	DC_Bloemfontein	0.00	0.00	0.00	0.00	0.00	0.00
	DC_Midrand D	2.09	3.21	1.91	1.72	1.76	2.12
	DC_Peninsula	0.33	0.15	0.40	0.44	0.46	0.38
	DC_Thekwini	0.06	0.01	0.09	0.10	0.08	0.06
5 Hub and Cross Dock without Flow Constraints Total		**2.48**	**3.38**	**2.40**	**2.27**	**2.30**	**2.57**
5 Hub Scenario	DC_Peninsula	0.19	0.10	0.28	0.34	0.30	0.25
	DC_Thekwini	0.16	0.03	0.22	0.26	0.19	0.15
5 Hub Scenario Total		**0.35**	**0.14**	**0.50**	**0.60**	**0.50**	**0.41**
Baseline	DC_Bloemfontein	0.00	0.00	0.00	0.00	0.00	0.00
	DC_Midrand D	0.72	0.88	0.62	0.56	0.60	0.67
	DC_Peninsula	0.22	0.11	0.29	0.33	0.32	0.27
	DC_Thekwini	0.06	0.01	0.09	0.10	0.08	0.06
Baseline Total		**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**
Baseline Optimised	DC_Midrand D	0.69	0.85	0.60	0.54	0.58	0.64
	DC_Peninsula	0.19	0.10	0.28	0.34	0.30	0.25
	DC_Thekwini	0.16	0.03	0.22	0.26	0.19	0.15
Baseline Optimised Total		**1.04**	**0.98**	**1.10**	**1.14**	**1.07**	**1.05**

Table 26: Inter facility flow of DC to DC

In Table 26, the flow of products is studied from one distribution centre to another. In terms of the actual flow of units, the scenario that enforces the 5 hub and cross dock with no flow constraints scores the highest with the optimised 5 hub and cross dock scenario, just behind it, scoring 2.32 as compared to the baseline. The outbound warehousing cost is much higher as compared to the baseline in all scenarios except in the 5 hub scenario and the optimised baseline. The aim is to have a significantly lower amount and the 5 hub scenario scores a

0.14. This may be due to the fact that less distribution centres are now being utilised. The warehousing cost of this particular scenario may be low, but the scenario also has a low flow of units. The in transit inventory and the holding cost associated with it relates directly to the flow of units. In other words, the higher the flow of units, the higher the inventory and holding cost. In the cases above where the flow of units is high, the transportation cost associated with it is also high and vice versa.

Scenario	Source	Flow Units	Outbound Warehousing Cost	Transportation Cost
5 Hub and Cross Dock Optimised	DC_Bloemfontein	0.02	0.01	0.00
	DC_Midrand D	0.61	0.86	0.65
	DC_Nelspruit	0.02	0.00	0.00
	DC_Peninsula	0.11	0.05	0.10
	DC_Polokwane	0.01	0.00	0.00
	DC_Port Elizabeth	0.06	0.06	0.01
	DC_Thekwini	0.18	0.01	0.12
5 Hub and Cross Dock Optimised Total		**1.00**	**0.99**	**0.89**
5 Hub and Cross Dock without Flow Constraints	DC_Bloemfontein	0.01	0.00	0.00
	DC_George	0.00	0.00	0.02
	DC_Midrand D	0.62	0.87	0.74
	DC_Nelspruit	0.02	0.00	0.00
	DC_Newcastle	0.00	0.00	0.00
	DC_Peninsula	0.11	0.05	0.10
	DC_Polokwane	0.01	0.00	0.00
	DC_Port Elizabeth	0.05	0.05	0.01
	DC_Thekwini	0.18	0.01	0.12
5 Hub and Cross Dock without Flow Constraints Total		**1.00**	**1.00**	**1.00**
5 Hub Scenario	DC_Bloemfontein	0.02	0.01	0.00
	DC_Midrand D	0.63	0.90	0.82
	DC_Peninsula	0.11	0.05	0.10
	DC_Port Elizabeth	0.06	0.06	0.01
	DC_Thekwini	0.18	0.01	0.12
5 Hub Scenario Total		**1.00**	**1.03**	**1.06**
Baseline	DC_Bloemfontein	0.01	0.00	0.00
	DC_George	0.00	0.00	0.02
	DC_Midrand D	0.62	0.87	0.74
	DC_Nelspruit	0.02	0.00	0.00
	DC_Newcastle	0.00	0.00	0.00
	DC_Peninsula	0.11	0.05	0.10
	DC_Polokwane	0.01	0.00	0.00

