

DEVELOPMENT OF AN OPTIMAL
DISTRIBUTION PLAN FOR GSA

by

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Executive Summary

This project is based on supply chain and logistics management functions and the optimisation thereof. It is sponsored by the logistics organisation, IMPERIAL Logistics and was supervised and supported by engineering consulting service organisation, Volition Consulting. The research conducted relates to IMPERIAL Distribution and their current project of taking over GSA's fleet. IMPERIAL Distribution currently serves as a third party logistics company to GSA, making use of their own as well as GSA's fleet. GSA would like to hand over their complete distribution needs as well as their fleet. This is where this project was introduced.

Analysis of the AS-IS system was done with respect to the network, distribution plan and fleet. A new cost system will be proposed to make improvements on the cost efficiency and reliability of the system. These improvements will be made using an optimization model for the distribution plan and network, as well as an analysis of the fleet.

The outputs of this project will include the new system proposed to result in cost savings as well as methods to ensure continuous improvements of the processes used.

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Abbreviations

3PL	Third Party Logistics
ERD	Entity Relationship Diagram
GSA	Glass South Africa
KPI	Key Performance Index
RFA	Road Freight Association
ROI	Return on Investment
SCOR	Supply Chain Operations Research
SQL	Structured Query Language
VBA	Visual Basic for Applications

Chapter 1

Introduction

1.1 Project Background

This project was initiated when an optimal distribution plan for the glass manufacture and distribution company, GSA, was required.

IMPERIAL Logistics and in this case more specifically, IMPERIAL Distribution, are employed by organisations requiring a solution to their distribution needs as a third party logistic company (3PL). GSA was approached by IMPERIAL Logistics to supply a more efficient and cost effective transportation solution for GSA's logistics requirements.

In this case, analysis of the organisation's current processes is required and areas should be identified where there is lack of control and a possible introduction of a more efficient process may be beneficial. IMPERIAL Logistics require a fleet analysis that would result in the establishment of a distribution network and optimal fleet specification for all GSA branches. GSA currently makes use of their own fleet for each of their depots countrywide as well as IMPERIAL Distribution's fleet for their external logistic needs. They aim to hand over to completely to IMPERIAL Distribution to fulfil all their logistics requirements, which is why a new, improved distribution plan should be considered.

The current system must be analysed and recommendations for a new system must be provided. This new system should surpass the current system's cost and time efficiency. Possible opportunities for further improvement and development in other areas will also make the proposed plan more attractive for GSA.

The focal problem covered in this dissertation is that an optimal distribution plan for GSA is required and various alternatives should be evaluated as there are different areas that contribute to this system.

1.2 Project Aim

This industrial engineering project is aimed at providing a solution to the above mentioned problem described, within the scope of IMPERIAL Logistics capabilities and company conventions. The solution should address the supply chain involved in the system and it's key performance indicators, as well as the costs involved to serve the required demand. The aim of this project includes findings ways to improve or

optimize these aspects. They should be investigated and solutions and recommendations should be developed that will be in line with IMPERIAL Logistics' key performance indicators.

The solution proposed should integrate continuous improvement so that throughout project development and growth, the solution can be adapted to suit the needs of the IMPERIAL Logistics as well as their clients.

Objectives identified in achieving the project aim are as follows:

- Develop a model to optimise the distribution network that can also be applied to other, similar projects.
- Recommend figures for the fleet, distances and staff that will make efficient use of money being used throughout the system.
- Identify areas of improvement opportunities that can impact distribution.

1.3 Project Scope

This project will include developing a distribution plan that will bring GSA's logistics operations as close to optimality as possible. Many aspects of the system need to be taken into account, researched and included in the final distribution plan.

1.3.1 Inclusions

The aspects intended to be covered in this dissertation include:

- A generic distribution plan whereby IMPERIAL Logistics can use specific project characteristics as inputs and obtain an optimal distribution plan with respect to the fixed and variable costs involved and distances covered as an output.
- A financial analysis of the costs involved in the system and how these can be reduced or used more efficiently.
- Analysis of the transportation vehicles being used and the use of their respective capacity and any capacity imbalances.
- Incorporate GSA's key performance supply chain metrics.
- Network design for GSA's depots.
- Integration of continuous improvement throughout the system.

All or selected aspects may be included in the final project analysis, depending on their relevance to the problem defined.

1.3.2 Exclusions

Aspects that will not be included in the scope of this dissertation have been identified as follows:

- The supply chain preceding and following the depots investigated.
- The inventory kept at each of the depots and their clients (assume the inventory kept is sufficient for each depots needs).
- Warehouse management and material handling aspects within the depots.
- Packaging of final products.

1.3.3 Project Deliverables

1. Final report of findings.
2. Distribution plan.
3. New fleet.
4. Savings.
5. Further opportunities for the client and 3PL.
6. Project presentation.
7. Poster.
8. Oral presentation.

Chapter 2

Data Collection

2.1 Tools and Techniques

The literature review was completed in order to understand the nature of how logistic services can be provided. The factors that influence this particular logistic system are important to find. Tools and information to come to a solution then to implement a solution need to be researched and evaluated to find which will work best.

2.1.1 Third Party Logistics (3PL)

Defining third party logistics is important because IMPERIAL Distribution will act as a 3PL company.

Combining Maxwell's definition of 3PL [6], as well as Coyle et al. [2], 3PL is described as the function where the owner of goods outsources all or part of the supply chain to a 3PL company to manage inbound freight, customs, warehousing, fulfilling orders, distribution and outbound freight for their client's customers and provide solutions to their supply chain and/ or logistic problems.

According to Coyle et al. [2], there are various types of 3PL companies, with their differences based on the services they provide. However, due to an ongoing increase in competition, most companies integrate a range of services into what they offer their clients thereby increasing their chances of being awarded contracts and long term business deals.

Included in the types of 3PL companies are transportation based, warehouse/ distribution based, forwarder based, financial based and information based providers. IMPERIAL Distribution is a transportation based provider.

Transportation based providers either use their own or other companies assets to carry out the transportation requirements of their clients. In the case where they use the assets of other companies, for example trucks, post, aeroplane, etc., for their services they are described as being leveraged. If the 3PL company utilizes the parent organisation's assets to complete their logistic function, they are described as being non-leveraged.

On taking over GSA's fleet, IMPERIAL Distribution will use their own and another companys assets for the transportation requirements of GSA. They will not use other external assets for their needs.

