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Abbreviated Title	Optimising the allocation of fleet across business units
Keywords	Optimisation, Assignment, Prioritisation
Abstract	The aim of this project is to develop the optimum implementable fleet allocation solution. This entails optimising the re-allocation process of fleets across all business units and achieving cost-efficiencies, taking into consideration all of the replacement rules and temperature capabilities of the fleets. Data visualisation will be conducted to highlight any trends that one should be aware of and will be incorporated into the model. A distribution network diagram showing all available routes will be created, followed by a cause and effect diagram to identify where all critical factors are situated and how they should be prioritised or ranked. The multiple criteria analysis combined with the linear program, modelled in Excel Solver, will determine the optimal fleet size. This will help to develop a new vehicle allocation procedure for any changes in the future. The solution is based on optimum consideration of identified critical factors. Different investigations will also be conducted to understand the full extent of possible risks that could affect the optimisation model.
Category	Operations Research
Confidentiality	**Not applicable**

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Final Project Report

Optimising the allocation of fleet across business units for Vector.

Nicole le Riche

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27 September 2018

Preliminary project submitted in partial fulfilment of the requirements for the module

BPJ 420 Project

at the

Department of Industrial and Systems Engineering

at the

University of Pretoria

DECLARATION OF ORIGINALITY

I, Nicole le Riche (student number: 14007488), hereby declare that this report is my original work, and that the references given provide a comprehensive list of all sources cited or quoted in this report.

Executive Summary

Vector is a third-party logistics (3PL) provider for the frozen food industry in southern Africa (Vector, 2008d). It has recently partnered with Pick n Pay to centralise all of the retailer's frozen suppliers through a dedicated network operated by Vector. Vector currently delivers frozen products at a maximum core temperature of -12°C, but Pick n Pay's frozen food basket includes ice cream. This increases logistical complexity as ice cream needs to be kept frozen at a core temperature of -25°C. With the introduction of ice cream to fleet distribution, the network for Pick n Pay's centralised distribution will require specialised equipment to handle lower temperature requirements.

The centralisation of Pick n Pay's distribution will require Vector's secondary business units to change from Customer Secondary Distribution (CSD) and Principal Secondary Distribution (PSD), to CSD, PSD *and* Pick n Pay (PNP). A new business unit will need to be added, which will require a fleet of specialised vehicles along with fleet optimisation, all while considering the critical factors. Vector is responsible for the current (as-is) fleet and the future (to-be) fleet. All new or converted vehicles will require upgraded load bodies, dual evaporators and tail lifts, to enable rolltainer delivery capability.

The aim of this project is to develop the optimum implementable fleet allocation solution. This entails optimising the re-allocation process of fleets across all business units and achieving cost-efficiencies, taking into consideration all of the replacement rules and temperature capabilities of the fleets. The project is limited to the allocation of secondary vehicles across Vector's business units, namely CSD, PSD and PNP. These business units form part of the secondary distribution chain.

The literature review is based on different methodologies that can optimise the re-allocation of fleet across all business units to achieve make them most cost-effective. Data visualisation will be conducted to highlight any trends that one should be aware of and will be incorporated into the model. A distribution network diagram showing all available routes will be created, followed by a cause and effect diagram to identify where all critical factors are situated and how they should be prioritised or ranked. The multiple criteria analysis combined with the linear program, modelled in Excel Solver, will determine the optimal fleet size. This will help to develop a new vehicle allocation procedure for any changes in the future. The solution is based on optimum consideration of identified critical factors. Different investigations will also be conducted to understand the full extent of possible risks that could affect the optimisation model. Vector's expectation is to receive an optimum implementable fleet allocation solution.

Even though Vector has been distributing Pick n Pay's products for a few years now, this new contract makes Vector responsible for *all* Pick n Pay's frozen products, including ice cream. The contract is valid for five years, and Vector is aiming to renew the contract for another five years thereafter. This project will help Vector to make an informed decision on where to allocate its trucks, so it can provide a more responsive service to Pick n Pay.

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1. Introduction

1.1. Background

Vector is a third-party logistics (3PL) service provider for the frozen food industry in southern Africa. The company provides integrated logistics services to the retail, wholesale and food service sectors (Vector, 2008d). It has partnered with some of the best food companies and retailers to guarantee the efficient distribution of multi-temperature food products (FOODS, 2018). Vector's expertise lies in supply chain intelligence, warehousing and distribution (FOODS, 2018), which positions it well to serve companies such as RCL Foods Ltd and their external customers (FOODS, 2018).

Vector's head office is in Durban, with 11 distribution sites across South Africa and Namibia. Vector offers top supply chain and technology systems that enable customer visibility in their supply chain (Vector, 2008c). Vector was one of the first companies in the food industry to introduce delivery vehicles that could handle multiple temperatures (Vector, 2008b). Ambient, chilled and frozen products can be delivered in a single delivery when using these vehicles (Vector, 2008b).

Vector has two secondary distribution fleets; one being CSD and the other PSD. Vector works differently from a typical 3PL. The company provides a full supply chain solution, which includes demand and supply analysis. Its PSD offers a combined outbound service, while it continues to be a core service. PSD's distribution network is classified as the most wide-ranging and sophisticated network in southern Africa (Vector, 2008c). Vector provides an all-inclusive route-to-market service across all channels when partnered with top market-leading manufacturers in the frozen and chilled industries (Vector, 2008c). PSD principals include Rainbow, I&J, Fry's, Eskort, Pieman's and Willowton Group (Vector, 2008c). Vector is able to provide a logistics service to large food companies that want to control their supply chain and strive for efficiency (FOODS, 2018). CSD customers include Nando's, The Spur Group and Chicken Licken (Vector, 2008b). Clients can focus on their core activities because Vector takes care of their distribution (Vector, 2008b). PNP will be the new business unit that originally came from the PSD unit. The actualisation of the PNP unit is what motivated the reallocation of the new and existing vehicles.

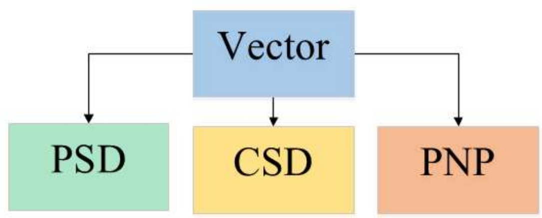

Figure 1: Types of clients as defined by Vector.

1.2. Process Overview

Figure 2 depicts how Vector's current procedure is followed once a client places an order. Some orders are loaded at the hub depot and transported via Vector's primary distribution vehicles to their satellite depots. Cross-docking takes place between primary distribution vehicles and secondary distribution vehicles. Other orders are placed on secondary distribution vehicles at the hub depots and taken directly to Vector's customers in the depot's area. All secondary distribution vehicles deliver to Vector's customers, which will be the prime focus of this project.

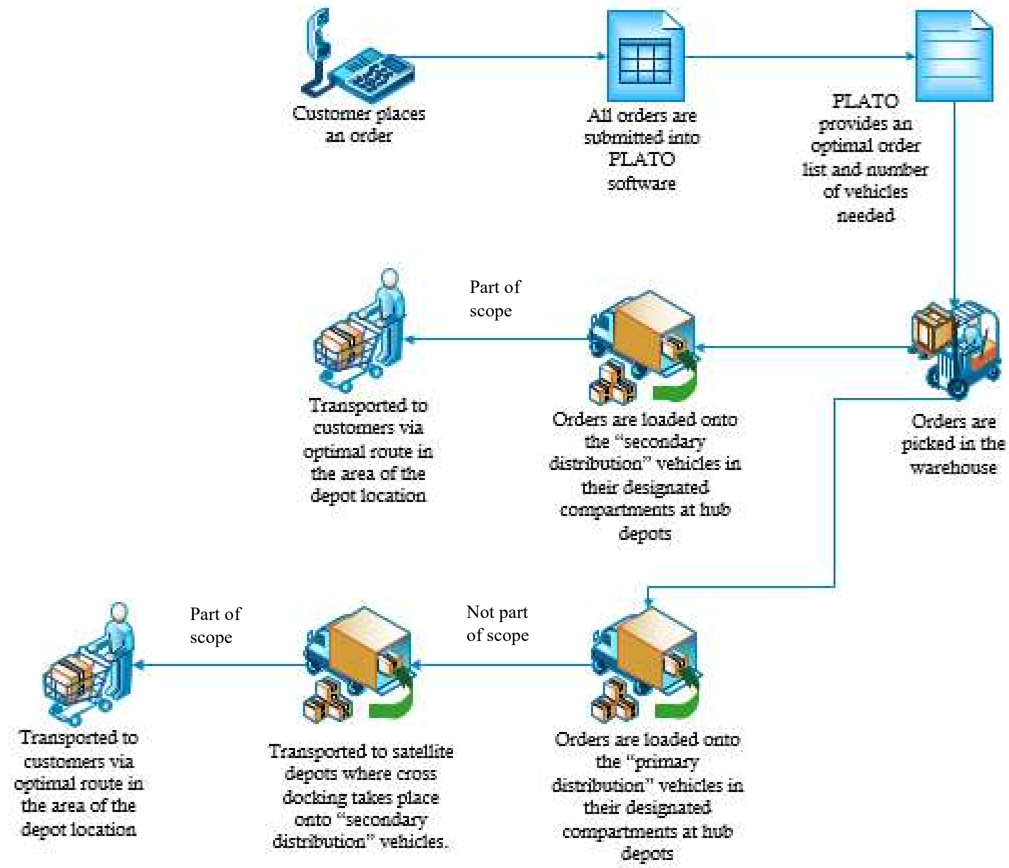

Figure 2: Process overview of Vector's standard operating procedure.

1.3. Problem Statement

Vector operates separate fleets for CSD and PSD. CSD uses multi-temperature vehicles that can accommodate frozen, chilled and ambient (room/surrounding) temperatures. PSD also uses multi-temperature vehicles but for frozen and chilled only. Multi-temperature vehicles are compartmentalised depending on the temperature zones required. Vector has recently partnered with Pick n Pay to centralise all of the retailer's frozen suppliers through a dedicated network operated by Vector. Vector currently delivers frozen products at a maximum core temperature of -12°C. Pick n Pay's frozen food basket includes ice cream, which brings a new level of complexity as ice cream is kept frozen at a core temperature of -25°C.

The centralisation of Pick n Pay's distribution will change Vector's secondary business units from CSD and PSD, to CSD, PSD *and* PNP. A new business unit will be added that will require fleet optimisation. Due to the introduction of ice cream to fleet distribution, the network for Pick n Pay's centralised distribution will entail specialised equipment to handle lower temperatures for ice cream. Thus the new business unit will need a fleet of specialised vehicles, all while considering the critical factors. Vector will provide the current (as-is) fleet and the total future (to-be) fleet. All new or converted vehicles will require upgraded load bodies, dual evaporators and tail lifts, to enable rolltainer delivery capability. Figure 3 gives an overview of how the problem originated and what elements will be highlighted in the following sections of this report.

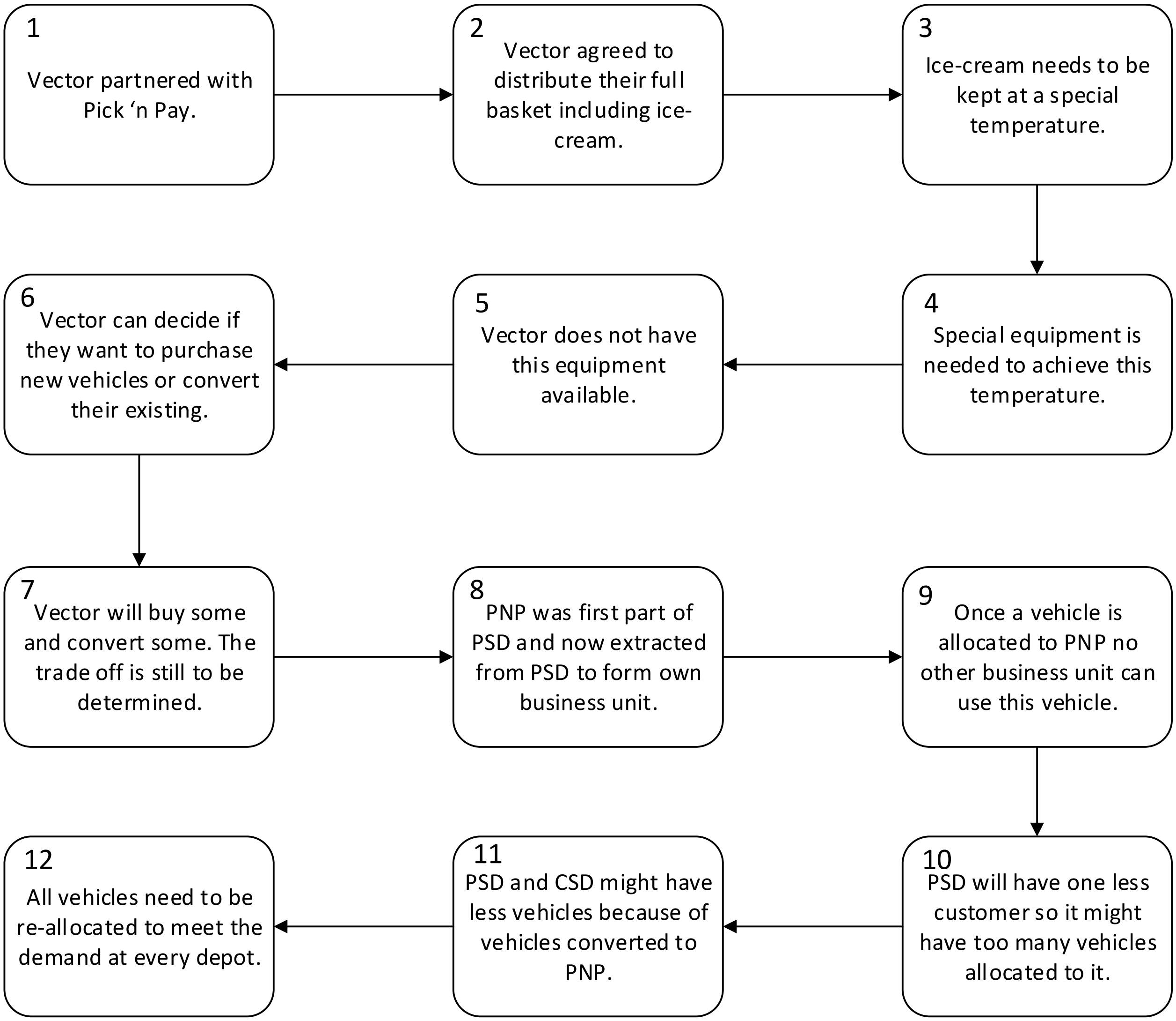

Figure 3: A flow chart of the Problem Statement.

1.4. Research Questions

The following research questions need to be asked:

- How could one optimally re-allocate the fleets without incurring too much expenditure?
- What methodology would best suit the demand of the customer and volume intake of each fleet?
- What impact would the conversion of a vehicle have on the existing fleet?
- What level of consideration should be given to the risks associated with the replacement rules as well as the temperature capabilities?

1.5. Aim and Objectives

1.5.1. Aim

The aim of this project is to develop the optimum implementable fleet allocation solution. This entails optimising the re-allocation process of fleets across all business units and achieving cost-efficiencies, taking into consideration all of the replacement rules and temperature capabilities of the fleets.