	DC_Port Elizabeth	0.05	0.05	0.01
	DC_Thekwini	0.18	0.01	0.12
Baseline Total		**1.00**	**1.00**	**1.00**
Baseline Optimised	DC_Bloemfontein	0.02	0.01	0.00
	DC_Midrand D	0.60	0.86	0.64
	DC_Nelspruit	0.02	0.00	0.01
	DC_Peninsula	0.11	0.05	0.10
	DC_Polokwane	0.01	0.00	0.00
	DC_Port Elizabeth	0.06	0.06	0.01
	DC_Thekwini	0.18	0.01	0.12
Baseline Optimised Total		**1.00**	**0.99**	**0.89**

Table 27: Costs associated with flow from DC to Customer

In Table 27, there are not many significant differences between the various scenarios except the transportation costs. Both the optimised baseline scenario and the optimised 5 hub and cross dock scenario score a 0.89 as compared to the 1 of the baseline. Therefore transportation costs are lower when delivering to the customer. This is due to the constraints placed on the model and the fact that there are less distribution centres.

Scenario	Throughput Level	Total Outbound Transportation Cost	Total Inbound Transportation Cost	Total Warehousing Cost
5 Hub and Cross Dock Optimised Total	1.01	0.94	0.98	1.02
5 Hub and Cross Dock without Flow Constraints Total	1.01	0.98	0.97	1.03
5 Hub Scenario Total	1.00	0.99	0.95	1.01
Baseline Total	1.00	1.00	1.00	1.00
Baseline Optimised Total	1.00	0.96	1.01	0.99

Table 28: Scenario Facility Summary

Finally, Table 28 looks at the throughput level which is an integral part as mentioned earlier in the document. Although the difference is not significant, there is a higher throughput rate in the 5 hub and cross dock scenario. The outbound transportation cost is also significantly lower when compared to the other scenarios.

6.2. Application of the Framework

Figure 23 through to Figure 26 depicts the main framework and the sub-criteria framework that needs to be applied to the various scenarios. The following points discuss each scenario by applying the framework features.

Optimised Baseline:

- Supply Chain Cost: Transportation costs remain approximately the same when compared to the baseline except in the instance where costs associated with the movement of goods from the distribution centre to the customer, are looked at. In terms of warehousing costs, it remains constant as well.
- Capacity: In terms of Pickface Utilisation, the flow of units is a good indication. The flow of units between distribution centres is 1.04 which is a slight improvement compared to the baseline. As per the tables above, the throughput rate and the stock on hold values are exactly the same as the baseline model.
- Risk: Since the optimised baseline model is extremely similar to the original baseline, risk is minimal in all four sub-criteria since not much change is occurring.
- Responsiveness to change: This is a qualitative measure whereby the optimised baseline does have the ability to change, but it is fundamentally the same as the baseline model.

5 Hub:

- Supply Chain Cost: The transportation costs are significantly lower with the cost associated with the movement between distribution centres being only half of what it was compared to the baseline model. Warehousing cost is extremely low at 0.14, for movement between distribution centres, but it is slightly higher at 1.03 when looking at cost of movement from the distribution centre to the customer.
- Capacity: In terms of Pickface Utilisation, the flow of units is extremely low at 0.35. This is the reason for transportation and warehousing costs also being low. The throughput rate remains exactly the same as the baseline model while there is less stock on hold as well.
- Risk: By having 5 hubs, the need to travel greater distances has been alleviated which also means less impact of fuel price fluctuations on the business. Since there will be the need to close down 4 of the distribution centres, the chance of industrial action is extremely high, unless it is dealt with and executed in a delicate manner. The impact of load shedding would be greater in a 5 hub instance since more goods are being placed at the hubs. Finally, since fewer roads are being travelled, the impact of E-Tolls is minimal.
- Responsiveness to change: The 5 hub scenario is a huge change as it is. If the company decides to close down the other distribution centres, but still own it, they can be opened again if the need arises.

5 Hub and Cross Dock without Flow Constraints

- Supply Chain Cost: Transportation costs are twice that of the baseline model and warehousing costs are 3.38 times greater when looking at the flow between distribution centres. In all other instances, it remains the same.
- Capacity: The flow of units is more than twice that of the baseline model. The throughput rate of the facilities in this scenario is 1.01 of the baseline, which can still

be considered as an improvement. Since the throughput rate is high, the stock on hold value is also more than twice that of the baseline. The fact that there are no flow constraints applied in this instance shows that the scenario is not as feasible even though flow rates are high.