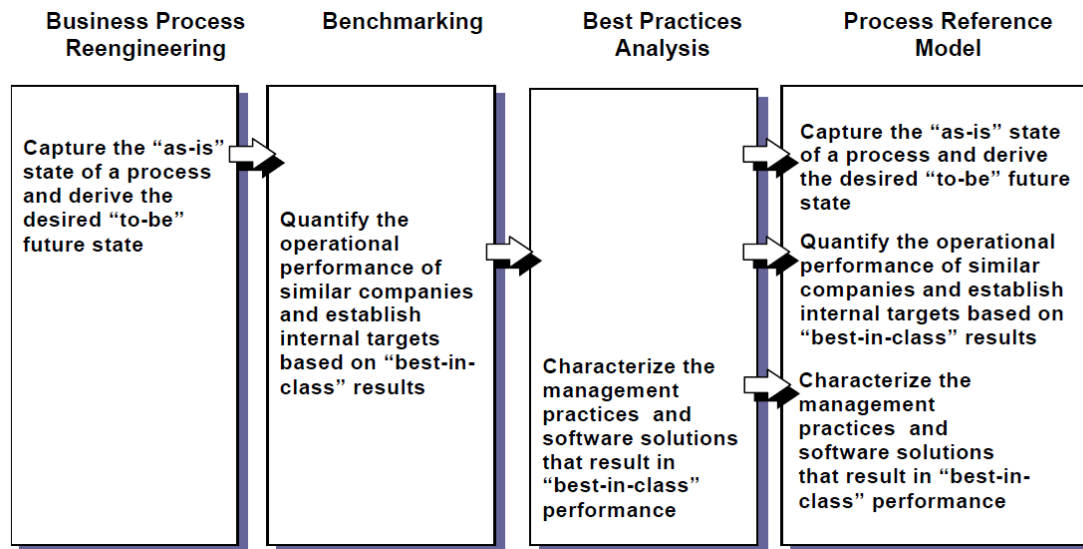


Figure 2.1: Business Process Reference Model [10]

2.1.2 Order Fulfilment

Fulfilling orders in a distribution organisation in terms of the supply chain starts from the sales enquiry and ends where the product(s) are delivered to the customer. The efficiency thereof depends on how well the organisation responds to customer's demand.

The first literature that will be discussed is that which covers the entire process and aims to optimise it.

2.1.3 Supply Chain Management

The supply chain relevant to an organisation is the chain of major management processes that contribute to getting the right order to the right customer at the right location and at the right time. The most widely used model to describe all the activities that make up phases to satisfy a customer's demand is the SCOR model; the Supply Chain Operations Reference model.

SCOR Model

This model focuses on integrating processes, performance metrics, practices and characteristics involved in a supply chain to enable it to function at an optimal level.

The SCOR model identifies a business process model that will help to carry out the function of linking the factors mentioned above. This is shown in figure 2.1.

Similar steps to the above reference model will be used in this project.

The Hierarchical Model

The structure of the SCOR model is based on the hierarchical model shown in figure 2.2.

		Level			
		#	Description	Schematic	Comments
Supply-Chain Operations Reference-model 	1		Top Level (Process Types)		Level 1 defines the scope and content for the Supply chain Operations Reference-model. Here basis of competition performance targets are set.
	2		Configuration Level (Process Categories)		A company's supply chain can be "configured-to-order" at Level 2 from core "process categories." Companies implement their operations strategy through the configuration they choose for their supply chain.
	3		Process Element Level (Decompose Processes)		Level 3 defines a company's ability to compete successfully in its chosen markets, and consists of: <ul style="list-style-type: none"> • Process element definitions • Process element information inputs, and outputs • Process performance metrics • Best practices, where applicable • System capabilities required to support best practices • Systems/tools
	4		Implementation Level (Decompose Process Elements)		Companies "fine tune" their Operations Strategy at Level 3.
Not in Scope					

Figure 2.2: SCOR Hierarchical Model [10]

Level 1 Metrics	Performance Attributes				
	Customer-Facing			Internal-Facing	
	Reliability	Responsiveness	Flexibility	Costs	Assets
Perfect Order Fulfillment	X				
Order Fulfillment Cycle Time		X			
Upside Supply Chain Flexibility			X		
Upside Supply Chain Adaptability			X		
Downside Supply Chain Adaptability			X		
Supply Chain Management Cost				X	
Cost of Goods Sold				X	
Cash-To-Cash Cycle Time					X
Return on Supply Chain Fixed Assets					X
Return on Working Capital					X

Figure 2.3: SCOR Performance Attributes and Performance Metrics [10]

From figure 2.2, there are three hierarchical levels included in the supply chain model scope; the top level, the configuration level and the process element level. These levels are used to represent the elements associated with each level, which will be indicated later on in this text.

The five basic management processes; plan, source, make, deliver and return are organised by a standard structure. This is specified and explained for each process in the SCOR Model document. For the sake of this project, only the elements associated with this specific project will be discussed.

Performance Attributes and Level 1 Metrics

The Level 1 metrics are primary, high level measures that can be used for more than one SCOR process but they do not have to relate to the SCOR Level 1 processes (plan, source, make, deliver, return). The performance attributes identified are measures that a company can use to evaluate themselves against other supply chains using standard characteristics. This makes it easier to evaluate a company with respect to the metrics that are most important to their type of organisation.

The performance attributes can be defined with respect to the Level 1 Metric that they are associated with. These definitions have been given in the SCOR Model as shown in figure 2.4.

Using these metrics and attributes as a basis, lower level, Level 2 metrics can be assigned to a smaller, more specific set of processes that will be discussed and identified according to the metrics specific to this project.

Key Metrics

The key metrics that have been associated with this project are reliability and cost.

Performance Attribute	Performance Attribute Definition	Level 1 Metric
Supply Chain Reliability	The performance of the supply chain in delivering: the correct product, to the correct place, at the correct time, in the correct condition and packaging, in the correct quantity, with the correct documentation, to the correct customer.	Perfect Order Fulfillment
Supply Chain Responsiveness	The speed at which a supply chain provides products to the customer.	Order Fulfillment Cycle Time
Supply Chain Flexibility	The agility of a supply chain in responding to marketplace changes to gain or maintain competitive advantage.	Upside Supply Chain Flexibility
		Upside Supply Chain Adaptability
		Downside Supply Chain Adaptability
Supply Chain Costs	The costs associated with operating the supply chain.	Supply Chain Management Cost
		Cost of Goods Sold
Supply Chain Asset Management	The effectiveness of an organization in managing assets to support demand satisfaction. This includes the management of all assets: fixed and working capital.	Cash-to-Cash Cycle Time
		Return on Supply Chain Fixed Assets
		Return on Working Capital

Figure 2.4: Definitions for SCOR Performance Attributes [10]

The cost metric identified in the SCOR Model is denoted by CO2.4 which indicates the Cost to Deliver metric. This is the total supply chain management cost for the five Level 1 supply chain processes that include the fixed and operational costs [11].

The second key metric is reliability and the RL2.2 metric is used, indicating the delivery performance to the customer committed date. This is a factor of RL1.1 which is perfect order fulfilment. This metric is used to measure the percentage of orders that are delivered at the right time (as specified by the client) and with the right level of quality. In this case, it will measure the fleet manager's performance to the level required by the client [12].

Make to Stock & Engineer to Order

GSA's order fulfilment policies are based on make-to-stock and engineer-to-order principles. These environments fit into the SCOR Model in the source, make and deliver process elements [10]. Demand becomes important when making use of SCOR. Accurately determining the demand will help provide models that can be used for stock keeping and distribution requirements.