1.5.2. Objectives

The objectives of this research are to:

i. Create a distribution network diagram showing all the available routes and the current vehicle allocation procedure.
ii. Identify all the potential factors that contribute to prioritising the vehicles and calculate the weights for each factor.
iii. Ascertain the optimal fleet combination for each depot based on the current (as-is) and future (to-be) fleets. The vehicle allocation procedure is based on optimum consideration of identified critical factors. The results will be compared against the proposed fleet requirements.
iv. Develop an optimisation model to validate Vector's current fleet size per business unit.

1.6. Rationale

The company has recently been nominated by Pick n Pay to provide a dedicated distribution network for all the retailer's frozen products. Even though Vector has been distributing Pick n Pay's products for a few years now, this new contract makes Vector responsible for *all* of Pick n Pay's frozen products, including ice cream. The contract is valid for five years, and Vector is aiming to renew the contract for another five years thereafter. This project will help Vector to make an informed decision on where to allocate its trucks, so it can provide a more responsive service to Pick n Pay.

1.7. Project Scope

The project scope is limited to the allocation of secondary vehicles across Vector's business units, namely CSD, PSD and PNP. These business units form part of the secondary distribution chain. The current and future requirements will be met as part of the data pack and no cost analysis is necessary, as this was done when determining the future fleet requirements. The volumes per depot will be given to determine the best scenario when allocating future fleets so that all demands are satisfied.

1.8. Project Plan

The problem will be addressed with an approach called the DMAIC principle. This principle consists of five steps, which guide a project through to the resolution of the project's problem. The DMAIC steps are: Define, Measure, Analyse, Improve and Control.

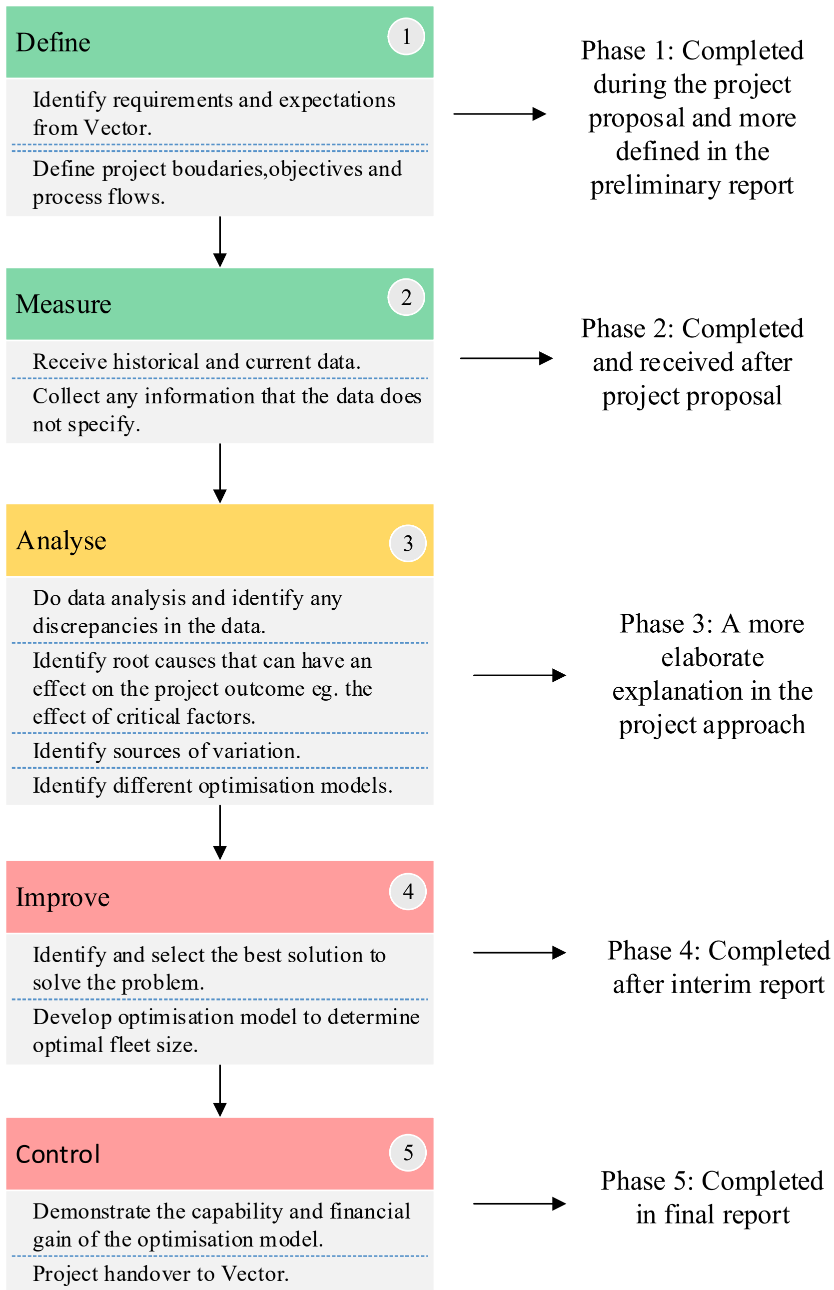

Figure 4: Project Plan based on the DMAIC approach.

1.9. Definition of Terms

1.9.1. Fleet

A large group of trucks that operate together.

1.9.2. CSD

This abbreviation stands for 'Customer Secondary Distribution'. This occurs when a client contracts Vector to distribute their full basket of products straight to customers. This means that Vector owns the stock. Vector then invoices the CSD client for the costs involved.

1.9.3. PSD

This abbreviation stands for 'Principal Secondary Distribution'. A principal is a client who contracts Vector as a 3PL to store and distribute their stock to customers. Once delivered, Vector invoices the customer and the principal accordingly.

1.9.4. PNP

This abbreviation stands for 'Pick n Pay'. This is the new business unit that Vector started after partnering with Pick n Pay. This unit needs a new fleet and will be the main focus of the project.

1.9.5. 3PL

A 3PL provides outsourced logistics and distribution services. These services encompass anything that involves the management of the way resources are moved to the areas where they are required (TechTarget, 2010).

1.10. Definition of Notations

Mathematical Notation	Definition
F_i	Critical factors of every vehicle, where factor i = 1, 2, 3, … , n
I_{RFi}	The intensity of the importance rating of factors
N_{sfi}	Number of subordinating factors
T_{nf}	Total number of factors
M_{sr}	Maximum rating in the scale of measurement
M_{psf}	Maximum possible subordinating factors
C	Constant
B/N_{sfi}	Variant ratio
N_{wi}	Normalisation factor

2. Literature Study

2.1. Introduction

The reliability of the cold chain is critical to the distribution of perishable food products. The term 'cold chain' refers to an unbroken, constant, temperature-controlled supply chain (Louw, 2014). Cold chains are regulated by specific temperatures in refrigerated trucks and in cold rooms. 'Core temperature' refers to the internal temperature of the chilled products and this temperature has to be maintained (Louw, 2014). Transporting various food products that require diverse temperatures in the same vehicle is known as 'multi-temperature loads'. The type of food product being transported determines the specific temperature settings; for example, ice cream needs to be frozen at -25ºC and vegetables are kept chilled between -1ºC and 4ºC. It is recommended that a refrigerated truck be divided into sections to accommodate different temperature zones when transporting multiple food products that require different temperatures (Louw, 2014). Cold chain distribution requires specialised equipment to protect perishable products throughout the supply chain, thus is it important to acquire the right type of equipment and to properly maintain it throughout its useful life (Hofmeyr, 2010).

2.2. Cross-docking

Vector has just moved over to cross-docking. The company distributes its products from the hub depots to the satellite depots. At the satellite depots, cross-docking takes place from the primary fleet to the secondary fleet. The secondary fleet stays overnight at the satellite depots and maintains the desired temperature, then it distributes the products to customers the next morning. The following research aims to give a more elaborate view on how cross-docking works.

Cross-docking consists of the movement of products straight from the receiving dock to the shipping dock, with the minimum timeframe between movement (Apte and Viswanathan, 2000). Cross-docking is an advanced distribution strategy that takes zero inventory based on the just-in-time (JIT) concept (Qijun, 2009). Since cross-docking has a zero inventory policy it automatically reduces inventory space in a warehouse, so warehouse storage is free for other purposes (Qijun, 2009). Cross-docking can also reduce labour costs since picking and packing are eliminated (Qijun, 2009).

Cross-docking has some areas that need consideration, such as the high volume of items that are needed for cross-docking to be effective (AdaptaliftGroup, 2011). The transportation vehicles have fuller loads, which lower transport costs in the long run and reach customers faster (AdaptaliftGroup, 2011). The company also needs to have reliable suppliers in order to deliver the right product, as there is little room for error (AdaptaliftGroup, 2011). This is an essential factor that needs to be considered when assigning fleet sizes at different depots. If a vehicle has insufficient capacity to receive the load from the main vehicle, then there is no space for storing these items as cross-docking is a zero inventory strategy. Communication across the supply chain is key in achieving the correct load that each vehicle can accommodate.

Demand volumes are a very critical feature when applying cross-docking as there cannot be an imbalance between incoming and outgoing loads (Apte and Viswanathan, 2000). Demand volumes should therefore be fairly stable over time (Apte and Viswanathan, 2000). Perishable food items' demand rates are seen as stable because customers and stores cannot buy in large quantities due to the items' short shelf life, so they would rather order more frequently (Apte and Viswanathan, 2000). Stable demand is more predictable and cross-docking becomes easier to plan for these types of products (Apte and Viswanathan, 2000). Vector is a cold chain supplier and clients' demands are stable due to frequent orders, making cross-docking easier to plan.

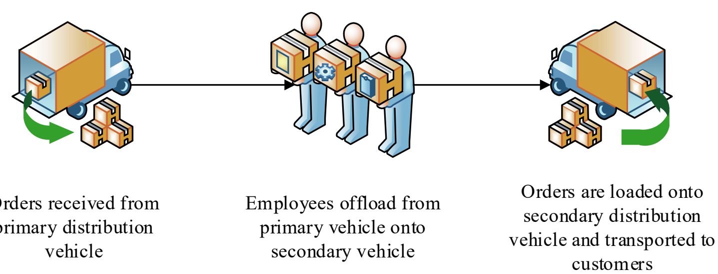

Figure 5: A demonstration of the cross docking process.

2.3. Risks

Risk can be defined as a situation being exposed to danger, harm or loss (Dictionaries, 2018). It is the probability of occurrence multiplied by the severity of the risk (Huda, 2015). Quality risk management can benefit the cold chain industry by lessening temperature deviations and releasing products faster (Huda, 2015). Firstly, one should understand the nature of the product. This represents how products are packaged or their sensitivity to certain temperatures (Huda, 2015). Vector has a range of different temperatures and these cannot mix with each other. This risk needs to be taken into consideration when assigning vehicles to their designated depots, so that all temperatures can be accommodated without affecting the quality of the products. The stages of delivery and drop-off points as well as fluctuating temperatures that link with all the drop off points need to be taken into consideration (Huda, 2015). Since Vector has moved over to cross-docking, this is one factor to keep in mind when products are moved from one vehicle to the next. One should also be ready for any emergency conditions, such as power failure or equipment failure (Huda, 2015). Failure Mode and Effects Analysis (FMEA) is a popular analysis tool that identifies, analyses and evaluates potential risks and their effects. It prioritises potential risks and identifies actions to avoid, reduce, transfer or accept (Huda, 2015).

A cause and effect diagram is an effective way to depict the critical factors that are part of the root cause. Such a diagram is also called a fishbone diagram or an Ishikawa (TechTarget, 2018). It offers a visual technique in identifying the causes and categorising them into different sections (TechTarget, 2018). The inventor of the fishbone diagram, Dr Kaoru Ishikawa, used this tool to avoid solutions that could only treat the symptoms of the larger problem (TechTarget, 2018). The diagram's name 'fishbone' comes from the design of the technique looking like the skeleton of a fish, where the different causes are ranked according to their level of importance (TechTarget, 2018). In the DMAIC approach, fishbone analysis is used in the analyse phase (TechTarget, 2018). This diagram consists of a head and backbone, which are the main problem. Then the causes that contribute to the problem are attached to the backbone, to form the spine of the fishbone diagram (TechTarget, 2018).

2.4. Data Visualisation

Data can be very confusing, especially when one does not know all the variables present (Inc). Data visualisation is when data is demonstrated in a graphical format and used when one wants to understand the data presented to you (Inc). It allows decisionmakers to recognise new patterns and trends or to convey a new concept, since it is easier to understand data in a graph or chart than it is in Excel sheets and reports (Inc). Data visualisation can identify parts that need improvement or indicate certain regions of variation that can be caused by customer behaviour or seasonality (Inc). It can help to forecast demands for the future and help to mitigate risks (Inc).

SAS Institute provides a course of action that one can use to best analyse the data:

i. Understand the data and identify elements that are unique.
   - By sorting through the data certain relationships between the elements will arise (Inc). Certain values will indicate that it has an effect or no effect on other elements (Inc). This way one can reduce the data to the necessary data needed, without compromising the values (Inc).

ii. Determine what information you need from the data to achieve the desired objective.
   - Once the objective is clear the specific information needed can be extracted from the data (Inc).

iii. Decide which visualisation will best represent the data, so that it conveys the right concept to the audience.
   - The visualisation should be clear and informative at the same time (Inc).

There are many graphs, charts and diagrams that can be used for visual data. A few graphs that would be beneficial for this project would be:

1. Column bar graphs: These graphs compare categories on one axis. They are the most straightforward graphs.
2. Stacked bar graphs: These graphs are used to compare multiple variables. They combine elements and show proportions in a specific category.
3. Scatterplots: These can show the precision and accuracy of plotted data. A regression analysis can be used on the data points to determine the impact that independent data has on dependent data.
4. Line graphs: These graphs indicate any trends and variations in demand or seasonality.
5. Histograms: These graphs are closely related to bar charts but can show distribution trends in the numeric data provided for the graph.

2.5. Optimisation Models

When re-allocating or assigning vehicles to a specific fleet, different characteristics and considerations need to take place. Each of these characteristics will be ranked differently, depending on their importance. One can use various methods to weigh the different characteristics and, in the process, assign the optimal size of vehicles in each fleet without compromising the ability of the fleet.

The most recognised and simplest multi-criteria decision-making method is the weighted sum model (WSM) (Song and Kang, 2016). The following equation shows how the best alternative is chosen for WSM (Song and Kang, 2016): M represents the alternatives; N represents the criteria; and A_{WSM} represents the best score. The a_{ij} variable represents the true value of the i^{th} alternate of the j^{th} condition, and w_j is the weight of the j^{th} condition (Song and Kang, 2016).

$$A_{WSM} = \max \sum_{j=1}^{N} a_{ij}\omega_j, \text{ for } i = 1, 2, 3, \ldots, M.$$

There are other methods such as the weighted product model (WPM), TOPSIS (the technique for order preference by similarity to the ideal solution) and the analytic hierarchy process (AHP) (Song and Kang, 2016). The WPM is similar to the WSM, except that the WPM uses multiplication instead of addition (Song and Kang, 2016). The TOPSIS method uses a basic concept that the nominated alternative should have the shortest distance from the ideal solution and the farthest distance from the negative-ideal solution (Song and Kang, 2016). TOPSIS defines two different solutions, the one being the ideal solution and the other being the negative-ideal solution. The ideal solution determines every best value of the criteria and is regarded as the highest benefits solution (Jothimani, 2014). The negative-ideal solution determines every worst value of the criteria and is thus treated as the lowest benefits solution (Jothimani, 2014).