- Risk: The risks that are mentioned in the 5 hub scenario also apply in this instance, but if the 4 distribution centres remain open as cross docks, the risk associated with industrial action are minimal.
- Responsiveness to change: This scenario shows one the effect that no constraints have on a distribution network. The option may not be as feasible but this scenario has a higher response to change since distribution centres will not be shut down as such.

5 Hub and Cross Dock Optimised

- Supply Chain Cost: The transportation and warehousing costs are not as high in this instance when compared to the previous scenario that was discussed. In the instance where the flow from the distribution centre is looked at, this scenario manages to be lower than the baseline at 0.89.
- Capacity: Once again, the flow of units is not as high as the previous scenario. The throughput rate is also 1.01 and the stock on hold is twice that of the baseline. This is all obtainable even after applying the flow constraints.
- Risk: Once again, the same risks discussed in the previous scenario are applicable here.
- Responsiveness to change: The fact that the scenario is managing to perform even under the flow constraints is a good indication that it will be able to manage change if executed correctly.

6.3. Scenario Selection

Based on the modelling done and the analysis of the results using the framework, the most ideal scenario that will be able to curb problems experienced by Vector Logistics and possibly allow the company to grow is the solution where the 5 Hub and Cross Dock Optimised is applied.

Since the distribution network is becoming more complex, as mentioned in the Problem Statement, the company needs a solution that will decrease logistical costs in the long run while also increasing the capacity. This scenario will address this problem and maximise resources optimally such as the current distribution centres.

The risk associated with making such a change is recognisable, but the savings that can be made in the long term, since capacity is increasing, would outplay the risk aspect.

Initial requirements stated that the new optimal design should be able to decrease the network complexity and handle all constraints placed on it currently and in the near future. As per this discussion, it can be seen that this scenario would be able to succeed in achieving this goal.

7. Conclusion and Recommendations

In order for any supply chain to grow, its unique challenges need to be dominated and eliminated. The complexity experienced by the Vector Logistics network can be decreased with supply chain network design. This document discussed the challenges faced that need to be addressed in the evaluation framework, namely the increase in SKU's and logistics costs.

The conceptual solution in the form of the development of the preliminary design and decision matrix was performed, where the matrix quantitatively established the most ideal software to use for this exercise. The choice of Supply Chain Guru ensures that the network design is conducted accurately.

From the Literature Study, it was noted that many problems were experienced by logistics companies in South Africa. Therefore a framework was established using the Analytical Hierarchy Process (AHP), together with the information obtained from the Literature Study and Vector Logistics. The framework acts as an aid for decision making.

Thereafter, the baseline model is discussed and scenarios are established and generated using the constraints and data provided. The model was run and output results were obtained which included information relating to logistical costs, flow of units and throughput rates.

The framework created was then applied and it was noted that all scenarios had strong and weak points, but due to the framework being created using AHP, not all points had the same importance.

Due to the steps taken to complete this project, it was finally recommended that the best option for Vector Logistics was to implement the scenario where there are 5 hubs and cross docks. The scenario addressed the problem of complexity by having a higher flow of units, increasing throughput and decreasing logistical costs, over the long run, associated with the current baseline model.

In conclusion, a feasible solution has been reached for the problem stated at the beginning of this project. Many risks are associated with making such a change, but if Vector Logistics wants to remain competitive within the 3PL industry and grow, the distribution network needs to change as it has the capability to improve.