Make to Stock

Make-to-Stock or Build-to-Forecast order fulfilment principles are where the products(s) are built according to figures described in a sales forecast. Products that are sold to customers are those from a finished goods stock produced according to the needs forecast.

In GSA's case, products are produced at their production factory in Springs, distributed to each depot according to orders placed then distributed to clients

according to their orders.

Engineer-to-Order

The Engineer-to-Order principle is based on specific customer orders. Customer specifications are given to GSA and their product is designed and built according to these specifications. This type of product is generally a once-off production.

For Engineer-to-Order products, GSA typically receives orders from their depots, designs and builds the products required at their production factory and delivers the products to the depots they were ordered by. The depot then delivers the custom products to the customers they were ordered by.

2.1.4 Network

When designing a distribution plan to improve the logistics network for GSA, the steps recommended by Coyle et al. [2] is followed.

These steps are

1. Define the logistics network design process
2. Perform a logistics audit
3. Examine the logistics network alternatives
4. Conduct a facility location analysis
5. Make decisions regarding network and facility location
6. Develop an implementation plan

2.1.5 Microsoft Office Access

Microsoft Office Access is a relational database management system that combines the relational Microsoft Jet Database Engine with a graphical user interface and software development tools [7]. It has a format that data is stored in but can import data that is stored in other programs. It allows users to view data and to import and export data to other formats. Where data relates to other data, it can be linked using relationships and utilized for purposes other than pure viewing. Data can thus be changed so that users have access to the latest data.

Microsoft Office Access can come in extremely useful when dealing with large amounts of data as its function is to create databases. As taught in our Information Systems 320 course, Microsoft Office Access's most simple use is to store data and extract information needed for a specific purpose. Tables are created that data is stored in, in a similar format to that of Microsoft Excel, and field types, referential integrity and indices can be used within the tables. It can also be used to create reports on the data stored and to create interactive forms to facilitate the input and display of information.

It is a relatively easy program to use as little or no code is needed to create the solutions and outputs required, with programmers and non-programmers making use

of it. According to Wikipedia [7], programmers can benefit from SQL statements used in Macros and VBA modules, making it versatile for programming uses as well.

Access can be used as a departmental solution as it can be used for individuals and workgroups across networks. 255 concurrent users can be connected to a network with a maximum of 20 simultaneous connections and generally solutions that have 1GB of data or less are acceptable. Access can support multi-user requirements by “splitting” it into the back end file, with the tables stored here on a shared network folder, and the front end file with the application components such as the forms, reports, queries, code, macros and linked tables which point the front end to the back end file [7].

2.1.6 Heuristics

Heuristics techniques are described by Winston and Venkataramanan [13] as rule-of-thumb techniques used when optimality cannot be assured. A “greedy approach” is generally used where the user goes on instinct to find a good solution. This method usually results in a local optimum instead of a global optimum.

Heuristics will be important to consider as a mathematical model does not have knowledge of the conditions of the roads being travelled and the traffic in certain areas, unless required as an input.

While many Industrial Engineering tools can be implemented, common sense and experience will play a role in decision making. A solution obtained from an optimisation model may be improved even further with slight changes from past knowledge and experience of the project environment.

2.1.7 Lingo Optimization Modelling Software

Lingo is a program used to build and solve linear, non-linear, quadratic and integer optimization models. Information can be extracted from external sources such as databases and spreadsheets and be used in the model. The solutions obtained from Lingo can also be output into databases or spreadsheets to generate reports using the solutions obtained [4].

There are three parts that define an optimization model; the objective function, the variables and the constraints.

The objective function is a formula describing what the model should optimize. The variables are the quantities that will be manipulated to produce the optimal value for the objective function. Constraints are the formulas defining the limits on the values for the variables [5].

2.1.8 Fixed and Variable Costs

A major performance indicator in many organisations is the cost efficiency. Often when implementing improvements in an organisation, management measures the degree of improvement with respect to whether savings were made, profits were increased and/or whether money is being appropriately spent.

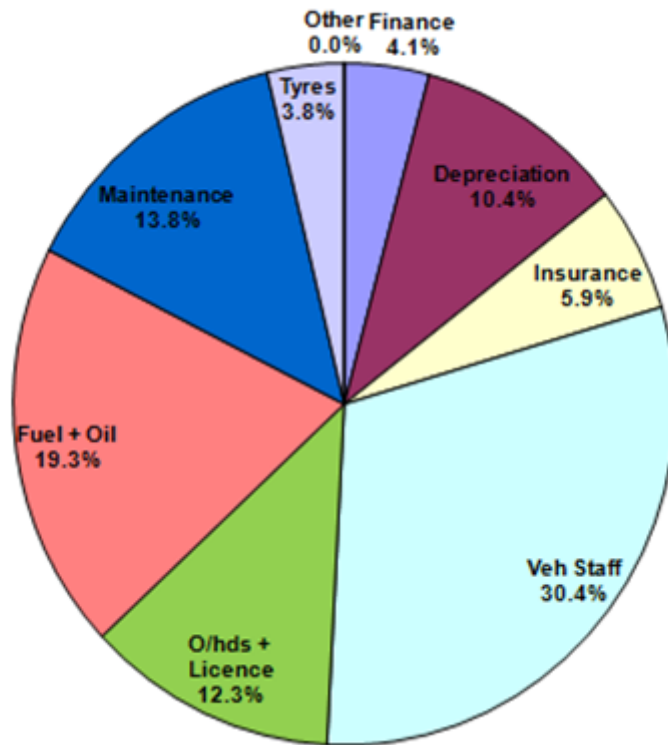


Figure 2.5: Pie Chart of the Cost Breakdown for a 4x2 Rigid Dropside Body [8]

According to logistic managers at IMPERIAL Logistics, the rising fuel price has had a huge impact on logistics providers and their costs. Where fuel was previously an expense that was relatively easy to manage, it has become the primary contribution to variable costs, as shown in figure 2.5 according to the Road Freight Association [8], and difficult to keep to a minimal. The high fuel prices have caused fuel budgets to be closely monitored and minimisation thereof has become a prime focus.

To provide an optimal distribution plan for GSA, the costs involved need to be considered and areas that can improve the performance measures need to be identified. Included in the scope of this project is the behaviour of costs associated with the logistics system. Cost behaviour is how a cost will respond to changes in the levels of business activity. Analyzing how much it will change is done by categorizing costs into fixed and variable costs [9].

Variable Costs

A variable cost is one that varies in direct proportion to the level of change in an activity [9]. As the level of activity fluctuates, so does the total cost associated with it. Variable costs are measured per unit; the per unit cost remains the same but the total costs changes as the level of activity changes.