A study about TOPSIS by (Jothimani, 2014)) was done to identify the key performance indicators for warehousing, customs and freight forwarding (these were the only domains the company was limited to). The way the study solved the problem was by incorporating the fuzzy analytical hierarchy process (FAHP) so that all the SCOR model processes were in a structure (Jothimani, 2014). TOPSIS was then combined with FAHP to normalise the values and compare the metric values having diverse units (Jothimani, 2014). A benchmark performance would be identified using the TOPSIS technique (Jothimani, 2014). The study demonstrated how FAHP can strengthen the ranking when combined with TOPSIS; however, due to subjective judgement in some of the criteria, FAHP was dropped in further analysis (Jothimani, 2014). Future works identified by (Jothimani, 2014) are to get additional data to achieve the benchmark year.

Table 1: Example of TOPSIS.

Criteria	Decision Makers			Weight
	Vehicle 1	Vehicle 2	Vehicle 3	
Factor 1	X_{11}	X_{12}	X_{13}	$(X_{11} + X_{11} + X_{11})/3 = Y_1$
Factor 2	X_{21}	X_{22}	X_{23}	$(X_{21} + X_{22} + X_{23})/3 = Y_2$
Factor 3	X_{31}	X_{32}	X_{33}	$(X_{31} + X_{32} + X_{33})/3 = Y_3$

The analytical hierarchy process (AHP) breaks down multiple attributes into hierarchies or groups according to their characteristics and compares them (Song and Kang, 2016); however, the AHP has several weaknesses including unclear questions, fixed measurement scales and diverse results, subjected to the form of hierarchy structure regardless of the attributes being affected (Song and Kang, 2016). Nevertheless, the AHP is widely applied as a wide-ranging and orderly method to select the best alternative under the confines of time and resources. Thus, AHP can be applied in a range of areas comprising resource allocation, priority and ranking, selection and optimisation (Song and Kang, 2016). AHP can make comparisons of quantitative and qualitative indices. Even though AHP is widely applied, other methods have been suggested (Song and Kang, 2016). These methods include the weighting method, multi-criteria analysis as well as the fuzzy pairwise comparison on assigning weights (Song and Kang, 2016).

Standard procedure of AHP:

1. State the specific problem and from it derive the objective.
2. Decompose the required attributes that are necessary to achieve the goal and from it identify the criteria (Song and Kang, 2016).
3. The hierarchy structure is constructed from low-level criteria to high-level criteria. The system forms separated sets according to the entities (Song and Kang, 2016). Each set is named a level and one set can only affect one other set.
4. Comparisons are made between the criteria, which return a matrix. Weights are then calculated based on these comparisons made by two factors rendering to relative preference (Song and Kang, 2016).
5. The consistency ratio (CR) is calculated with the intention of verifying the reliability of responses. The dependability of the responses can only be sustained if the consistency ratio is equal to 0.01 or less than 0.01 (Song and Kang, 2016).

The disadvantages of using AHP are that values are dependent on the shape of the structure and vary as the structure does (Song and Kang, 2016). Another method can be followed where the priority is determined first. This is done so as to maintain the consistency of all values (Song and Kang, 2016). The weights are then calculated while the comparisons are being reduced (Song and Kang, 2016). Entities within a group should be compared, then entities from different groups but having the same priorities should be compared (Song and Kang, 2016). Lastly, work on entities that have not been compared but do, however, have joined priorities. While the priority of the entity is maintained, the weights are calculated through comparisons. The consistency ratio matches that of the AHP, which indicates that this method is superior to the AHP method (Song and Kang, 2016). The new method’s weights do not vary when the hierarchy structure does and so the AHP disadvantage is eliminated (Song and Kang, 2016). This method can be solved in Excel and be applied to areas involving weight assignment.

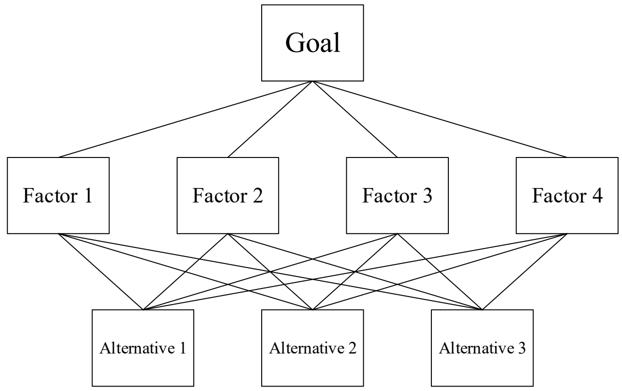

Figure 6: Example of the Analytical Hierarchy Process.

The Analytic Network Process (ANP), developed by Thomas L. Saaty, can also be used to weigh different criteria. The Analytic Network Process deals with dependencies where hierarchy is not a necessity, while the Analytical Hierarchy Process requires hierarchy and does not focus on interdependencies (Acar and Aplak, 2016). ANP is thus a generalisation of AHP and can be seen as superior. Not all decision problems can be built via a hierarchical structure due to the dependency of components. ANP is structured in such a way that it can interact in any direction, whereas AHP has a linear top-to-bottom structure (Acar and Aplak, 2016). Mathematical problems are often solved using Linear Programming (LP) as a technique (Acar and Aplak, 2016). Transportation problems often deal with products being moved from depots to customers, and in doing so try to minimise distribution costs (Acar and Aplak, 2016). LP always has an objective function that is subjected to constraints. In an LP model there will always be defined variables with given values, then parameters that cannot be controlled. The input data is used with the constraints and parameters to identify the optimal objective function.

Transportation problems have a special element, namely the assignment problem. The number of sources must equal the number of destinations, as this is an important characteristic of the assignment problem (Acar and Aplak, 2016). This study is based on the assignment problem being combined with the ANP technique. The first step is to calculate the criteria weight by using the ANP method (Acar and Aplak, 2016). The second step is to assign vehicles to each district based on their performance values (Acar and Aplak, 2016). The third and last step is to acquire the vehicle assignment by modelling the problem, including the ANP weights (Acar and Aplak, 2016). This approach can be defined as the ANP-LP hybrid approach.

The ANP approach will determine the weights of the criteria, while the maximum performance will be determined by the linear program as well the solution (Acar and Aplak, 2016). The linear program model is solved in GAMS Solver (Acar and Aplak, 2016). The ANP approach can transform qualitative data to quantitative data (Acar and Aplak, 2016). This study developed the assignment of security services on a large scale. The objective function value increased in this study and can conclude that the assignment has been improved (Acar and Aplak, 2016). This study suggests more integration of other multi-criteria decision-making for future studies (Acar and Aplak, 2016). The study proposed that goal programming can also be used for this model, as discussed in detail below.

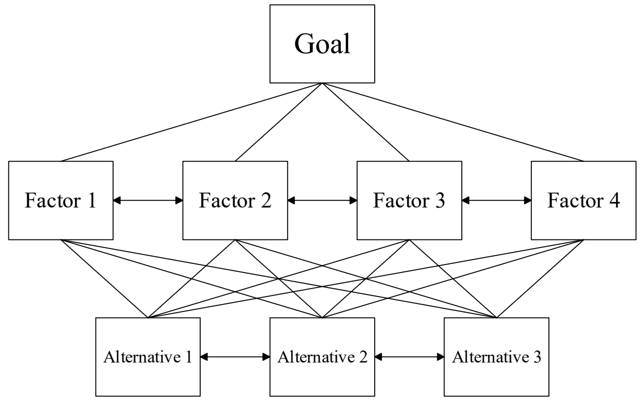

Figure 7: Example of the Analytical Network Process.

Another method that can be used is known as goal programming, which allows for the consideration of numerous goals (Badri et al., 1998). Goal programming considers multiple goals as well as conflicting goals, but operates in such a way that low-priority goals are addressed after high-priority goals have been met (Badri et al., 1998). If multiple goals exist then the ranking of goals must be specified by the decision maker; however, the specified goals do not have to have identical dimensions or units of measurement (Badri et al., 1998). Vehicle scheduling for refrigerated vehicles needs to consider the factor of cold chain food perishability. Algorithms such as improved algorithms, exact algorithms and heuristic algorithms, where saving algorithm is one, can be used for solving vehicle scheduling problems (Ren X, 2015). The saving algorithm is simple and has advantages above the other methods because of its good distribution node expansion (Ren X, 2015). It is also adaptable to constraints being increased and can produce a satisfying scheduling scheme (Ren X, 2015).

A study was done to determine the location of fire station facilities using the multi-criteria modelling approach, namely goal programming (Badri et al., 1998). The problem discussed multiple conflicting objectives that needed to be addressed (Badri et al., 1998). Due to the number of objectives, goal programming could be an ideal approach due to the characteristics mentioned about goal programming (Badri et al., 1998). Probabilistic models could not be used due to insufficient data; however, mathematical models need less data to determine certain parameters and so goal programming was the best choice (Badri et al., 1998). The study showed that each objective solution could be provided depending on what objective they chose to work with (Badri et al., 1998). The extensions mentioned in the study included better travel time models for longer time periods and to take larger samples of demand areas, so that forecasts could be estimated accurately (Badri et al., 1998).

A Bayesian network is a probabilistic network of events that displays casual dependencies and depicts causes and effects in a relationship (Sharma, 2015). The Bayesian network method can also be used by means of fleet allocation. Investigating the effectiveness of using a Bayesian network provides numerous benefits in a cold chain and allows reasoning, even under the circumstances of incomplete information (Sharma, 2015). One can identify interdependencies by identifying the factors that are accountable for effective operations. This study approach is based on the effectiveness of cold chain. For this study to be universally applied, a robust model is required (Sharma, 2015). The objective of this paper is to build an appropriate model based on the inter-relations between the factors (Sharma, 2015). The study suggests fuzzy logic, but reminds the reader that the proposed model has dependency amongst relations (Sharma, 2015). The Bayesian model can deal with uncertainty and thus qualifies as the approach to be used for cold chain (Sharma, 2015). All interdependencies will need to be identified for the chosen variables. The Bayesian model has the ability to incorporate quantitative and qualitative data into a single network (Sharma, 2015).

The Bayesian model allows reasoning, even when there is incomplete information. Under these conditions the model can still provide advantages to evaluate a cold chain and to streamline the process of collecting data (Sharma, 2015). Each factor is assigned a probabilistic value and if the value is high the cold chain will operate effectively (Sharma, 2015). This model will stay true for the different products as variable importance can be changed to suit the need requirement (Sharma, 2015).

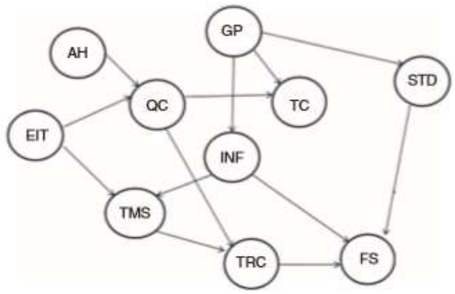

Figure 8: Example of the Bayesian Network Diagram from. (Sharma, 2015)

Another application that can be used is MDCEV (multiple discrete continuous extreme value). This method closely resembles a fleet mix model system. The method of MDCEV involves running a simulation procedure repeatedly, where each simulation run offers a different prediction of the vehicle fleet configuration and utilisation (You et al., 2014). The average of all the prediction runs of the simulation procedure can be computed; however, there is no assurance that this approach will provide valid forecasts of vehicle fleet composition and utilisation (You et al., 2014).

This project can be seen as a fleet assignment problem (FAP) because one needs to assign different types of vehicles with different capacities to the scheduled fleets (Wang, 2013). The different types of vehicles all have different equipment capabilities, operating costs and potential revenues (Wang, 2013). These need to be taken into consideration when one allocates vehicles to a designated fleet. We can model the FAP as an integer programming problem, since an integer linear programming model can address the problem of multiple fleets serving multiple stations (Wang, 2013). Different food products with different temperatures cannot be mixed during transportation, thus specific assignment of orders to the vehicles is required (Redmer et al., 2012). This can be done using the Fleet Composition Problem (FCP). The decision problem lies in composing an optimal fleet of refrigerated trucks, namely in defining the optimal types of refrigerated trucks to be used and an optimal number of trucks in each type (Redmer et al., 2012).

The hybrid structural interaction matrix (HSIM) methodology is a problem-solving tool that integrates a weighing model into a prioritisation procedure (Oke and Ayomoh, 2005). This methodology prioritises attributes by using subordination principles and has similar features to that of the hierarchical tree structure diagram (HTSD) (Oke and Ayomoh, 2005). The HSIM concept is a new but well-structured methodology that shows all pairwise comparisons in a matrix-oriented structure (Oke and Ayomoh, 2005). The HSIM methodology integrates a weighing factor, whereas the structural interaction matrix (SIM) is limited to subordination and the HTSD (Oke and Ayomoh, 2005). The HSIM methodology can be followed in ten steps.

The HSIM concept focuses on constructing a matrix that shows all attributes and their pairwise comparisons (Oke and Ayomoh, 2005). It involves formulating a contextual relationship between the factors to show the relationship between them (Oke and Ayomoh, 2005). The matrix presents asymmetric characteristics, meaning that $e_{ij} = 1$ and $e_{ji} = 0$. If there is an interaction between attribute i and attribute j, then there cannot be any interaction between j and i (Oke and Ayomoh, 2005). A different response will come from each factor when assessing the pair-wise comparisons by using the contextual question. A ‘yes’ response will result in a 1 and a ‘no’ response will result in a 0.

Mathematically this is written as:

$$e_{ij} = \begin{cases} 1 & \text{if } i \text{ depends on the occurrence of } j, \\ 0 & \text{if } i \text{ does not depend on the occurrence of } j, \end{cases}$$

The determination of the weights for the factors is what sets HSIM apart from the other methodologies (Oke and Ayomoh, 2005). The importance of a factor is independent of the number of subordinating factors it has. If the factor has more subordinating factors than another, then the factor has a higher level of intensity rating compared to another factor (Oke and Ayomoh, 2005).

(Ayomoh and Oke, 2006) use the HSIM technique to demonstrate how HSIM is used to prioritise safety parameters in an organisation. The proposed methodology in the paper was used to integrate the SIM, the goal programming concept and the HTSD (Ayomoh and Oke, 2006). The paper proposed using the HSIM model, since the model treats its factors as goals. (Ayomoh and Oke, 2006) applied the principle of subordination integrated into the HTSD. The paper concluded that HSIM is an easily adaptable model that can be integrated with other methodologies. (Ayomoh et al., 2008) also demonstrates the HSIM concept in a paper that covers the disposal of municipal solid waste in developing countries. The HSIM prioritised health factors that came to light due to the improper disposal of solid waste (Ayomoh et al., 2008). The proposed method aided decision makers in which factors should have more preference. The concept was used to prioritise and weigh determining factors, and resources were optimally allocated based on the factors that had more preference (Ayomoh et al., 2008). The paper demonstrated problem solving by using critical factors that are represented in the structured hierarchy.

2.6. Conclusion

Some of the critical factors mentioned in the project approach have dependencies between each other, so the Bayesian network method will identify which factors carry more weight. The FAP and FCP methods are also expressed as optimisation models. They are fairly similar to each other, with only some equations that differ due to different problems being addressed. These equations can be used as guidelines when formulating one's own objective function and constraints. These combined methodologies stand out above the rest and would be the most useful when considering a solution for this project. An extensive research analysis will be conducted on all four possibilities before the best methodology that delivers the most promising results is applied to the problem.