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Appendix

Distribution Network Diagrams

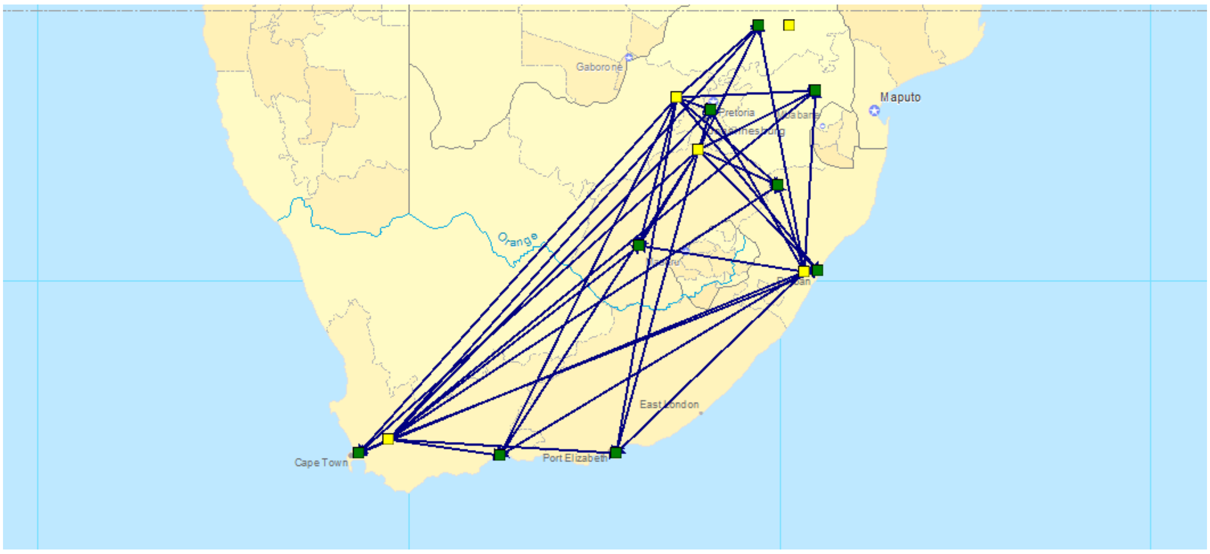

Figure 32: Baseline PBCS to DC

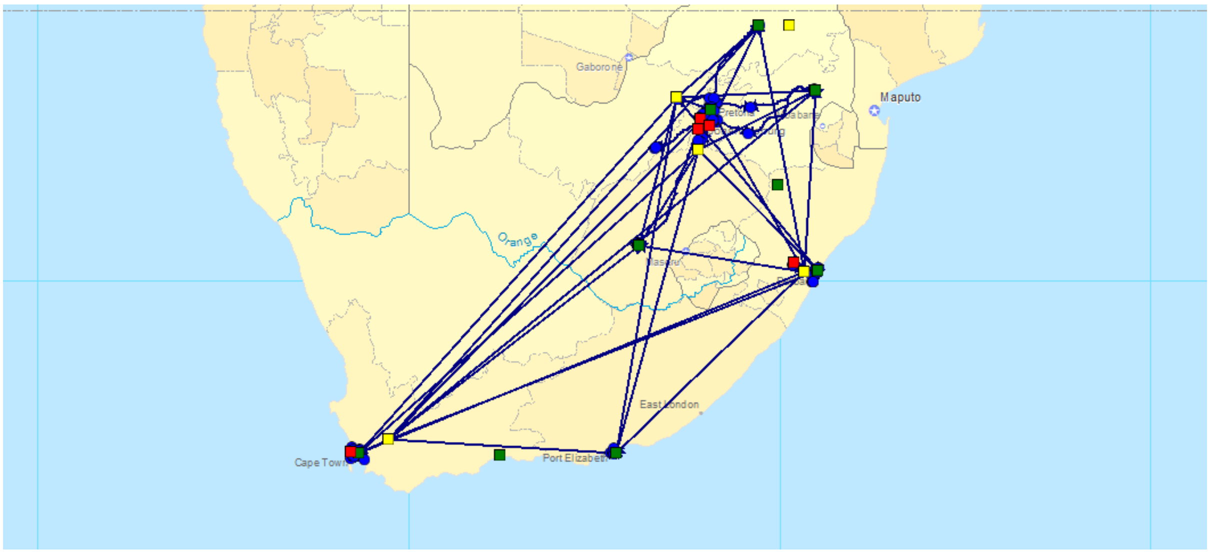