The variable costs for this project are:

- Fuel

- Tyre wear
- Maintenance
- Lubricants

Fixed Costs

A fixed cost is one that stays the same regardless of whether the level of activity changes. The total fixed cost for an activity does not change with the activity, unless affected by an outside source. Fixed costs are generally not expressed on a per unit basis as the fixed cost is not dependant on the activity. However, if fixed costs are apportioned with respect to the level of activity, they will decrease per unit as the level of activity rises and increase as the activity level falls [9].

The fixed costs for this project are:

- Capital value payoff (asset value)
- Depreciation
- Insurance
- License fees
- Driver salaries
- Administration overheads
- Operational overheads

For this project, the activity level that will affect the variable costs is the number of kilometres travelled by each vehicle. The fixed costs can also be apportioned per kilometre to get a total cost for a vehicle per kilometre travelled. This means that costs will be saved here by reducing the kilometres travelled.

2.2 Information Gathering

2.2.1 Network

The findings for the network design steps described in the literature review were as follows.

Step 1: Define the Logistics Network Design Process

The design objectives and parameters need to be identified. The objectives for GSA are

1. An improved distribution plan for GSA's depots and their clients.
2. A fleet analysis for what is currently in use and any changes that could be made to improve on the current operation.

3. Measurement of GSA with regard to their key performance indicators.

Another aspect that should be considered in this step is the involvement of 3PL suppliers. In this case, GSA is currently performing majority of their own logistic functions but seeks to hand over their logistic function to IMPERIAL Distribution completely. It is thus up to IMPERIAL Distribution to determine the status of GSA's current fleet and how/ if it can be improved upon. Vehicles may need to be sold or purchased and the lifetime of all current vehicles should also be considered as this will determine maintenance requirements that may incur additional costs.

Step 2: Perform a Logistics Audit

Coyle et al. [2] suggest information that should be included in this audit.

Customer Requirements and Key Environmental Factors: The aim of this project is to improve on the current distribution plan for GSA. The requirements that will form the outputs for this project are a generic distribution plan, a fleet analysis, where savings can be made and areas for further opportunities.

Along with the outputs required for this project, there are also the Supply Chain Operations Research Model metrics that are key for GSA. These metrics are cost and reliability.

Profile of the Current Logistics Network and the Firms Positioning in the Supply Chain: A study was completed on GSA's current logistics network. This study considered each depot and their main customers, where they are located and how their location in the network fits in with the improved distribution strategy.

Order details for each depot were obtained that included their order history from March 2010 until May 2011. These order details consisted of each order, the customer the order was for, their address, dates that products were ordered and delivered, billing numbers for each product ordered and the details for each product (product code, amount, weight etc.) Main customers were extracted from this order history by taking customers that placed orders for 30 or more products over the time period the data was given for.

GSA's positioning in the supply chain is that each depot is a supplier's customer (GSA's main production plant in Springs) and each depot is also a customer's supplier, for the companies that require glass products for production and a supplier's supplier, for the companies that keep glass products stocked and supply to smaller companies around them.

Benchmark/ Target Values for Logistics Costs and Key Performance Measurements: According to the SCOR Model previously described, the key performance indicators will be the supply chain cost to deliver and the ability of each depot to fulfil customer orders perfectly.

The supply chain cost for the system being analysed consists of the fixed and variable costs that apply to the resources involved in fulfilment of orders, such as staff, vehicles, fuel etc. The KPI for this will be the amount that the total operational cost can be reduced by.

The perfect order fulfilment measurement will be measured as the percentage of orders that are correctly delivered at the right time, which will be the KPI.

Identification of Gaps between Current and Desired Logistics Performance: This section consists of further improvements that GSA can consider to improve their service to their customers and save money where possible. Possible places of improvement were identified as

- Smooth demand over the week so that the trucks required are utilized better (not idle).
- Analysis of the turnaround time for orders placed, whether this can be improved at all.

Step 3: Examine the Logistics Network Alternatives

This section applies to methods that can improve the logistics system quantitatively and qualitatively. These alternatives should affect the system in terms of how it functions and its reliability and cost effectiveness.

The method used to create quantitative improvements of the system will be the use of an optimization model and by percentage improvements that can be made.

The qualitative improvements will use information systems and heuristics.

Step 4: Conduct a Facility Location Analysis

The logistics network involved in each depot's customer base will be determined in Step 2. Making use of this network, quantitative improvements can be implemented and qualitative improvements will then be considered. Qualitative improvements can be made in terms of scheduling and cost reductions.

Step 5: Make Decisions Regarding Network and Facility Location

The methods of implementing improvements described in Steps 3 and 4 should be checked against the benchmark and target values set in Step 1. The overall supply chain should also be evaluated. For this project, the fleet analysis will need to be evaluated and a new fleet or improvements to the old fleet will be identified.

Step 6: Develop an Implementation Plan

This will be done in the solution for the project and will be the plan to create the desired change.

2.2.2 Data Modelling

In order to store the data received from IMPERIAL Distribution and to filter it as required, a simple, fast and thorough method was needed. The order history from each depot consisted of at least 60 000 entries from March 2010 until May 2011. These entries were stored on Microsoft Excel in a spreadsheet format. Entries

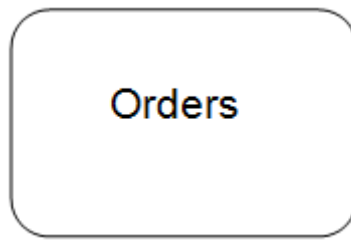


Figure 2.6: ERD Entity Example

included the dates that products were ordered and delivery was required, billing numbers for each order, each product associated with the order, their respective weights and the name and address for the customer the order was required by.

There were six depots and each had gathered the above information. Manually attempting to sort through all the data received would have been extremely time consuming and, more than likely, very inaccurate. Thus a Microsoft Access database was created to store all the information received and to create simple, quick and thorough reports that contained all the information required for a specific purpose in a logically ordered layout.

Entity Relationship Diagram

A basic data model was created using an entity relationship diagram (ERD) that shows the entities involved in the system and the relationships that exist between the data.

Entities

An entity represents something that the business needs to store data about [1]. An entity is represented in the ERD by a rectangle with rounded corners. An example is shown in figure 2.6.

Attributes

The information about each entity that needs to be stored is done so in the form of attributes. An attribute is a property or characteristic that describes the entity.

Every instance or entry for an entity's attributes needs to be uniquely identified; this is done by a key. In this case, since the ERD will be simple, primary keys and foreign keys will be used. A primary key is the most commonly used key in ERD modelling as it is the unique number assigned to each entry. A foreign key is when the primary key of another entity is used in an entity along with that entity's primary key to uniquely identify an instance of a relationship [1].