Software to use for the LP model is LINGO as it is available to students. LINGO is an optimisation software tool that can solve linear, non-linear, integer, stochastic and many other models (LINDO Systems, 2017). It is coded in a readable and understandable language that helps formulate the given problem (LINDO Systems, 2017). LINGO can pull information from other documents and even generate reports directly into the application of the user's choosing (LINDO Systems, 2017). LINGO also provides a user manual, which guides the user when certain features are unclear (LINDO Systems, 2017). If the problem is not too complex, then Microsoft Excel is a good option to explore as stated in the article of (Song and Kang, 2016). Excel Solver is another tool that could help to optimise the allocation of resources. Excel Solver is also available for use, like the LINGO software that is provided by LINDO Systems. Excel Solver is a Microsoft Excel add-in program that one can use to find an optimal value for a formula in one cell (Microsoft, 2018). This value, the objective cell, can either be maximised or minimised depending on the objective of the analysis (Microsoft, 2018). The objective value is subjected to the constraints and limits of other cells in the worksheet. Solver works with the defined decision variables and then adjusts the values in the cells to satisfy the limits of the constraints (Microsoft, 2018). These values produce the result for the objective.

The most promising methodology would be the ANP method combined with a linear programming model. This alternative was chosen over the AHP approach because (Acar and Aplak, 2016) stated that the ANP approach is superior to that of the AHP approach. The ANP approach brings in the element of a hierarchy structure, which would prioritise the factors and then the LP model could optimally solve the assignment of vehicles to each business unit. The TOPSIS approach can be linked with the abovementioned approach to strengthen the ranking (Jothimani, 2014). The HSIM model is built on the concept of ANP and also focuses on the weights between different factors and how they are all interrelated. Using the HSIM concept combined with Excel Solver will enable an optimal solution to be reached.

3. Project Approach

3.1. Introduction

This section will describe how the problem will be addressed using different techniques in various steps. These steps will conclude with the accomplishment of all objectives.

3.2. Conceptual Framework

Figure 9 is an expanded representation of the Analyse step mentioned in the Project Plan.

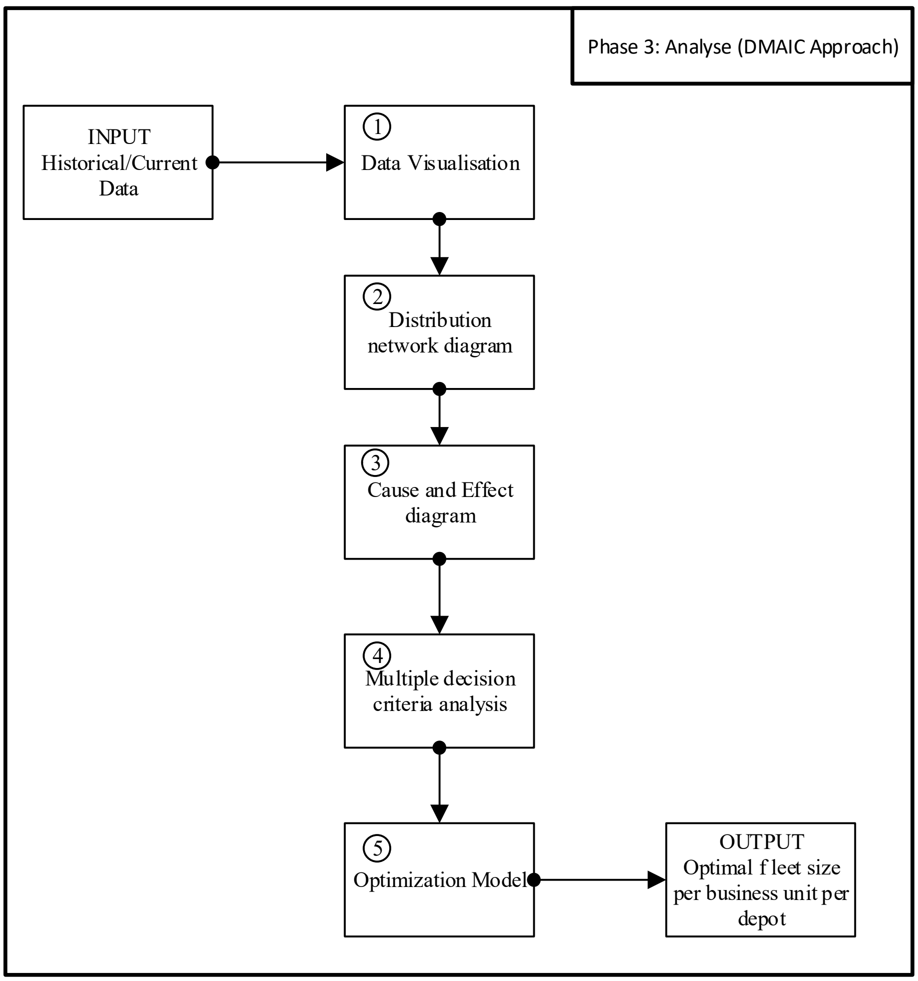

Figure 9: An expanded illustration of the Analyse Phase in Figure 4.

Step 1: Data Visualisation

In this step the data visualisation technique will be used to demonstrate what the data represents. The data and graphs were provided by Vector to extract certain assumptions to be used for the allocation procedure and weight prioritisation. The literature review states why data visualisation is always good to use.

Step 2: Distribution Network Diagram

In this step a distribution network diagram will be constructed to show how Vector wants its future distribution flows to look. The flows that are represented by dashed lines are part of the primary distribution and are not part of the scope of this project. The red block, Midrand D, is a PSD depot, meaning that only PSD vehicles are stationed at the depot. The green block, CSD Gauteng, is a CSD depot, meaning that only CSD vehicles are stationed at the depot. All of the blue blocks indicate that PSD, CSD and PNP will share the depot. All of the satellite depots share CSD and PSD routes.

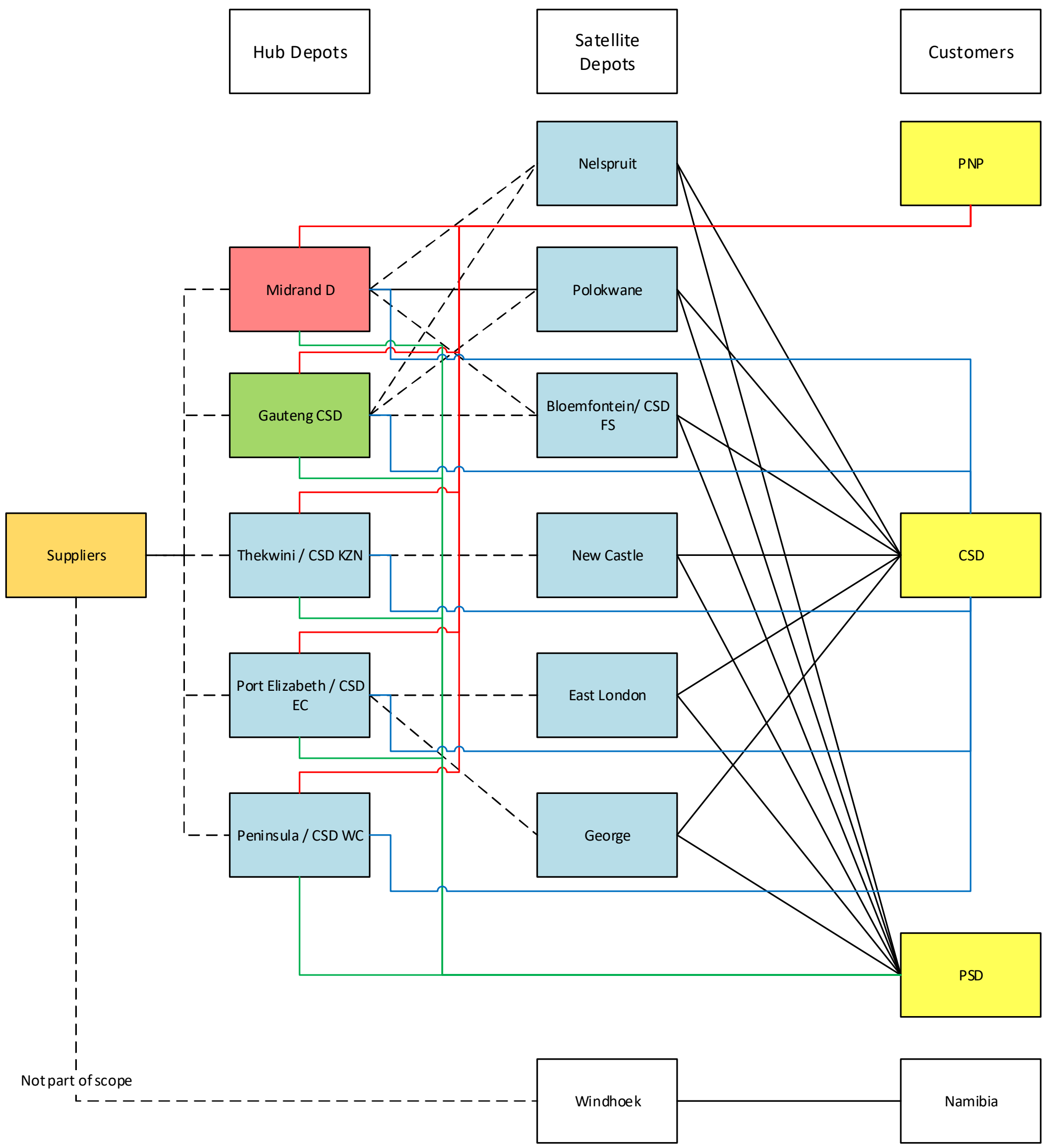

Figure 10: The Distribution Network Diagram.

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Step 3: Cause and Effect Diagram

This step uses the cause and effect diagram tool to identify where all the critical factors are situated and how they might be dependent on one another. The straight line method will be used when assessing the depreciation costs.

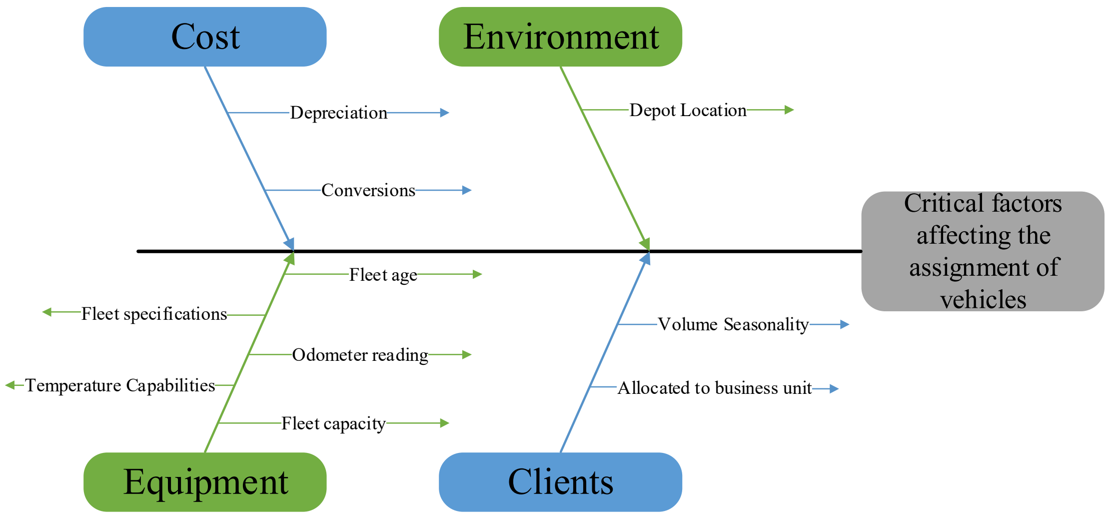

Figure 11: The Cause and Effect Diagram of the critical factors.

Step 4: Multiple Decision Criteria Analysis

This step will use the HSIM concept to determine the prioritisation and difference in weights between all the factors. This technique will be used to determine which factors have higher priority over the others. These ratings will be incorporated into the optimisation model discussed in Step 5. Microsoft Excel can accommodate these techniques and help to identify the values' rankings.

Step 5: Optimisation Model

This step will use the LP model as an optimisation technique to calculate the optimal fleet size for every business unit at every depot. The model will need input on all the available vehicles and depots. The output will then be the optimal fleet size for every depot. Excel Solver will be used to build the model. The output will be compared to the future fleet requirements, to see if any changes need to be made.

3.3. Theoretical Framework

3.3.1. Data Visualisation

It is necessary to investigate the historical and current data to see how Vector has been operating. The information will indicate where Vector has experienced demand fluctuations or specific trends during its most current months and in previous years. Vector has indicated that demand will stay the same as in previous years; therefore, we can conclude that previous trends can be assumed for future trends. The data regarding the vehicles that travel every day will be compared to the requirements of the future fleet.

3.3.2. Distribution Network Diagram

Vector mentioned that the company wants only the hub depots to distribute PNP ice cream orders, so it can limit the number of ice cream vehicles needed. In addition to this, it is difficult to maintain the temperature of ice cream products and it will be risky to move these products via the cross-docking approach. Cross-docking takes place when the primary distribution vehicle offloads products at the satellite depot. The products are moved across the satellite warehouse floor and then loaded onto a secondary distribution vehicle. The satellite depots only operate at chilled temperatures, so the quality of the ice cream will be affected when it moves through the warehouse floor. In Vector's current flow, the supplier drops products off at all the main hub depots and at the Bloemfontein satellite depot. The company has decided to eliminate the distribution flow from suppliers to Bloemfontein due to capacity constraints at the depot.

3.3.3. Cause and Effect Diagram

The identified critical factors to be used in the research approach include:

- Fleet age
- Odometer readings
- Fleet specifications
- Current depot location
- Volume seasonality
- Fleet capacity
- Depreciation
- Temperature capability
- Current business unit assigned

The weighted average of the fleet age should be identified across each business unit. The vehicles in each fleet should be prioritised or ranked using all the factors mentioned above.

3.3.4. Multiple Decision Criteria Analysis

The flow diagrams represented in Figure 12 and Figure 13 show the necessary steps to conduct the HSIM and HTSD methodologies for the project. The only interactions that are relevant to the matrix are those that interact with each other when considering the contextual question. The following steps are briefly discussed to show how the HSIM methodology coupled with the HTSD methodology is followed.

The first step is to identify and list all the critical factors that take part in any decision concerning the vehicle. The total number of factors is nine for each vehicle. The second step is to identify the contextual question of the matrix, to evaluate how the factors interact with each other. The contextual question will help to identify the relationships the factors have between each other and which factors carry more preference.

The contextual question for this paper is: Does factor i depend on factor j? This contextual question is used throughout the matrix by asking the same question for each cell. If the response to the contextual question is 'yes', then the cell is allocated a value of 1. If the response is 'no', then the cell is allocated a value of 0. If there is an interaction between i and j there cannot be an interaction between j and i.

Steps three and four explain how the matrix is drawn up, while steps five to ten indicate that the pairwise comparison must be followed through for each factor until the matrix is full. The HSIM methodology has been followed through and the HTSD methodology is applied for the next part.

The HTSD approach uses a level of importance to prioritise factors. This shows which factors have more preference and dominate other factors. The factors are also given an order based on how many subordinating factors they have. This order is crucial when executing an assessment. A weight factor is calculated for every factor based on their total number of subordinating factors. If a factor has more subordinating factors than another factor, it is seen to have a higher level of importance than the other factor. These weights can then be used in the assignment model to allocate each vehicle.