Figure 33: Optimised Baseline PBCS to DC

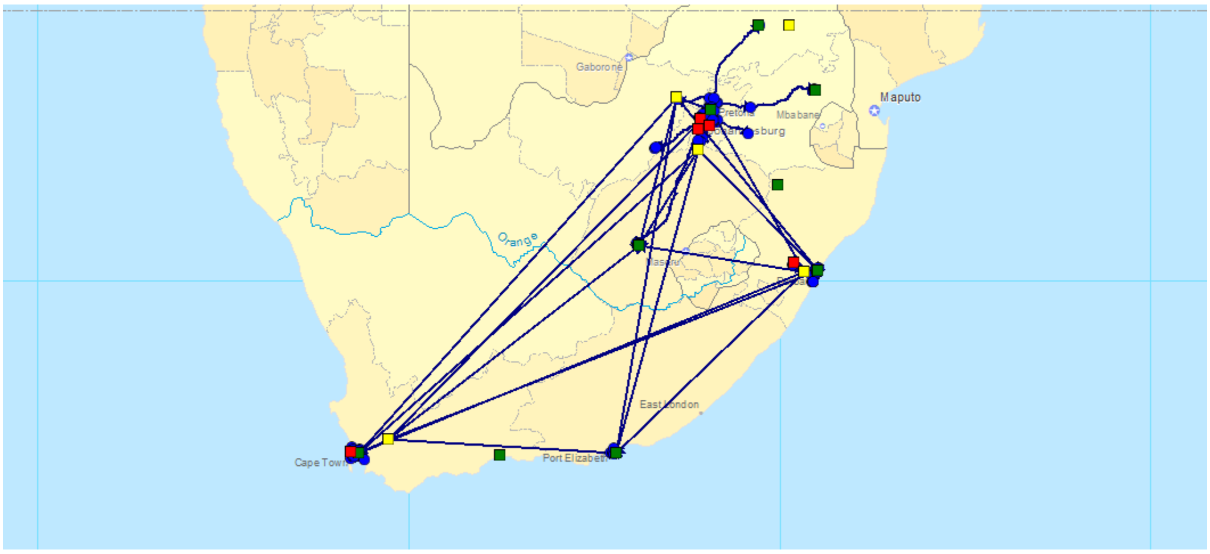

Figure 34: 5 Hub PBCS to DC

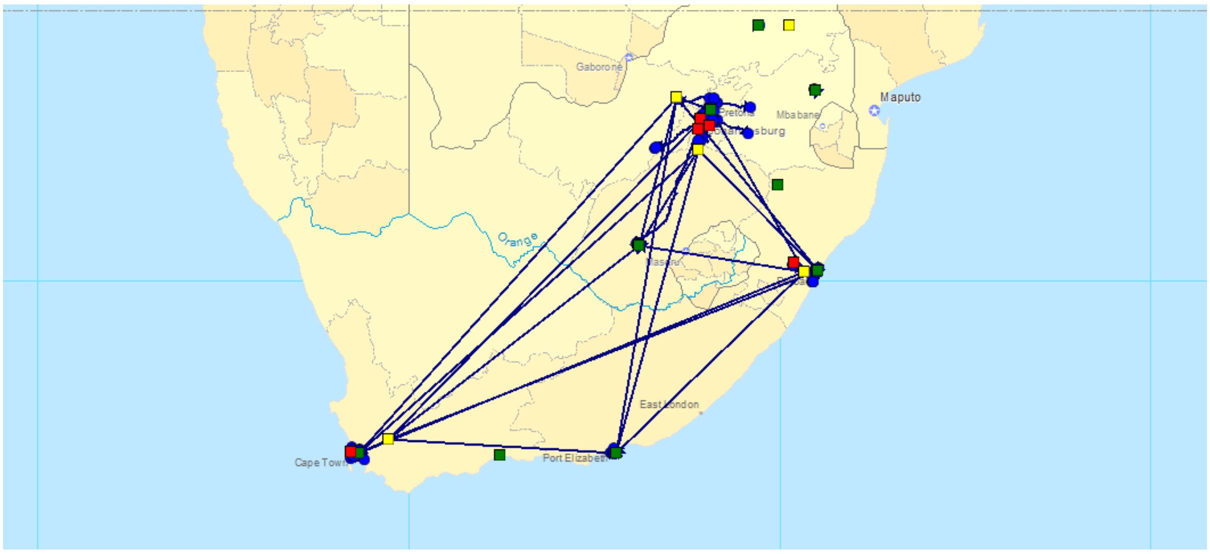