Relationships

Relationships need to be defined to show how entities and their attributes interact with one another. A relationship is a natural business association between one or

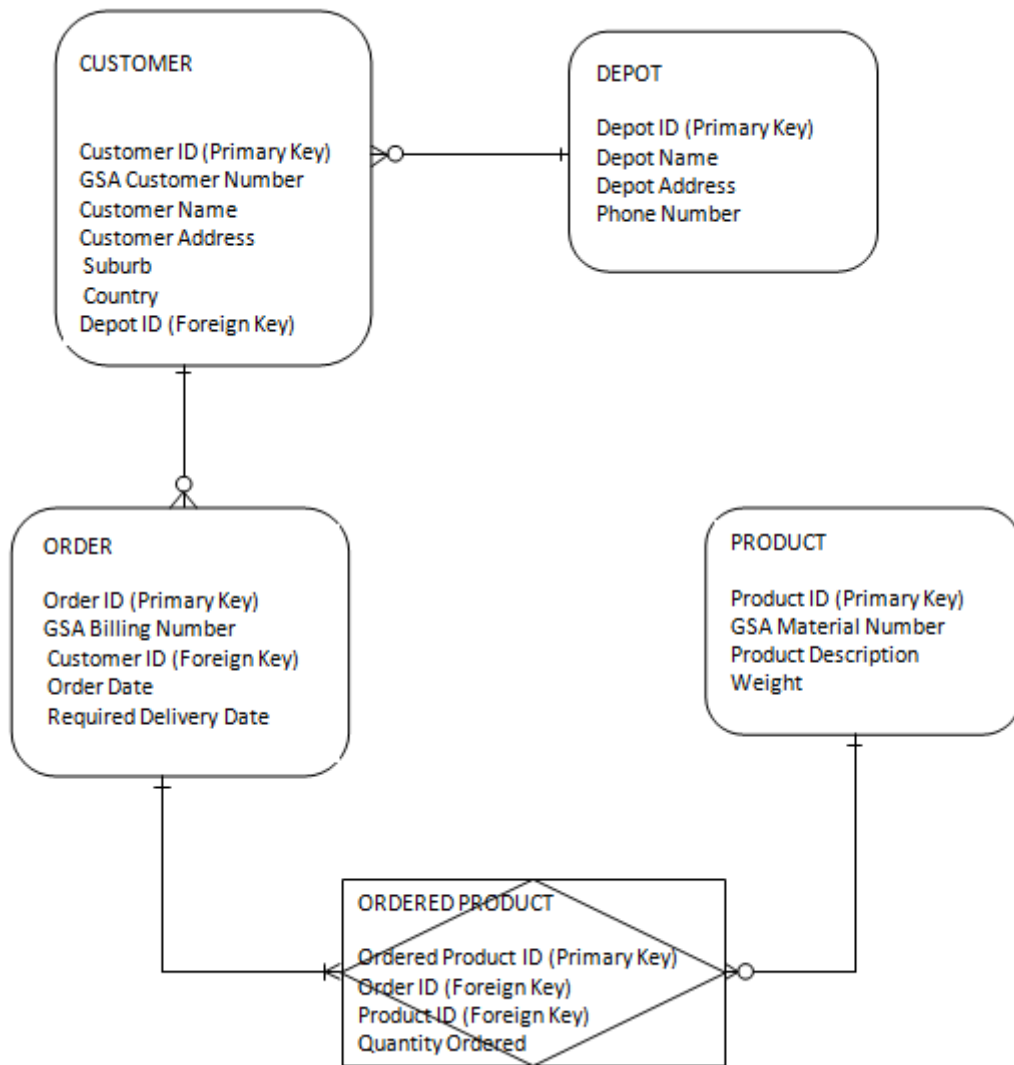


Figure 2.7: Order ERD

more entities [1]. Relationships are used to show occurrences and natural associations that exist between entities.

The number of occurrences that can exist from one entity to another is identified using cardinality. Relationships between entities are bidirectional and for every relationship cardinality is shown in both directions. Cardinality shows the minimum and maximum number of occurrences of one entity that can be related to a single occurrence of the other entity [1].

Diagram

The ERD for use in this project was modelled in figure 2.7.

ERD Explanation

The entities identified for the purpose of data collection for this project are depot, customer, order, ordered product and product.

The depot entity will store all information regarding each depot. The attributes identified for depot are the unique Depot ID that will be the primary key and the location of each depot. Each depot services a number of customers, so depot links to customer with a zero-to-many relationship. This indicates that one depot can have zero-to-many customers.

The customer entity will store all data collected about the customers and where they are situated. Each customer will also have a Depot ID assigned to them as a foreign key to identify which depot services that customer.

Customer then links to Order for all orders placed by each customer. The relationship shown indicates that one customer may have zero-to-many orders attributed to them. The Order entity will store information about each order placed as well as the customer the order was placed by, shown by the foreign key.

Order would then typically link to Product as an order would be associated with one or many products but the relationship that exists between Order and Product is a many-to-many relationship. This is called a non-specific relationship and means that many products could be associated with many orders. The existence of a many-to-many relationship in a database would result in the wrong or no relations to be made where they are required. As an order is placed for one or many products, this would need to reflect in the Product entity as well but due to the many-to-many relationship would reflect erroneously. Thus another entity was added, called an associative entity and identified by the rectangle and diamond within the rectangle. The associative entity will resolve the many-to-many relationship into two one-to-many relationships.

Order links to Ordered Product by a relationship that shows that one order is related to one-to-many ordered products. In the Ordered Product entity, the attributes used to store data here are the Order ID and Product ID as foreign keys to identify the order and the quantity of the products ordered.

Ordered Product is linked to Product with a relationship that indicates that zero-to-many ordered products are related to one product. The Product entity will store data on each product.

It should be noted that this model was created for simplicity and solely for the purpose of data collection for this project. There are many other attributes associated with each of the entities but these are not relevant to the data used for this project.

2.2.3 Demand

To service GSA's needs efficiently, the demand and how well it is being serviced will be determined.

The first factor to determine in finding the AS-IS fact base was identified as the demand. The demand was determined by using data for the past year and a half. Orders placed by each company and the details thereof were used from the Microsoft Access database developed in the previous section.

Depot	Maximum(tons)	Minimum(tons)	Average(tons)
Meadowdale	267	30	99
Montague	257	0.11	32
Pretoria	370	39	135
Roodepoort	175	11	72
Springs	159	24	61
Vereeniging	397	51	118

Table 2.1: Demand for Representative Week for each Depot

A query was created in Access that extracted the Billing Number, Billing Date and Product Weight for each order. From this query, a report was then created using those three attributes. The report that was generated sorted the information into all the orders that were delivered per day and their respective Billing Numbers and Product Weights. Then the weights for all the products delivered each day were added together to get a total weight for each day deliveries were made. These totals were used to create graphs for the total weight of products delivered for each week over the period using Microsoft Excel. These are shown in Appendix A.

The graphs were used to derive a representative week that showed the average weight of products delivered in a week, the maximum weight delivered in a week and the minimum weight of products delivered in a week. The values for these averages are shown in table 2.1.

2.2.4 Distribution Plan and Fleet

Since GSA would like IMPERIAL Distribution to take over their fleet and all the logistic needs, it was necessary to determine the AS-IS status of the vehicles that are part of GSA's current fleet. All of IMPERIAL's vehicles that are being used to service GSA's needs are under a maintenance plan and are thereof generally in good condition and are assessed regularly for problems. However, none of the vehicles in GSA's fleet are under a maintenance plan and many of the vehicles require refurbishment or even replacement. The distribution of the GSA and IMPERIAL's fleet was determined as well as the status of GSA's vehicles. This information gathered is shown in table 2.2.