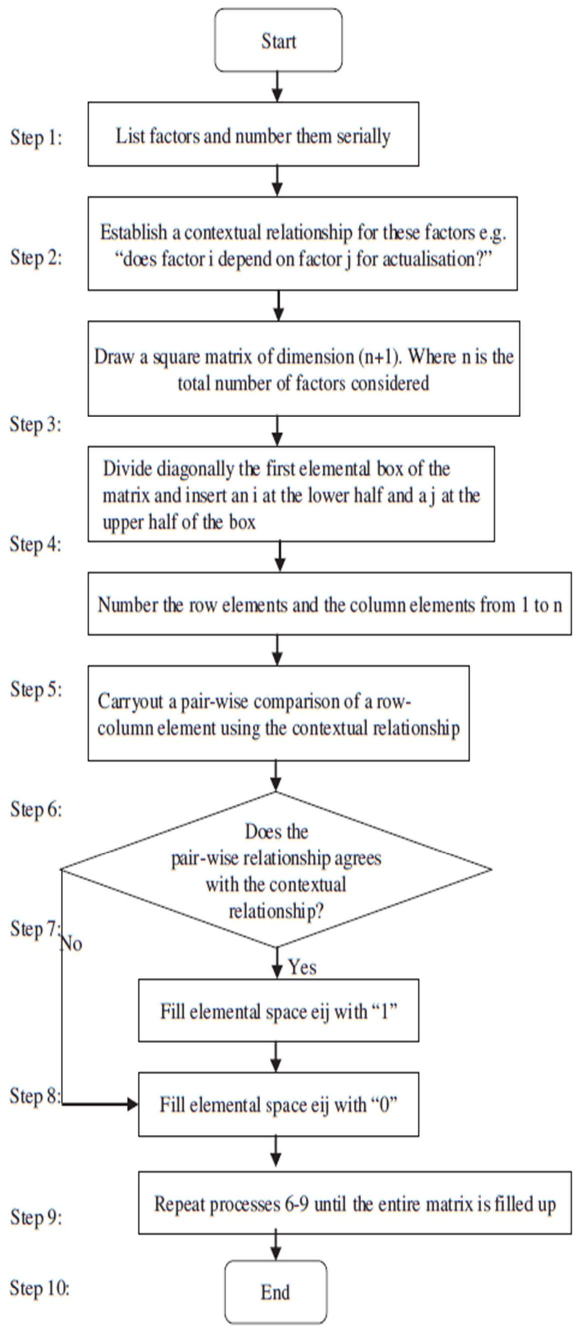

Figure 12: Flow diagram of the HSIM concept.

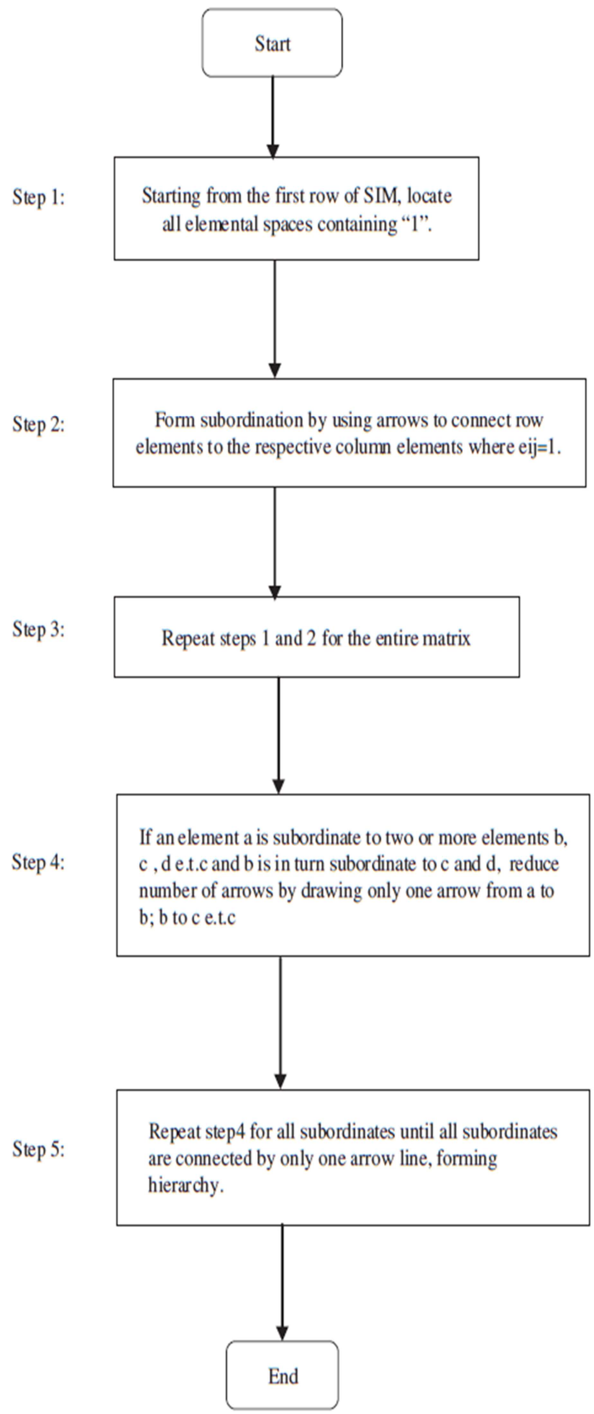

Figure 13: Flow diagram of the HTSD concept.

The formulas mentioned below are used to calculate the weight of each factor. The factors are rated on a scale from zero to nine. These calculations depend on the interaction matrix and their corresponding subordinating factors. The higher the value of the weight the higher the level of priority is to the corresponding factor.

$$I_{\mathrm{RF}i} = \left\{ \frac{N_{\mathrm{SF}i}}{T_{\mathrm{NF}}} \times M_{\mathrm{SR}} \right\} + \left\{ \frac{b}{T_{\mathrm{NF}}} (M_{\mathrm{SR}} - C) \right\}, \qquad (1)$$

$$C = \frac{M_{\mathrm{PSF}}}{T_{\mathrm{NF}}} \times M_{\mathrm{SR}}, \qquad (2)$$

$$b = N_{\mathrm{SF}i} + 1, \qquad (3)$$

Where:

I_{RFi} = Intensity of importance rating of factors

N_{SFi} = Number of subordinating factors

M_{SR} = Maximum rating scale of measurement

T_{NF} = Total number of factors

M_{PSF} = Maximum possible subordinating factors

C = Constant

b / T_{NF} = Variant ratio

After the weights have been calculated they will need to be normalised. The values of the factors are normalised so that they all lie between the same range of values. The normalisation range will fall between zero and one, so that the factors can be compared on the same level. Once the normalisation ratings have been calculated, it will be clear which factors have stronger levels of importance compared to the other factors. The sum of all the normalisation ratings of all the factors should equal 1. The following steps supported the normalisation process:

1. A matrix for each rating was calculated in column form, as in Table 3 for each of the nine factors.

2. The n^{th} root of each rating was calculated, where 'n' denotes the total number of factors.

3. The results in the previous step were summed together.

4. The n^{th} root for each factor calculated in step 2 was divided by the summation result in step 3.

These steps can also be transformed into the following mathematical model:

$$N_{\mathrm{w}i} = \frac{X_i^{1/n}}{\sum_{i=1}^{n} X_i^{1/n}}, \qquad (4)$$

Where:

N_{wi} = Normalised weight for each factor i

n = Total number of the factors considered

Xi = Initial rating of the factor i before normalisation

The weights have been calculated and normalised. They can now be used in the allocation model to assign the vehicles to their designated depots and business units.

3.3.5. Optimisation Models

The objective of this model is to maximise the utilisation of trucks. The current and future fleets, mix and specifications need to be taken into consideration. Excel Solver was used to develop the optimisation model, to optimally allocate all existing fleet to their business units.

3.3.5.1. Optimisation Model for Fleet Allocation

Two matrices were drawn up. The one being the preference matrix and the other the allocation matrix. The allocation matrix contained adjustable cells where the model decided on the best place to allocate a vehicle, based on the preference in the preference matrix.

The preference matrix was divided into columns where a vehicle could possibly be allocated. Each row of the matrix was a specific vehicle with a specific preference. A cell in a matrix would either have a preference value or a 0. The response of a 0 meant that the specific vehicle was not allowed to be allocated to that specific temperature, depot or business unit. The preference value could only be used to differentiate between two vehicles, to see which vehicle would carry the most priority. The preference for each vehicle was premised on the weight factors calculated in the HSIM model, then used for every factor to compare the different vehicles with each other.

The constraints made sure that a vehicle could only be assigned to one depot, but that a depot could have more than one vehicle. The maximum constraints were provided by Vector as a guideline on where they wanted most of their vehicles allocated. The objective cell in the model was used to maximise the utilisation of the vehicles allocated to a depot.

The following formula was used:

Objective Cell = SUMPRODUCT(Preference matrix ; Allocation matrix)

This formula allocates vehicles to all their potential designated areas, to maximise the objective cell to its highest value and give output on where each vehicle should go.

3.3.5.2. Cost Validation

The other optimisation model was developed to validate Vector's current fleet size per business unit. The following constraints were fashioned together to give a feasible result:

Notation and definition
X_1 : The set of existing CSD/PSD vehicles
X_2 : The set of possible new CSD/PSD vehicles
X_3 : The set of new PNP 8 ton (8T) vehicles
X_4 : The set of converted PNP 14 ton (14T) vehicles
X_5 : The set of converted PNP 8 ton (8T) vehicles
X_6: The set of new PNP 14 ton (14T) vehicles
X_7: The set of rentals
C_i: The costs related to each set of vehicles where i = 1, 2, 3, ..., 6

Decision Variable

Xi = Number of vehicles

where i = 1, 2, 3, 4, 5, 6

Objective Function

$$\text{Min } Z = C_1*X_1 + C_2*X_2 + C_3*X_3 + C_4*X_4 + C_5*X_5 + C_6*X_6$$

Subjected to:

$$X_1 \leq 179 \quad (1)$$

$$X_2 + X_7 \geq 30 \quad (2)$$

$$X_3 + X_7 \leq 22 \quad (3)$$

$$X_4 \geq 0 \quad (4)$$

$$X_5 \geq 0 \quad (5)$$

$$X_6 \geq 15 \quad (6)$$

$$X_7 \geq 0 \quad (7)$$

$$X_1 + X_2 = 209 \quad (8)$$

$$X_3 + X_4 + X_5 + X_6 = 80 \quad (9)$$

$$X_1 + X_4 + X_5 = 222 \quad (10)$$

$$X_1 + X_2 + X_3 + X_4 + X_5 + X_6 = 289 \quad (11)$$

$$X_4 + X_6 = 24 \quad (12)$$

$$X_3 + X_5 = 56 \quad (13)$$

The objective function minimises the cost associated with acquiring a specific vehicle. Constraint 1 indicates that there are only 179 vehicles left in the existing fleet, since the other 43 have been suggested for conversion to the PNP business unit. Constraint 2 needs to replace vehicles that have been converted from the existing fleet and can be either new or rentals. This will need to be 30 vehicles or more to meet the required 209 vehicles for the end result of the existing fleet. Constraint 3 is the suggested value to buy new vehicles for the PNP business unit or obtain rentals from another company. Constraint 4, 5 and 7 are there to ensure that there is an option to convert or rent vehicles. Constraint 6 establishes that Vector has already bought 15 new vehicles, but there is the option to buy more. Constraints 8 to 13 make sure that the sum total of all the variables are aligned with what Vector expects at the end.

4. Results and Discussion

4.1. Data Visualisation

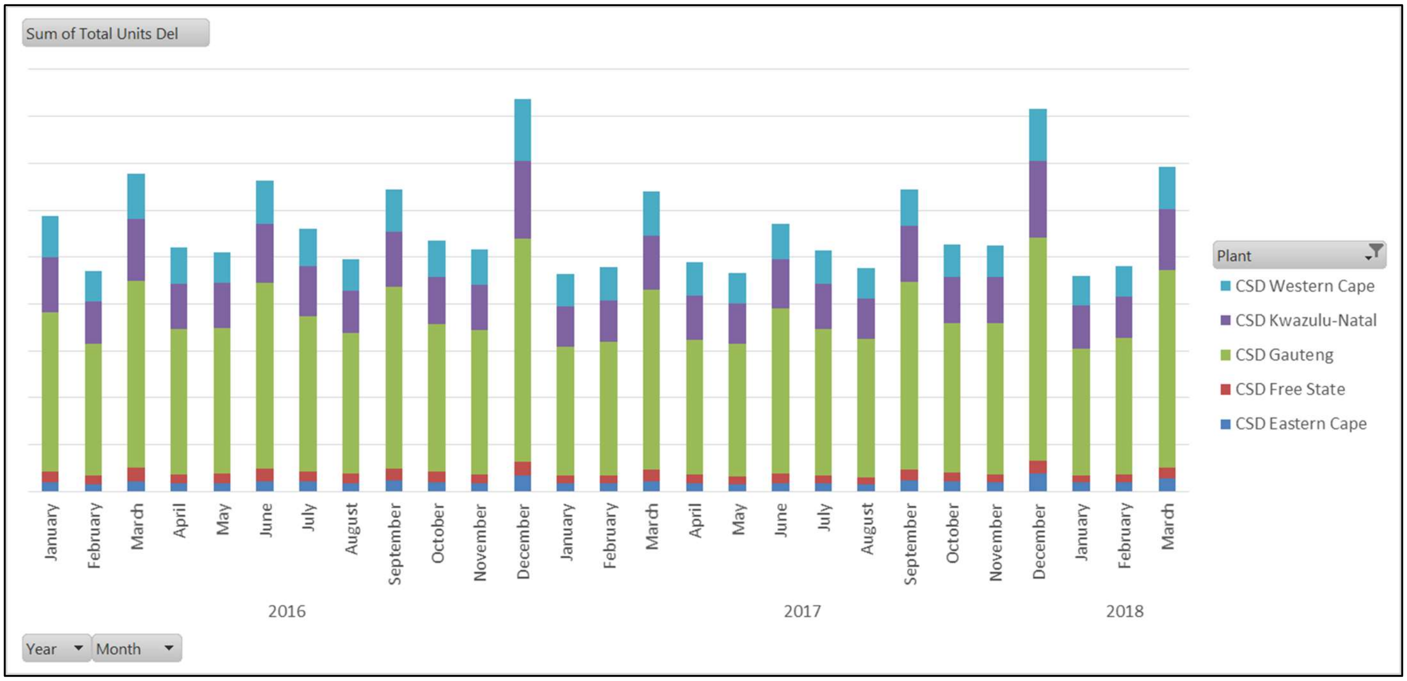

Figure 14: A graph representing the historical trends of the CSD business unit. (Vector, 2018 #133)

Figure 14 represents the historical trend of the CSD business unit. The graph shows that the green demarcated area, the CSD Gauteng depot, is the depot that delivers the most units throughout the year. The Western Cape and KwaZulu-Natal depots fall next in line. The two depots that deliver the lowest number of units a month are Free State and Eastern Cape. The graph also indicates that there is a trend during the December holiday season, when people are likely to spend money more than they do in other months. The demand is much higher during December and vehicles need to be allocated to the relevant depots so all deliveries are fulfilled. Instead of incurring costs that might only be beneficial for a few months of a year, Vector could rent vehicles in the months that demand more distribution. This graph justifies why more vehicles should be allocated at busier depots during busier seasons.