Figure 35: Optimised 5 Hub and Cross Dock PBCS to DC

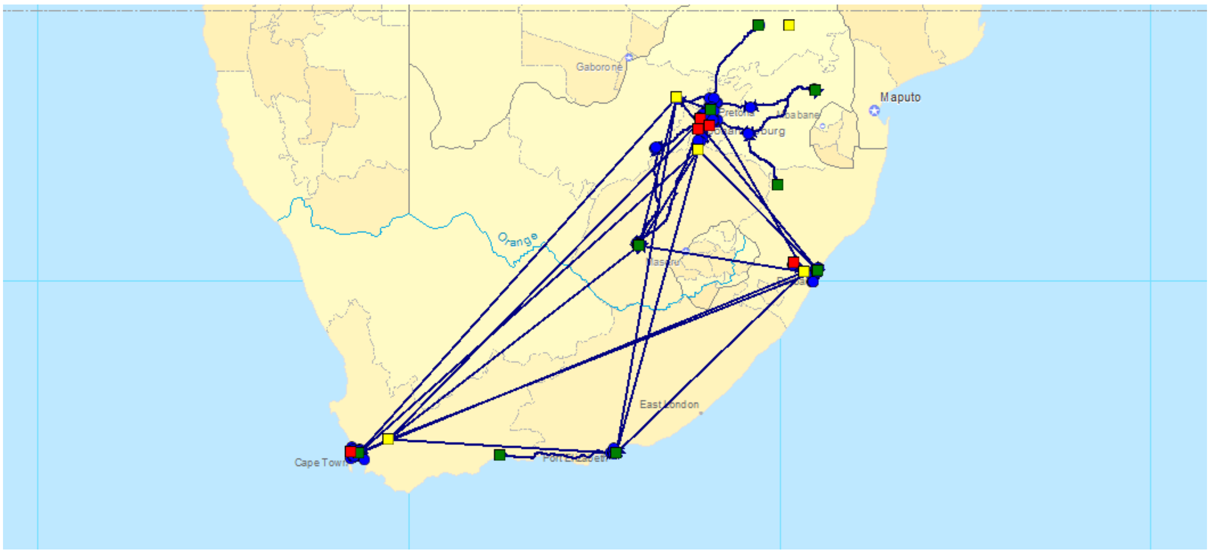

Figure 36: 5 Hub and Cross Dock without Flow Constraints PBCS to DC

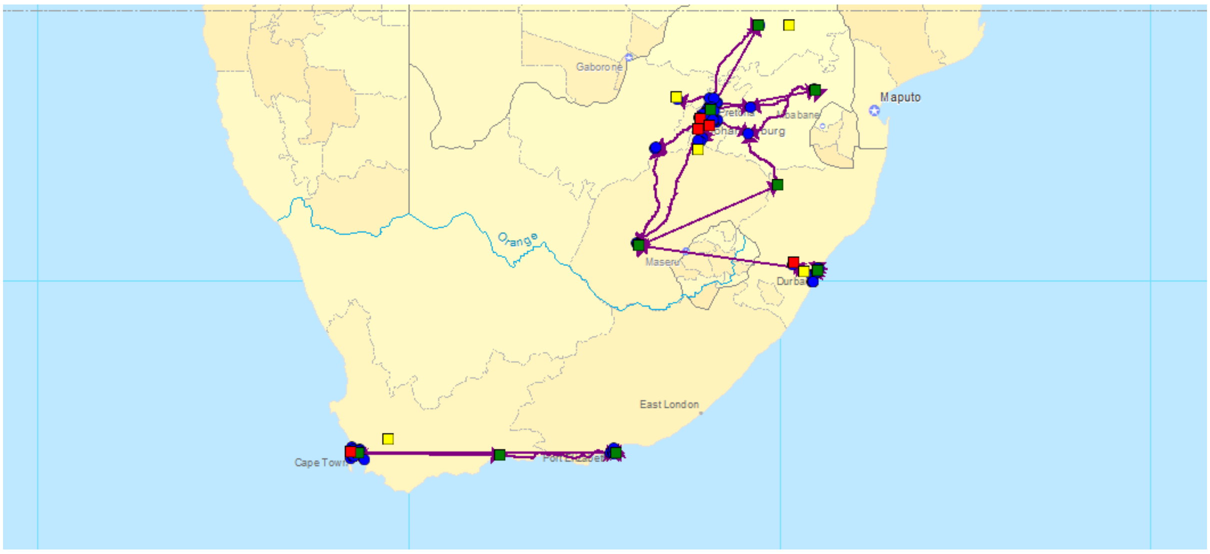