Depot	Vehicle	Current Odometer	Capacity	Owned By	Comments
Meadowdale	SPZ 253 GP	172 673km	8 ton	GSA	Good condition
	SLN 658 GP	173 540km	8 ton	GSA	Good condition
	XMP 489 GP	138 988km	4 ton	GSA	Good condition
	XSZ 560 GP	234 742km	4 ton	GSA	Good condition
	NWT 857 GP	416 173km	1 ton	GSA	Km very high
Montagne	WPR 255 GP	144 606km	8 ton	Imperial	
	WCS 696 GP	182 955km	1 ton	Imperial	
	CY 212 456	211 762km	4 ton	GSA	Good condition
Pretoria	GSG 371 FS	652 372km	4 ton	GSA	Km very high
	CY 132 043	499 950km	1 ton	GSA	Good condition
	CA 241 456	239 167 km	5 ton	GSA	Good condition
	BG 42 DG GP	202 624km	9 ton	GSA	A frame broken
	WWK 051 GP	136 124km	8 ton	GSA	Rear bumper dented
	LHR 369 GP	1 146 424km	6 ton	GSA	ODO clogged over
	ZMY 422 GP	33 454km	1 ton	GSA	Good condition
Springs	NCW 721 GP	252 969km	6 ton	GSA	Badly maintained
	TVK 931 GP	415 633km	8 ton	Imperial	
	WLM 931 GP	226 785km	8 ton	Imperial	
	NRW 587 GP	438 861km	1.1 ton	GSA	Km very high
	XSZ 560 GP	67 036km	3 ton	GSA	Good condition
Roodepoort	TCK 939 GP	248322km	3.5 ton	Imperial	
	CAW 1077	400 847km	3.5 ton	GSA	Km very high
	XKX 774 GP	128 758km	3.5 ton	GSA	Good condition
	CXL 050 GP	135 192km	2.5 ton	GSA	Good condition
	TTZ 294 GP	351 000km	2 ton	GSA	Km very high
	SGG 253 GP	157 909km	4.5 ton	GSA	Good condition
	WCS 696 GP	157 702km	1 ton	Imperial	
Vereeniging	WLT 105 GP	176 635km	6.5 ton	Imperial	
	WDF 636 GP	235 000km	1 ton	GSA	Good condition
	PKX 795 GP	700 000km	1 ton	GSA	Poor condition
	MMW 909 GP	520 000km	3 ton	GSA	Km very high
	RCZ 122 GP	351 000km	3 ton	GSA	Km very high
	ZSB 213 GP	21 000km	6.5 ton	GSA	Good condition

Table 2.2: Fleet Information

2.2.5 Costs Involved

As mentioned in the literature review, the costs involved in this logistics system are comprised of fixed and variable costs.

To get a generic value for these fixed and variable costs for each vehicle, those calculated by the Road Freight Association [8] were used. This publication was obtained from Volition Consulting who form part of the IMPERIAL Logistics organisation.

Using the vehicle dimensions, the costs involved with logistic operations are broken down according to averages taken from vehicle data nationwide. Many organisations, including Volition Consulting, make use of this model when creating an estimated cost model for their vehicles and operations. For this project, the values from the RFA Vehicle Cost Schedule will be used mainly as inputs for an optimisation model. Since the costs will be used as variable inputs for the optimisation model, IMPERIAL Distribution can insert their own calculated values into the model when specifying the inputs required.

Utilisation of the RFA Cost Schedule is described in the following steps:

1. There is a Vehicle Concept page where dimensions, permissible weights, unloaded weights and maximum payload are given. The vehicle under consideration should be categorised into one of these concepts using its dimensions and weight specifications.
2. Once the vehicle concept has been chosen, the page for that specific concept should be opened.
3. On the concept page for each vehicle, all the costs associated with that sized vehicle are broken down into annual fixed and variable costs and estimated values are given for the costs involved with each type.
4. The assumptions made and calculations made are also shown, allowing the user to use what information is relevant to their situation and edit values where necessary, if desired.
5. The estimated percentages that values will increase by over time are also given.

Using the capacities for all the vehicles at each depot, the fixed and variable costs were calculated using the standard values given, shown in table 2.3. The fixed costs will be apportioned per kilometre along with the variable cost.

2.3 Conclusion

This chapter demonstrated how the the AS-IS data was collected for the current logistics system and synthesized into a more usable form. Tools, methods and techniques were investigated that can be applied to the information obtained to develop a solution or recommendations that will address the deliverables for this project.

Capacity	Fixed costs	Variable Costs	Total Operational Costs
1 ton	143 268	64 701	207 969
2 ton	267 438	93 270	360 708
3 ton	267 438	93 270	360 708
3.5 ton	286 581	130 465	417 046
4 ton	286 581	130 465	417 046
4.5 ton	286 581	130 465	417 046
5 ton	286 581	130 465	417 046
6 ton	340 412	161 019	501 431
6.5 ton	340 412	161 019	501 431
8 ton	345 069	201 760	546 829
9 ton	345 069	201 760	546 829

Table 2.3: Costs According to Capacity

Chapter 3

Analysis and Solution Development

3.1 Data Analysis

3.1.1 Network Analysis

The customer network for each depot was established using the database developed. Their addresses were found and they were grouped together with customers in the same area to form a number of zones. If a customer was not in close proximity to any others, they were classified as “outliers.” The outliers were grouped with a zone so that they can be serviced en-route to that zone or customers in that zone can be serviced en-route to the outlying customer.

The depots that were included in this project are situated in Meadowdale (Gauteng), Montague Gardens (Western Cape), Pretoria (Gauteng), Roodepoort (Gauteng) and Vereeniging (Gauteng).

For each depot, a network diagram was created to show where each depot is and the locations of the zones that their customers were allocated to. The areas and suburbs included in each zone are listed in Appendix B.

Note that the letters surrounded by red rings indicate zones, while the letters close to the edges of the maps next to arrows indicate that an area serviced that is relatively far away from any other area on the map.

3.1.2 Fleet Analysis

Using the average kilometres travelled by each vehicle per month, shown in Appendix C, charts were created to show the percentage that each vehicle is used in comparison with the rest of the vehicles for each depot. Using this information it will be obvious which vehicles are the most useful to each specific depot. When doing the analysis on the vehicles required to meet each depot’s needs, if a depot has more vehicles than necessary, the ones that are least used should be considered as obsolete (along with other factors like mileage, costs etc.).