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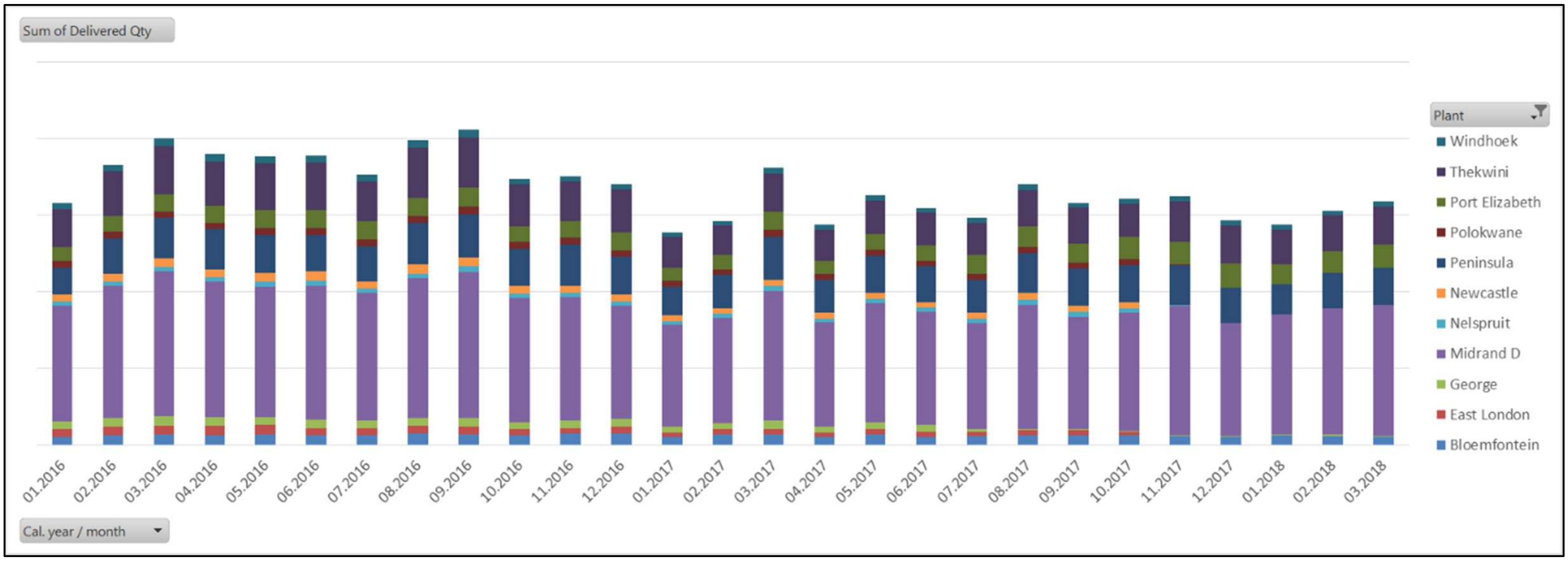

Figure 15: A graph representing the historical trends of the PSD business unit. (Vector, 2018 #132)

Figure 15 represents the historical trend of the PSD business unit. The graph shows that the purple demarcated area, the Midrand depot, is the depot that delivers the most units throughout the year. The Peninsula and Thekwini depots are second to the Midrand depot, while the rest of the depots follow thereafter. The depot that delivers the lowest number of units each month is in Nelspruit. The graph does not indicate any specific trend, but the number of delivered units does increase in the months of March and August. This could indicate that customers stock up on groceries before the winter months. Items bought before winter might be specific items that can be stored for a longer period of time. The increase is not that severe and the demand per depot remains relatively stable during the year. This graph also justifies why more vehicles should be situated at busy depots to meet the demands of their customers

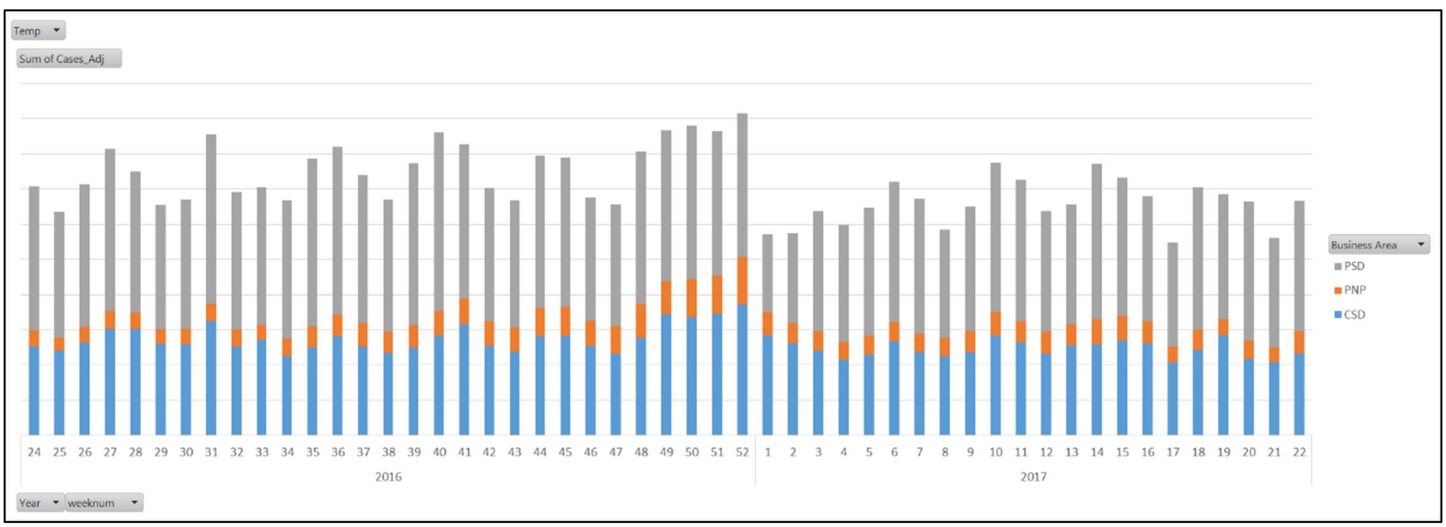

Figure 16: A graph representing the volume seasonality of the different business units. (Vector, 2018 #134)

Figure 16 represents seasonality across the business units. It shows that the PSD business unit is the most demanding unit out of the three. The CSD business unit is the second most demanding unit and then PNP, which is a newly established unit and will be the least demanding. The demand does not seem to fluctuate too much across each business unit but does show increases between week 1 to week 52. The PNP business unit shows that the demand increases slightly during December. Ice cream is part of the PNP business unit, which could explain the increase in December as people are more likely to satisfy their need for a cold delight on a hot day.

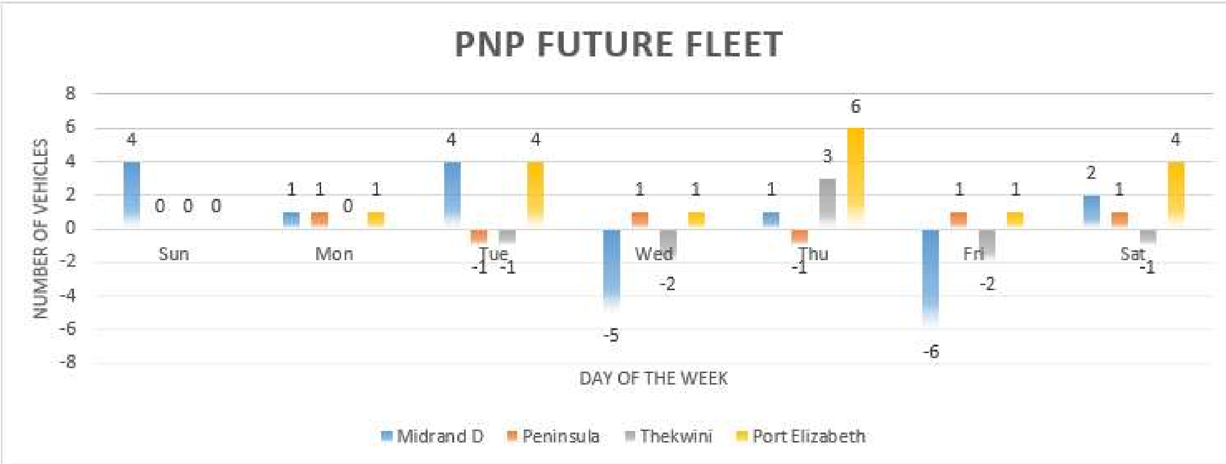

Figure 17: A graph depicting where there is a shortage or excess of vehicles in the PNP fleet.

Vector provided their first month of demand when all three business units will be implemented. Figure 17 represents the PNP future fleet with regard to the required fleet that Vector suggested. The graph indicates where Vector will fall short or have excess vehicles, if they choose their suggested configuration. On a Tuesday there will be a shortage of vehicles at the Peninsula and Thekwini depots. On a Wednesday there is a big shortage of vehicles at the Midrand depot and a minor shortage at the Thekwini depot. On a Thursday there is a shortage of one vehicle at the Peninsula depot. On a Friday there is again another big shortage at the Midrand depot and a minor shortage at the Thekwini depot. The Friday statistics looks similar to those of Tuesday and then there is one vehicle short on s Saturday at the Thekwini depot. Vector can move one of the vehicles from the Port Elizabeth depot to the Peninsula depot. The rest of the vehicles can either be rented or extra vehicle should be bought to be able to decrease the shortage of vehicle per week.

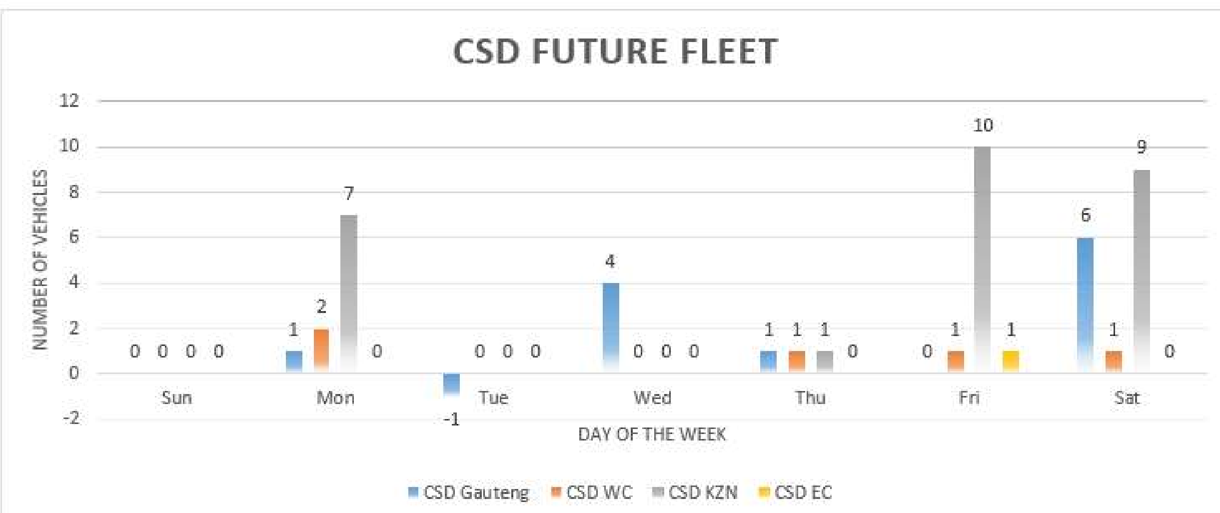

Figure 18: A graph depicting where there is a shortage or excess of vehicles in the CSD fleet.

Figure 18 represents the CSD future fleet with regard to the required fleet that Vector suggested. In the CSD business unit there is only one day that has a shortage and that would be on a Tuesday at the CSD Gauteng depot. On this specific day a vehicle from the PNP business unit can be loaned for the day and if the vehicle is not available it is best to rent out a vehicle when this shortage happens again.

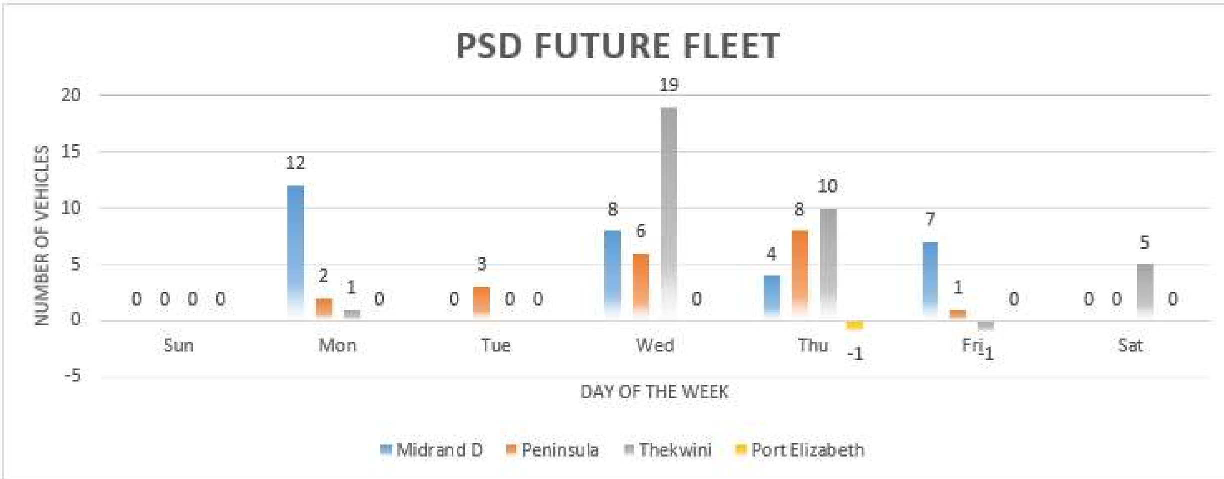

Figure 19: A graph depicting where there is a shortage or excess of vehicles in the PSD fleet.

Figure 19 represents the PSD future fleet with regard to the required fleet that Vector suggested. In the PSD business unit there are two days that have a shortage of vehicles. The one day is on a Thursday at the Port Elizabeth depot and the other is on a Friday at the Thekwini depot. The Thekwini depot can loan a vehicle from the CSD business unit on that specific day to counter act the shortage. The manual bulk dividers can be removed to make a multi-temperature vehicle a single temperature vehicle. The Port Elizabeth depot will either need to rent a vehicle to counter act the shortage or buy and extra vehicle to make sure there is enough vehicles to satisfy the demand.

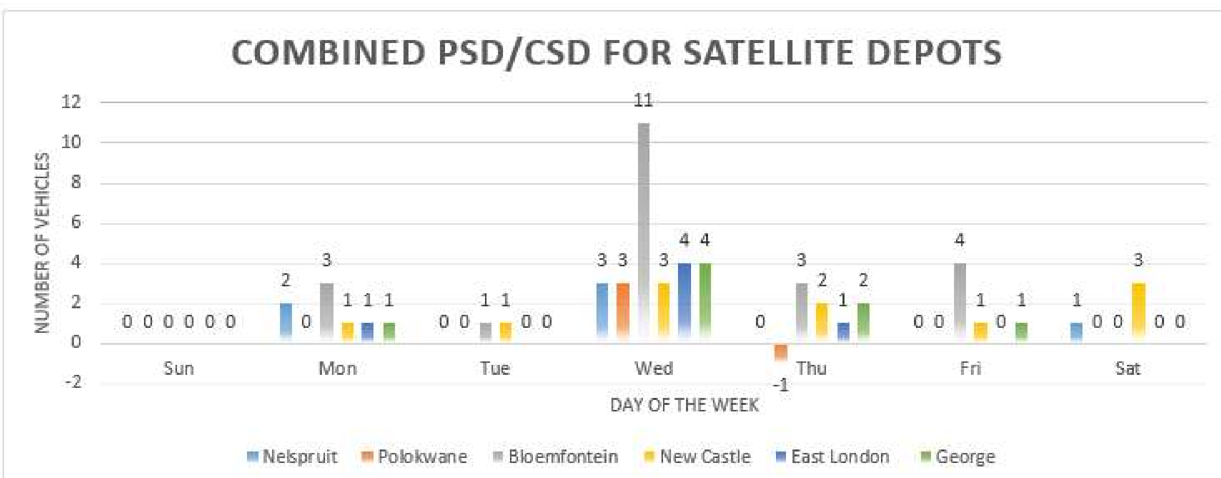

Figure 20: A graph depicting where there is a shortage or excess of vehicles in the combined PSD/CSD fleet.