Figure 37: Baseline DC to DC

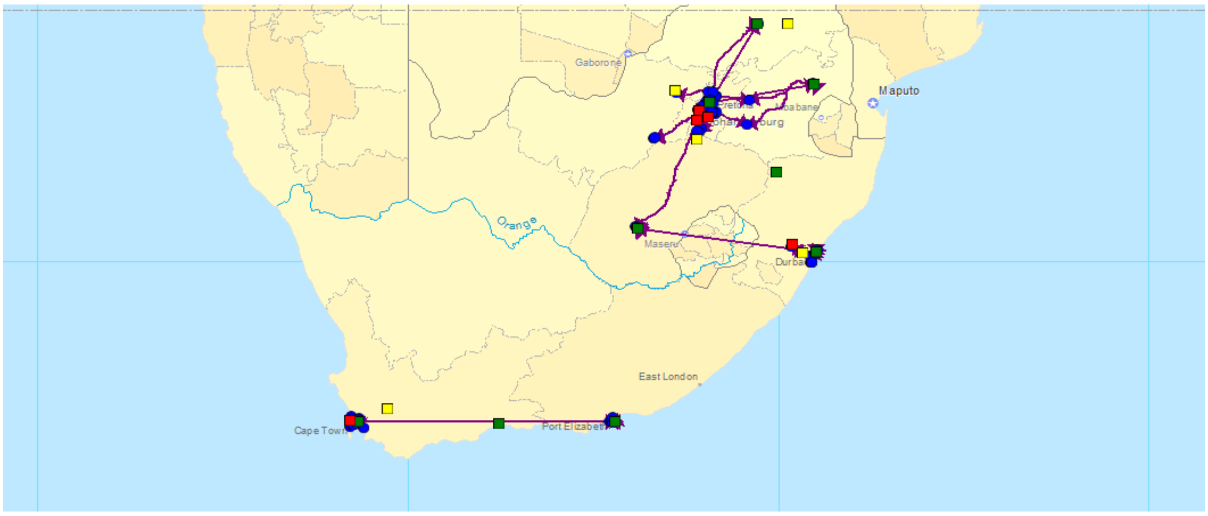

Figure 38: Optimised Baseline DC to DC

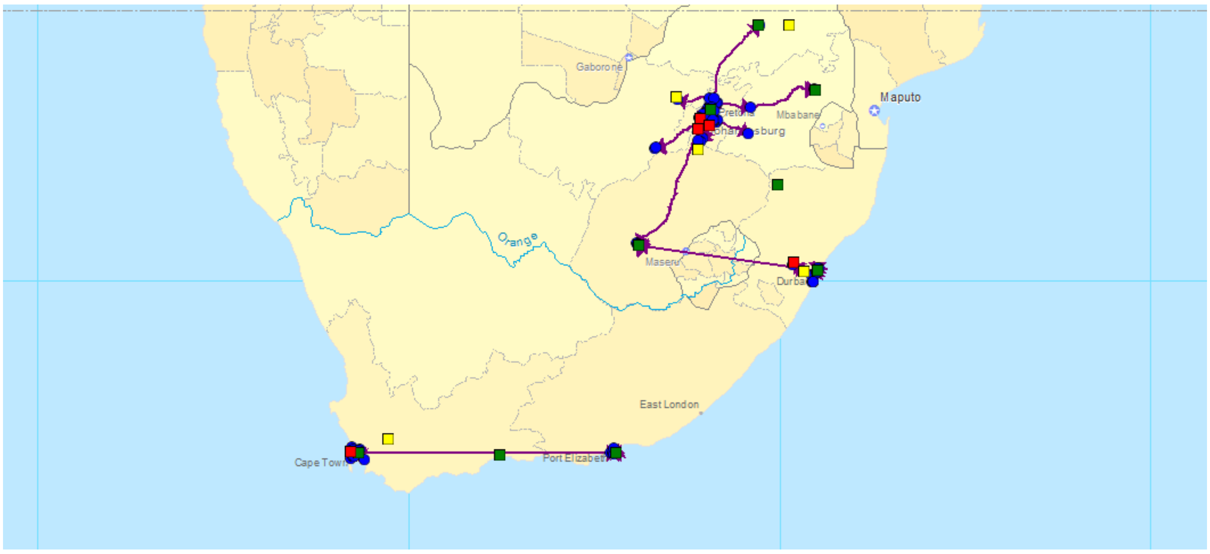

Figure 39: 5 Hub DC to DC