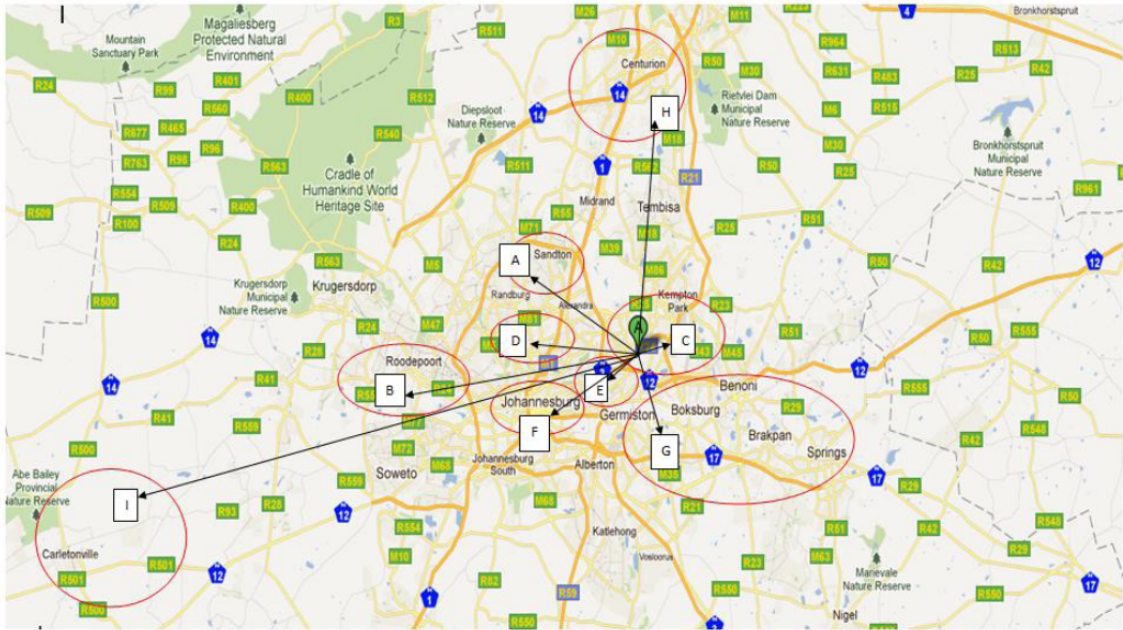


Figure 3.1: Meadowdale Allocated Zones

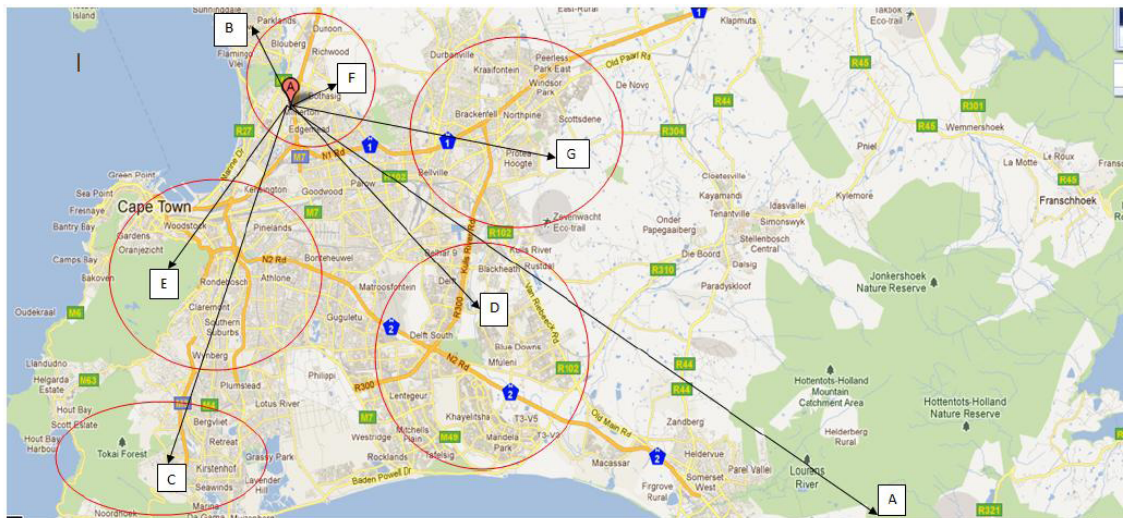


Figure 3.2: Montague Gardens Allocated Zones

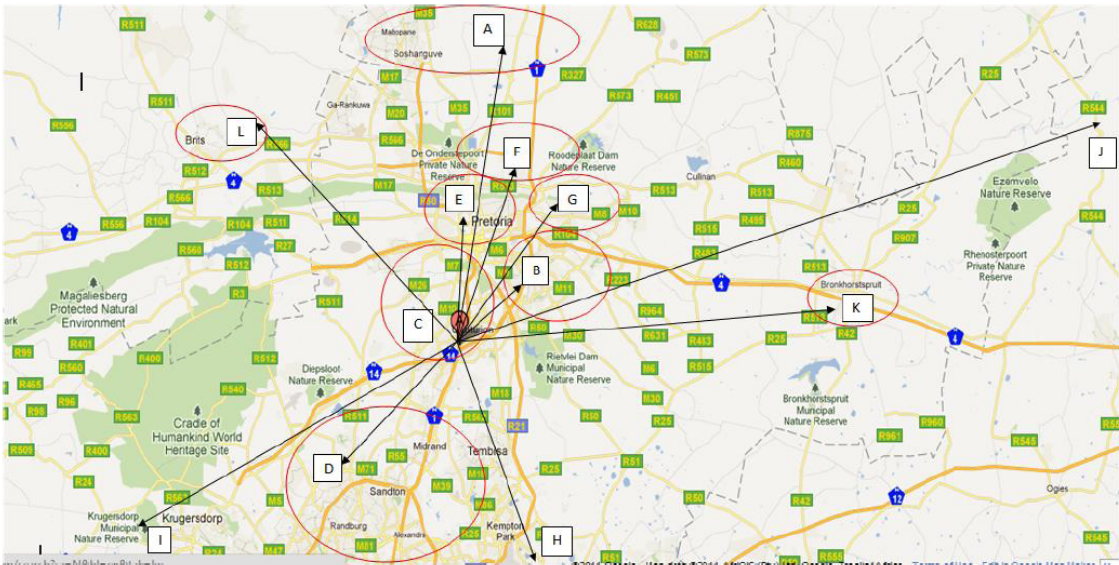


Figure 3.3: Pretoria Allocated Zones

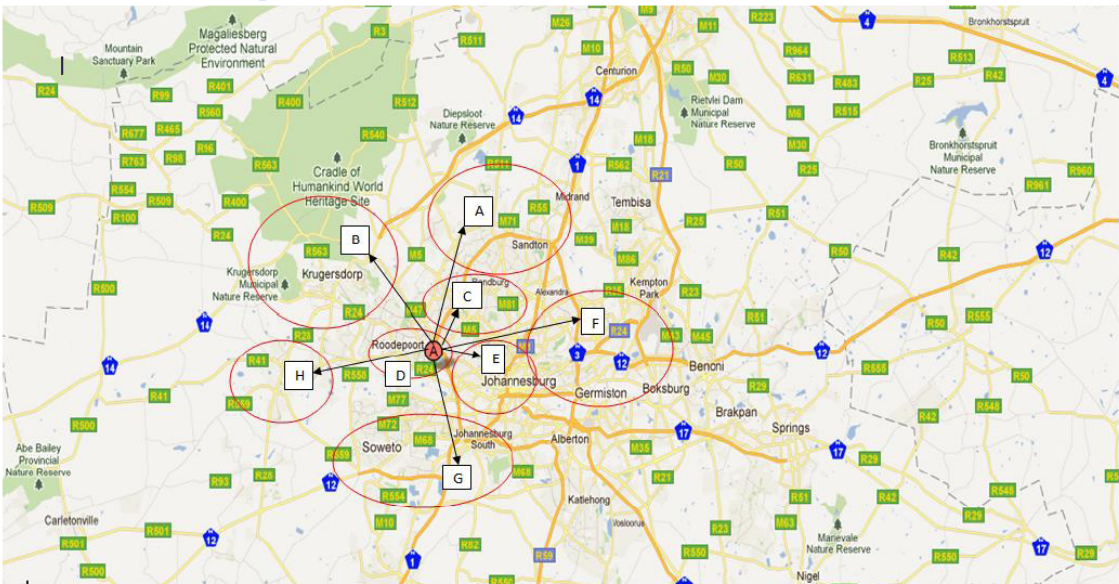