Figure 20 represents the combined future fleet with regard to the required fleet that Vector suggested. In this graph there is also only one day that a shortage occurs. This on a Thursday at the Polokwane depot. A vehicle can be transferred from the New Castle depot to the Polokwane depot since the New Castle depot has enough vehicles to be able to give one over to the Polokwane depot. No rentals would be needed for the combined depots.

4.2. Multiple decision criteria analysis

Listed below are the nine factors that were used in the HSIM methodology and their description of how they fit into the prioritisation.

1. Fleet age

This attribute of the vehicle defines how long the vehicle has been operational. This is important because it determines how well a vehicle might be operating. A new vehicle might adjust better to a high demand depot than an older vehicle would.

2. Fleet capacity

This is the size of the vehicle. The two sizes applicable in this paper are an eight ton (8T) vehicle and a fourteen ton (14T) vehicle. Capacity is important because different capacities add flexibility to a distribution network. A 14T vehicle has a higher capacity and can hold more stock in its load body. The 14T vehicle can also have more temperature compartments than what an 8T vehicle might be able to accommodate; however, the 8T vehicle will be able to deliver smaller orders. Some customers do not have loading bays for big vehicles and 8T vehicles are more flexible.

3. Odometer reading

This is a reading on the vehicle's dashboard that indicates how many kilometres the vehicle has travelled throughout its useful life. Some vehicles might have a young vehicle age but still have a high odometer reading. Vehicles with a higher odometer reading show that the vehicle has been very active in distributing products to customers. A high odometer reading can also tie up with the age of the vehicle.

4. Depreciation

This attribute is the decrease in value of an asset over its useful life. The vehicles are depreciated differently, depending on the age and type of vehicle.

5. Fleet specification

This attribute specifies what brand of vehicle is being used. Vector uses brands such as Nissan, Isuzu, Scania and Hino.

6. Temperature capability

A vehicle's temperature capability is either multi-temperature or single temperature. A multi-temperature vehicle is more flexible as it accommodates more temperature compartments. The temperature is important because the PSD business unit uses only single temperature vehicles, and the CSD and PNP business units use multi-temperature vehicles.

7. Current depot location

This attribute defines at what depot the vehicle has previously been situated. This attribute is important because some depots have a higher volume demand than others and need more vehicles allocated to them.

8. Current business unit assigned

This attribute defines which business unit the vehicle was previously part of. The attribute is dependent on the depot location because certain business units operate at certain depots. The PNP business unit operates at hub depots, so if a vehicle is allocated to a hub depot then it can be part of any business unit depending on other factors as well. If a vehicle is assigned to a satellite depot, then it can be allocated to the CSD or PSD business unit.

9. Volume seasonality

This attribute focuses on how each business unit operates during their peak and off-peak times over the course of the year. It depends on the depot's location because different depots have higher demands, while hub depots specifically work with more delivered products.

4.2.1. HSIM Model Applied

Table 2 represents the binary interaction matrix between the factors.

Table 2: The binary interaction matrix that illustrates the pair-wise comparisons between the different factors.

		1	2	3	4	5	6	7	8	9
	i depends on j	Fleet age	Fleet capacity	Odometer readings	Depreciation	Fleet specification	Temperature capability	Current depot location	Current business unit assigned	Volume Seasonalities
1	Fleet age	0	0	0	0	0	0	0	0	0
2	Fleet capacity	1	0	0	0	0	1	1	1	1
3	Odometer readings	1	0	0	0	0	0	0	0	0
4	Depreciation	1	0	0	0	1	0	0	0	0
5	Fleet specification	0	1	0	0	0	1	1	1	0
6	Temperature capability	1	0	0	0	0	0	0	1	0
7	Current depot location	0	0	0	0	0	0	0	0	0
8	Current business unit assigned	0	0	0	0	0	0	1	0	1
9	Volume Seasonalities	0	0	0	0	0	0	1	0	0

4.2.2. HTSD Model Applied

Figure 21 represents the level each factor lies within and its priority in conjunction with the other factors. The diagram presents seven levels of priority, where factor 7 and factor 1 have the highest priority. The arrows indicate which factor is subordinate to another and how the priorities should be followed when deciding about a critical factor. Factors 3 and 4 have no subordinating factors and have the lowest level of importance. The weight level of importance is dependent on how many subordinating factors a specific factor has.

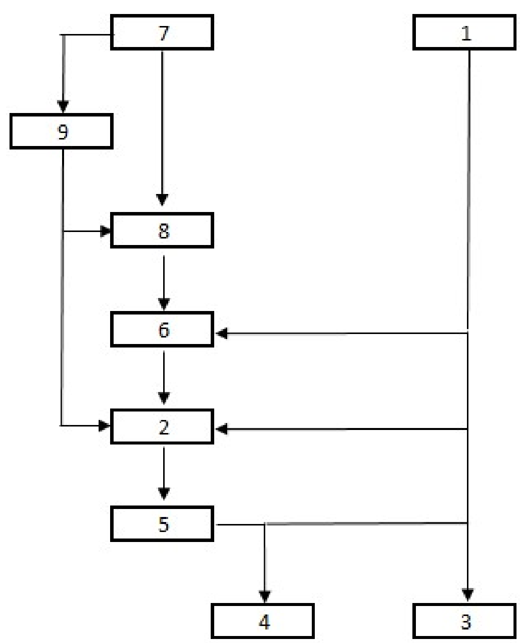

Figure 21: The HTSD diagram for the different factors.

4.2.3. Weight Factors

The following three tables represent the number of subordinating factors that each factor has and their associated ratings. The weights and normalisation ratings are then calculated by using the formulas mentioned in the theoretical framework in section 3.3.4. Table 3 represents the subordinating factors of each factor. Table 4 represents the weight rating of each factor. The weight rating equation can be viewed in section 3.3.4 in formula 1. Table 5 represents the normalisation ratings of each factor. The normalisation rating equation can be viewed in section 3.3.4 in formula 4.

Table 3: The number of subordinating factors.

Factor	Number of subordinating factors
1	4
2	1
3	0
4	0
5	1
6	2
7	4
8	3
9	2

Table 4: The weight rating for each factor.

Factor	Weight Rating
1	4.5556
2	1.2222
3	0.1111
4	0.1111
5	1.2222
6	2.3333
7	4.5556
8	3.4444
9	2.3333

Table 5: The normalization rating for each factor.

Factor	Normalisation Rating
1	0.2291
2	0.0615
3	0.0056
4	0.0056
5	0.0615
6	0.1173
7	0.2291
8	0.1732
9	0.1173

4.3. Assignment Model

Table 6 represents the proposed vehicles per depot. Red cells indicate that the number of vehicles allocated to this depot did not meet the requirements of Vector's proposed allocations. Even though the allocation model allocates the correct number of vehicles to each depot, it focuses on what vehicle number was allocated to the specific depot. For instance, the two vehicles allocated to the CSD Eastern Cape depot were vehicles 121 and 128. Another example would be vehicle 162, which was allocated to CSD Gauteng MT 8T. The allocation of vehicles would change by adjusting the total number of vehicles per depot. In this specific model working with the proposed allocations, 12 vehicles could not be allocated. These 12 are all 14T multi-temperature vehicles.

The vehicles were allocated using the normalisation ratings of the critical factors. Each vehicle was assessed by its attributes and then a sum weight was obtained to give some sort of preference to the vehicle. This means that some vehicles have more preference over others based on their attributes and the weight that each attribute carries.

Table 6: Number of allocated vehicles per depot for the CSD and PSD business units.

	MT		ST		Total	Shortage
	8T	14T	8T	14T		
CSD Eastern Cape		2			2	
CSD Free State	6	9			15	
CSD Gauteng	1	36			37	
CSD Thekwini	1	14			15	
CSD Peninsula	2	7			9	
East London	1	6			7	
George	2	3			5	
PSD Midrand			38	8	46	4
Nelspruit	3	2			5	
Newcastle	4	2			6	
PSD Peninsula			10	5	15	8
Polokwane	7	1			8	
PSD Eastern Cape			3	4	7	
PSD Thekwini			10	10	20	
	27	82	61	27	209	12

Table 7 represents the allocations for the PNP business unit and works on the same concept as that of the table above. If Vector decides to change the total number of vehicles per depot, then the allocation procedure will allocate the new and converted vehicles to different depots.

Table 7: The number of allocated vehicles per depot for the PNP business unit.

	MT		Total
	8T	14T	
Midrand	31	18	49
Peninsula	8	3	11
Eastern Cape	9	1	10
Thekwini	8	2	10

Vehicle	CSD EC MT14	CSD Bloem MT8	CSD Bloem MT14	CSD Gauteng MT8	CSD Gauteng MT14	CSD KZN MT8	CSD KZN MT14	CSD Peninsula MT8	CSD Peninsula MT14
1	1.792522346	0	1.792522346	0	1.792522346	0	1.792522346	0	1.792522346
2	0	1.563472067	0	1.563472067	0	1.563472067	0	1.563472067	0
3	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0
9	1.798108939	0	1.798108939	0	1.798108939	0	1.798108939	0	1.798108939
10	2.557932961	0	2.557932961	0	2.557932961	0	2.557932961	0	2.557932961

Figure 22: A snippet from the preference matrix.

Figure 22 represent what the preference would be for a specific vehicle to be allocated to a specific depot. This means that if a vehicle is a 14 ton multi-temperature (MT 14T) vehicles then it can be allocated to all the depots that can accommodate the MT 14T vehicles.

East London MT8	East London MT14	George MT8	George MT14	PSD Midrand ST8	PSD Midrand ST14	Nelspruit MT8	Nelspruit MT14	New Castle MT8	New Castle MT14
0	1.792522346	0	1.792522346	0	0	0	1.792522346	0	1.792522346
1.563472067	0	1.563472067	0	0	0	1.563472067	0	1.563472067	0
0	0	0	0	1.79814581	0	0	0	0	0
0	0	0	0	1.786972626	0	0	0	0	0
0	0	0	0	1.792559218	0	0	0	0	0
0	0	0	0	2.021609497	0	0	0	0	0
0	0	0	0	0	1.79814581	0	0	0	0
0	0	0	0	2.016022905	0	0	0	0	0
0	1.798108939	0	1.798108939	0	0	0	1.798108939	0	1.798108939
0	2.557932961	0	2.557932961	0	0	0	2.557932961	0	2.557932961

Figure 23: A snippet from the preference matrix.

Figure 23 represent the same information that figure 22 represent except for the change in depots. Another example would be that if a vehicle is an 8 ton single temperature vehicle it would only be placed at a depot that accommodates the same features.

Vehicle			Fleet age	Scale	Weight	Unit	Fleet capacity	Scale	Weight	Unit	Odometer readings	Scale	Weight	Unit
1	MAN 25.280 TGM	14T	10	1	0.22905	0.22905	14T	1	0.061453	0.061453	653898	1	0.005587	0.005587
2	MAN 18.240 BB-C	8T	11	0	0.22905	0	8T	1	0.061453	0.061453	688917	1	0.005587	0.005587
3	NISSAN UD90	8T	7	2	0.22905	0.458101	8T	1	0.061453	0.061453	432689	3	0.005587	0.01676
4	NISSAN UD95	8T	7	2	0.22905	0.458101	8T	1	0.061453	0.061453	629980	1	0.005587	0.005587
5	NISSAN UD95A	8T	7	2	0.22905	0.458101	8T	1	0.061453	0.061453	571896	2	0.005587	0.011173
6	NISSAN UD 95	8T	6	3	0.22905	0.687151	8T	1	0.061453	0.061453	541000	2	0.005587	0.011173
7	ISUZU FVZ1400	14T	7	2	0.22905	0.458101	14T	1	0.061453	0.061453	401477	3	0.005587	0.01676
8	NISSAN UD 95	8T	6	3	0.22905	0.687151	8T	1	0.061453	0.061453	655789	1	0.005587	0.005587
9	MAN 25.280 TGM	14T	10	1	0.22905	0.22905	14T	1	0.061453	0.061453	502612	2	0.005587	0.011173
10	SCANIA P310	14T	3	4	0.22905	0.916201	14T	1	0.061453	0.061453	154568	4	0.005587	0.022346

Figure 24: A snippet of the factors with their weights and ratings allocated to each vehicle.

Figure 24 represents some of the vehicles and their weights and ratings per factors. Each factor was scaled between zero and five so that they all fall in the same range. The weight comes from the normalisation rating in table 5 in section 4.2.3.

Vehicle	CSD EC MT14	CSD Bloem MT8	CSD Bloem MT14	CSD Gauteng MT8	CSD Gauteng MT14	CSD KZN MT8	CSD KZN MT14	CSD Peninsula MT8	CSD Peninsula MT14
1	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0
10	0	0	0	0	1	0	0	0	0
11	0	0	0	0	1	0	0	0	0
12	0	0	0	0	1	0	0	0	0
13	0	0	0	0	1	0	0	0	0
14	0	0	0	0	1	0	0	0	0
15	0	0	0	0	1	0	0	0	0
16	0	0	0	0	1	0	0	0	0
17	0	1	0	0	0	0	0	0	0
18	0	0	0	0	1	0	0	0	0
19	0	0	0	0	0	0	0	0	1
20	0	0	0	0	0	0	1	0	0
21	0	0	0	0	0	0	1	0	0
22	0	0	0	0	0	0	1	0	0
23	0	0	0	0	0	0	1	0	0
24	0	0	0	0	0	0	1	0	0
25	0	0	0	0	0	0	1	0	0
26	0	0	0	0	1	0	0	0	0

Figure 25: A snippet of the allocation matrix.

Figure 25 represents the allocation matrix. The cells are all blue because they are “adjusted cells”. This means that excel solver decides where a one or where a zero should come. The snippet shows where the model decided to allocate a specific vehicle to a specific depot.

1	No Allocation	MT	14
2	Polokwane MT8	MT	8
3	PSD Midrand ST8	ST	8
4	PSD Midrand ST8	ST	8
5	PSD Midrand ST8	ST	8
6	PSD Midrand ST8	ST	8
7	PSD PE ST14	ST	14
8	PSD Midrand ST8	ST	8
9	No Allocation	MT	14
10	CSD Gauteng MT14	MT	14
11	CSD Gauteng MT14	MT	14
12	CSD Gauteng MT14	MT	14
13	CSD Gauteng MT14	MT	14
14	CSD Gauteng MT14	MT	14
15	CSD Gauteng MT14	MT	14
16	CSD Gauteng MT14	MT	14
17	CSD Bloem MT8	MT	8
18	CSD Gauteng MT14	MT	14
19	CSD Peninsula MT14	MT	14
20	CSD KZN MT14	MT	14
21	CSD KZN MT14	MT	14
22	CSD KZN MT14	MT	14
23	CSD KZN MT14	MT	14
24	CSD KZN MT14	MT	14
25	CSD KZN MT14	MT	14
26	CSD Gauteng MT14	MT	14

Figure 26: A snippet of the outputs given from the allocation model.