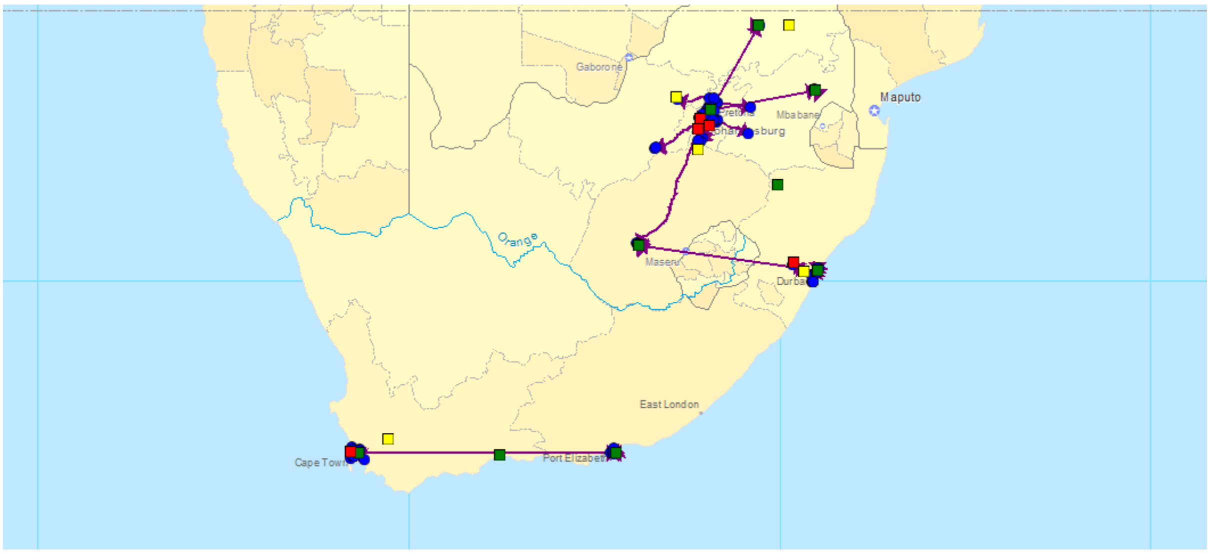

Figure 40: Optimised 5 Hub and Cross Dock DC to DC

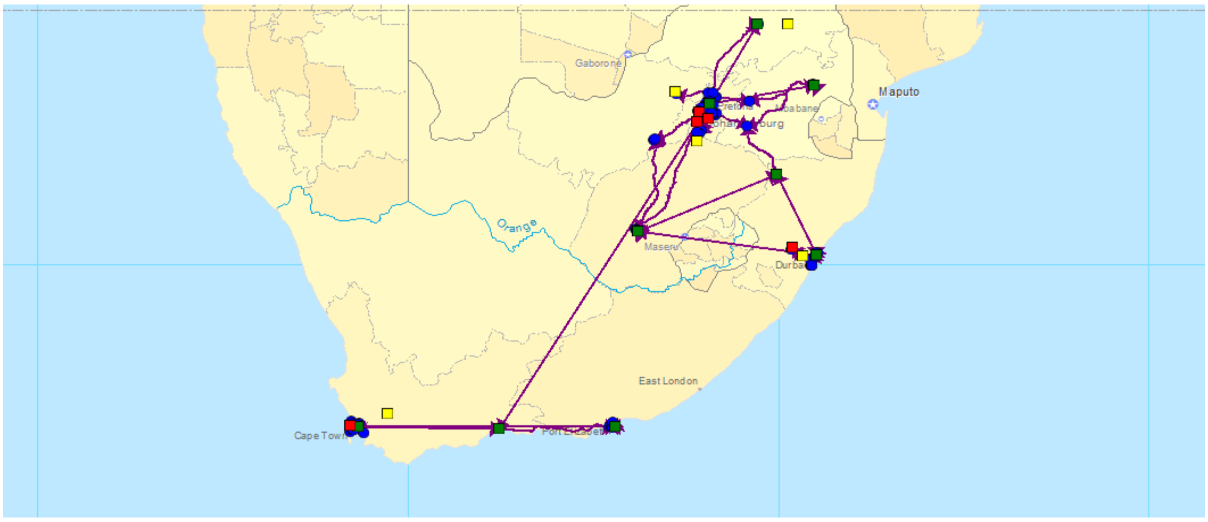

Figure 41: 5 Hub and Cross Dock without Flow Constraints DC to DC