Figure 26 represents the outputs given from the allocation model. A depot is assigned a specific vehicle and a quick summary is drawn up to make sure that the depot and characteristics of the vehicle are aligned.

No Allocation	CSD EC MT14	CSD Bloem MT8	CSD Bloem MT14	CSD Gauteng MT8	CSD Gauteng MT14	CSD KZN MT8	CSD KZN MT14	CSD Peninsula MT8	CSD Peninsula MT14	East London MT8	East London MT14	George MT8	George MT14	PSD Midrand ST8	PSD Midrand ST14
1	121	17	38	162	10	136	20	135	19	133	33	131	57	3	76
9	128	65	54		11		21	182	35		34	144	58	4	193
145		66	64		12		22		40		39		59	5	194
146		123	72		13		23		41		47			6	195
147		132	81		14		24		46		55			8	196
148		138	120		15		25		48		178			74	197
149			134		16		36		49					79	207
152			143		18		42							89	208
155			163		26		50							92	
158					27		53							95	
159					28		62							96	
164					29		63							111	
					30		141							119	
					31		142							122	
					32									124	
					37									125	
					43									137	
					44									139	
					45									150	
					51									151	
					56									160	
					61									165	
					67									166	
					68									167	
					69									168	
					70									169	
					71									170	
					80									171	
					82									172	
					83									173	
					84									183	
					129									184	
					174									185	
					175									186	
					176									187	
					177									188	
														189	
														190	

Figure 27: The vehicle allocation per depot for CSD/PSD Part 1.

Figure 27 represent a part of the vehicle allocation for CSD and PSD. The figure shows what vehicle should go to what depot depending on what the preference was in the allocation model. There were twelve vehicles that could not be allocated as this would have not met other requirements in the allocation model. Since PSD Midrand and PSD Peninsula short vehicles, one can allocate the MT 14T vehicles to those depots. A multi temperature vehicle can be used as a single temperature vehicle because the manual dividers can be removed to make it a single temperature vehicle.

Nelspruit MT8	Nelspruit MT14	New Castle MT8	New Castle MT14	PSD Peninsula ST8	PSD Peninsula ST14	Polokwane MT8	Polokwane MT14	PSD PE ST8	PSD PE ST14	PSD Thekwnini ST8	PSD Thekwini ST14
78	73	87	60	52	117	2	116	90	7	91	77
156	179	130	75	101	127	85		107	191	93	105
161		154		102	199	86		113	192	94	115
		157		104	200	88			198	97	118
				108	204	153				98	201
				109		180				99	202
				112		181				100	203
				114						103	205
				126						106	206
				140						110	209

Figure 28: The vehicle allocation per depot for CSD/PSD Part 2.

Figure 28 represent a part of the vehicle allocation for CSD and PSD. The figure shows what vehicle should go to what depot depending on what the preference was in the allocation model.

Midrand ST8	Midrand ST14	Peninsula ST8	Peninsula ST14	PE ST8	PE ST14	Thekwnin ST8	Thekwini ST14	No Allocation
210	232	211	276	245	289	242	275	
214	233	212	277	249		244	283	
215	234	213	288	251		256		
216	235	250		252		259		
217	236	260		254		261		
218	237	264		262		269		
219	238	265		263		270		
220	239	266		272		274		
221	240			273				
222	278							
223	279							
224	280							
225	281							
226	282							
227	284							
228	285							
229	286							
230	287							
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271								

Figure 29: The vehicle allocation per depot for PNP.

Figure 29 represent a part of the vehicle allocation for PNP. The figure shows what vehicle should go to what depot depending on what the preference was in the allocation model. All vehicles were allocated to the designated depots.

4.4. Cost Validation

Table 8 is the result of all the formulas (formula 1-13) mentioned in the theoretical framework in section 3.3.5.2. These values are based on the proposed sizes of the different vehicle types. Vector has already bought 15 new PNP 14T vehicles, so the model chose 15 and not more as this is the most expensive option. The suggested number of vehicles to convert was 9 for the 14T vehicles and 34 for the 8T vehicles. The model was constructed so that it had the option to choose the specified value or more. Since Vector started with 222 vehicles in total and suggested converting 43 vehicles, it meant that only 179 vehicles would be left for the existing fleet. The model could then choose to convert more vehicles or stay with the existing 179 vehicles left. Vector requires an end result of 209 vehicles for its CSD and PSD business units; therefore, if more vehicles are converted from the existing fleet, then new vehicles would need to be bought to replace them. Another option for the model was to leave the existing fleet and buy new vehicles for the PNP business unit. This means that no conversion cost would be necessary, just the initial investment. The model then had the option to choose if it wanted to purchase a vehicle or convert it. Since the proposed option was buying only 22 vehicles, the model had the option to buy 22 vehicles or less. The model does not choose any rentals because it is more when looking at the initial investment of the new vehicle versus the cost of renting per year. Vector did not want to increase expenditure if conversion might be the best option.

Having these suggested values and tight constraints, the model gave an output of exactly what was suggested by minimising the cost of each type of vehicle investment. The cost has been index to keep the initial investment confidential.

Table 8: The suggested size of fleet needed for every vehicle type.

Variable	Type of vehicle	Vehicles	Cost (R)
X_1	Old CSD/PSD	179	0
X_2	New CSD/PSD	30	160 000
X_3	New PNP 8T	22	280 000
X_4	Converted PNP 14T	9	186200
X_5	Converted PNP 8T	34	186200
X_6	New PNP 14T	15	400 000
X_7	Rentals	0	238 296

Table 9 shows the same concept but with more relaxed constraints to see if the model has a better option for the suggested values. The same constraints were applied in terms of the totals given for the future fleet requirements, while other constraints were adjusted. Variables X_2, X_3, X_4 and X_5 (formulas 2-5) were all changed so that their values could be anything above zero while still meeting the other requirements. Variable X_1 (formula 1) was adjusted so that it had the option to keep all existing fleet or less. This meant that X_1 could be 222 vehicles or less because that was the maximum available.

Table 9: The size of fleet needed for every vehicle type.

Variable	Type of vehicle	Vehicles	Cost (R)
X_1	Old CSD/PSD	209	0
X_2	New CSD/PSD	0	160 000
X_3	New PNP 8T	52	280 000
X_4	Converted PNP 14T	9	186200
X_5	Converted PNP 8T	4	186200
X_6	New PNP 14T	15	400 000
X_7	Rentals	0	238 296

4.5. Scenarios

The following scenarios indicate whether Vector might want to adjust their suggested output. The allocation model allocates cased on the preference given, so changing the "number of vehicles per depot" would either increase or decrease the "No Allocation" block as indicated in Figure 27 and Figure 29. The PNP business unit has all of its vehicles allocated. When any changes are made to the suggested "vehicles per depot" mentioned in Table 6 then the some vehicles cannot be allocated. This indicates that the current suggested "vehicles per depot" is the optimum configuration.

In the CSD and PSD business units there are twelve vehicle that could not be allocated. This can be confirmed in Table 6 as well as a detailed view in Figure 27. All the CSD depots and their configurations have been met but the PSD business unit has not. The Midrand depot, that is part of the PSD business unit, are eight vehicles short and the Peninsula depot, which is also part of the PSD depot, are four vehicles short. The twelve vehicles that could not be allocated are all multi-temperature vehicles but their manual bulk dividers can be removed to make them all single temperature vehicles. The non-allocated twelve vehicles can be allocated to the Midrand and Peninsula depots, then all configurations will be satisfied. If the configuration of the suggested "number of vehicles per depot" for the CSD/PSD business units are changed then different outcomes will occur.

The only scenarios where the outcome decreases the non-allocated vehicles is when vehicles are taken from the Thekwini and the Port Elizabeth depots. However, this will compromise the number of vehicles and then the demand will not be satisfied at those two depots. The best option is to keep the configurations as is and to allocate the twelve non-allocated vehicles to the Midrand and Peninsula depots that form part of the PSD business unit.

5. Activities/Tasks

Investigate the current approach for fleet assignment and keep it in mind when the future fleet will be allocated across the business units. This will give a good starting point as to which critical factors might be more important to the company than other critical factors. Research fleet characteristics and decide which characteristics are more important than others. Decide how one could optimally prioritise the characteristics to assign the most important ones first, then proceed to less important characteristics. One should also investigate the impact on the existing business units when one wants to convert existing vehicles to new vehicles. Research possible risks associated with the replacement rules. Consider temperature capabilities and how one could accommodate all fleet mixes to fit with the temperature capabilities. The most important task is to optimally re-allocate the fleet without too much expenditure.

6. Deliverables

6.1. Departmental Deliverables

6.1.1. Project Proposal

Understand the scope and objectives given by the project sponsor and define the possible problem associated with the objectives. Define specific research questions that can be addressed throughout the project and that it will contribute to the rationale of the project. Determine the project plan of how the project will be executed during the course of the year and determine deadlines for the university as well as those of the project sponsor. Understand specific constraints that might affect the project and keep them in mind during the literature review and formulation of the solution. Investigate the area of focus in Vector's process flow and ensure there is a mutual understanding.

6.1.2. Interim Report

Continue with the literature review and other research engines to inspect different methodologies. Decide if these methodologies are applicable to the current problem or if they have some attributes that might contribute to the solution. Investigate the research questions asked in the project proposal and research similar solutions to the specific problem. Define methodologies that will be used to solve the problem and compare methodologies to each other to find the optimal solution to the problem. Define characteristics and possible scenarios that might influence the vehicle allocation to the specific fleet. A risk assessment of all characteristics should be done to understand what composition of fleet mix will be less risky.

6.1.3. Final Report

Develop a network diagram, linear programming model, algorithm or a multi-criteria decision analysis. This depends on what the optimal methodology will be when the interim report is completed. The solution should have different scenarios and the impact and risk of each scenario will be determined. The solution should be validated to make sure it is based on what is actually happening at Vector. Verification should then take place by using the model outputs to confirm suggested scenarios. After the model has been tested one can recommend model improvements and enhance the model to meet added requirements.

6.2. Industry Deliverables

Vector's expectation is to receive an optimum implementable fleet allocation solution. This can be achieved in various methods depending on the methodology that will be used to complete the project. These proposed methodologies can range from an algorithm model to a simulation model, depending on what methodology will solve the problem in the most cost effective way. Vector also expects a detailed report of one's findings during the project which emphasizes the different scenarios and how to achieve them. The University of Pretoria will also expect a preliminary- and interim report to review the progress of the report and that specific engineering tools will be used when proceeding with the project. The University of Pretoria also expects a final report at the end of the second semester so as to have proof that the necessary engineering techniques and principles have been applied to ensure optimisation of allocating fleet across all business units. All ECSA outcomes must be achieved to show competency towards the engineering degree.

7. Resources

My mentors at Vector have supervised and supported me by coaching and giving feedback throughout the module. Vector has also provided an extensive range of data, which was used to analyse and determine different scenarios in the project. Vector's Midrand depot has also given a better understanding of what Vector is about and how their depots operate throughout the day. Visual representation of the project has given a good view of how the company allocates its fleet and how the fleets are divided up into the different business units. Different resources on the university's library page have been used. These resources included Google Scholar, Endnote, Scopus, Science Direct and UPSpace, where previous theses and dissertations could be found.

8. Conclusion

Vector's vision is to be Africa's chosen multi-temperature route-to-market solution for food manufacturers, food service customers and retailers(Vector, 2008a). This project can assist with their vision by determining the optimum allocation of fleet across business units. The company strives to provide supply chain excellence through state-of-the-art supply chain solutions, whilst building partnerships for long-term sustainability(Vector, 2008a). Its success is linked to cold chain logistics expertise, integrated distribution network, information systems and its people(Vector, 2008a).

The objectives of this project has been achieved by meticulously following the steps in the conceptual framework. The data analysis that led to the data visualisation was used to draw different conclusion as to how Vector operates. It also indicated which depots are clearly the most demanding and where there were any shortages or excess to vehicles at the different depots. The distribution network diagram (Figure 10) indicated where all the different network nodes flowed. It clarified the hub depots as well as the satellite depots and how each depot delivers to different business units. The cause and effect diagram (Figure 11) indicated what the critical factors are, and were incorporated in the multiple decision criteria analysis. The research to this report indicated different alternatives to solve problems that are similar to this one in the report. However, the best technique for this report was to use the HSIM and HTSD methodology to prioritise all the factors and to then use these factors in an optimisation model that would optimally allocate the vehicle to their specific depots. The result given from the allocation model was more than expected, and gave a very precise answer compared to other methods. The cost validation is to confirm the amount of vehicles purchased to make sure that there is no extra expenditure for Vector.

An output of where the different vehicles should go was determined and illustrated in figures 27-29. All vehicles can be placed at their designated depots and so meet the given "number of vehicles per depot", indicated in table 6 and table 7, that Vector suggested. If the "number of vehicles per depot" or "number of vehicles" should ever change then the model can easily adapt to this. The fleet's characteristics brought complexity to the project and was studied carefully before any decisions were made. Each scenario produced by the model was investigated to determine which one would best suit the company. Several scenarios were calculated and the one with the least risk was chosen.

The aim of the project to develop an optimal implementable fleet allocation solution was achieved. Being recently nominated by Pick n Pay to provide a dedicated distribution network for all the retailer's frozen products, Vector can now distribute Pick n Pay's products for the next few years and the next five thereafter. This project will help Vector make an informed decision on their allocated vehicles, in order to provide a more responsive service to Pick n Pay.

9. Recommendations

The given future fleet requirements have been the best outcome to the model up until now. If the future fleet requirements i.e. the number of vehicles per depot are changed, then the model cannot allocate all the vehicles. The only way to reduce the non-allocated vehicles is to take them from the existing PSD business units. However, this will increase the risk towards the PSD depots as they will not be able to meet the demand with less vehicles than before. It is best to allocate the twelve vehicles to the Midrand depot and the Peninsula depot that has a deficiency in their fleet requirements. The allocation model thus validates that the future fleet requirements, Vector has chosen, are correct and that any changes will only decrease the utilisation of the vehicles.

The following underlisted are future work recommended for this project:

i. The project can further be pursued after all the vehicles have been purchased.
ii. The factors of the newly purchased vehicles have all been rough estimates. When the new vehicles are purchased and their factors can be confirmed, then the model can run again and might give a different outcome. This will enhance the model and the preferences in the allocation model.
iii. Further monitoring can be conducted to make sure each depot has enough vehicles to meet their future demand.
iv. The cost validation model can be reused as the costs change over time.

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11. Appendix B: Sponsorship form

Department of Industrial & Systems Engineering
University of Pretoria

Final Year Project Mentorship Form
2018

Introduction

An industry mentor is the key contact person within a company for a final year project student. The mentor should be the person that could provide the best guidance on the project to the student and is most likely to gain from the success of the project.

The project mentor has the following important responsibilities:

1. To select a suitable student/candidate to conduct the project.
2. To confirm his/her role as project mentor, duly authorised by the company by signing this **Project Mentor Form**. Multiple mentors can be appointed, but is not advised.
3. To ensure that the **Project Definition** adequately describes the project.
4. To review and approve the **Project Proposal,** ensuring that it clearly defines the problem to be investigated by the student and that the project aim, scope, deliverables and approach is acceptable.
5. To review and approve all subsequent project reports, particularly the **Final Project Report** at the end of the second semester, thereby ensuring that information is accurate and the solution addresses the problems and/or design requirements of the defined project.
6. Ensure that sensitive confidential information or intellectual property of the company is not disclosed in the document and/or that the necessary arrangements are made with the Department regarding the handling of the reports.

Project Mentor Details

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Project Description:	**Optimising the allocation of fleet across business units for Vector Logistics.**
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