Figure 3.4: Roodepoort Allocated Zones

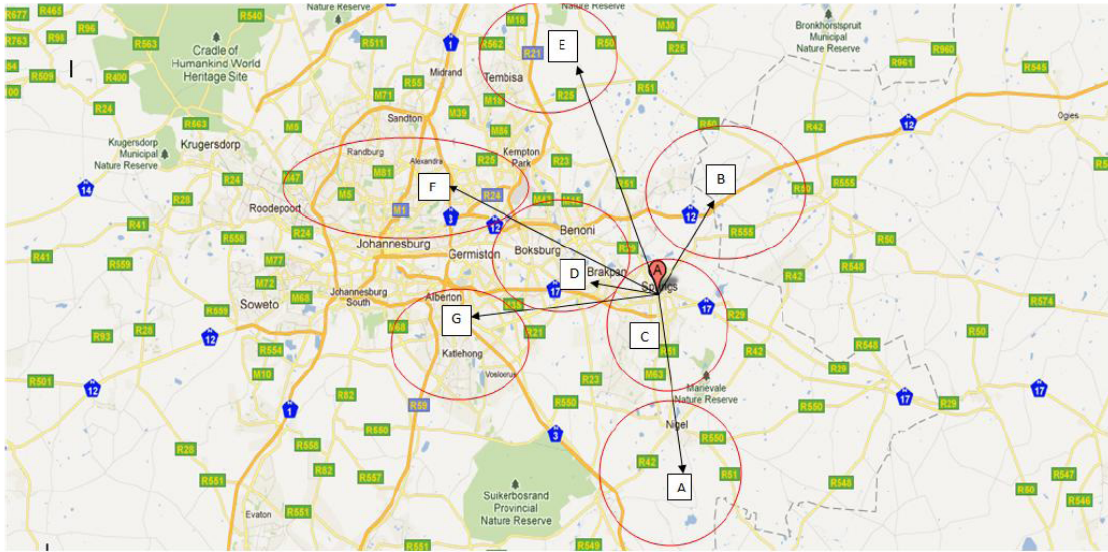


Figure 3.5: Springs Allocated Zones

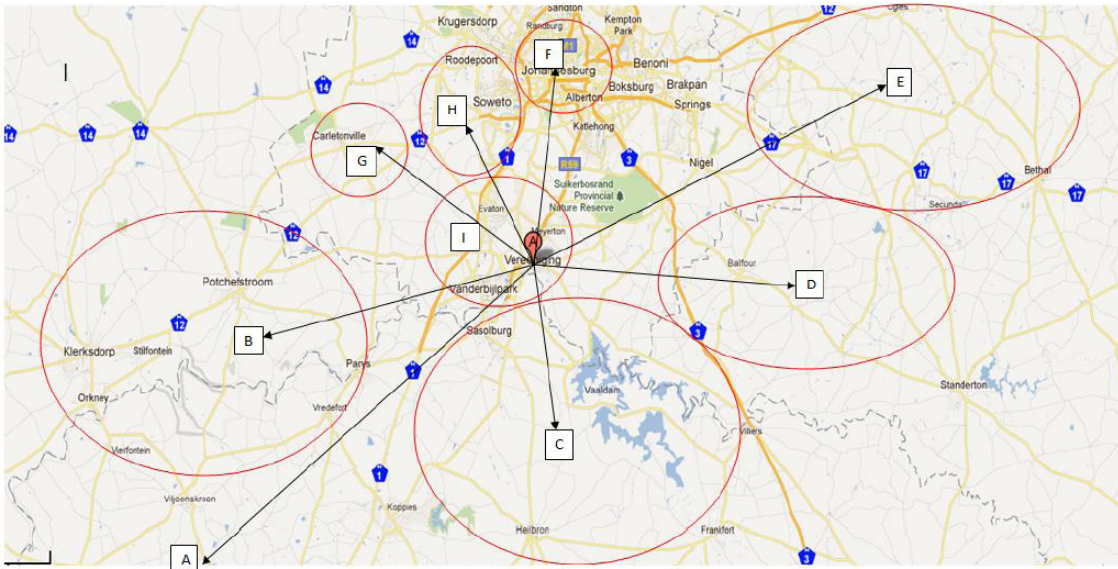


Figure 3.6: Vereeniging Allocated Zones

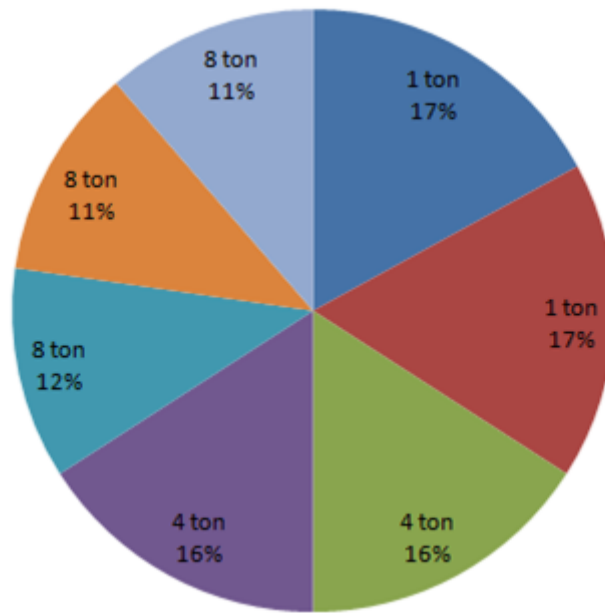


Figure 3.7: Pie Chart for Meadowdale Truck Usage

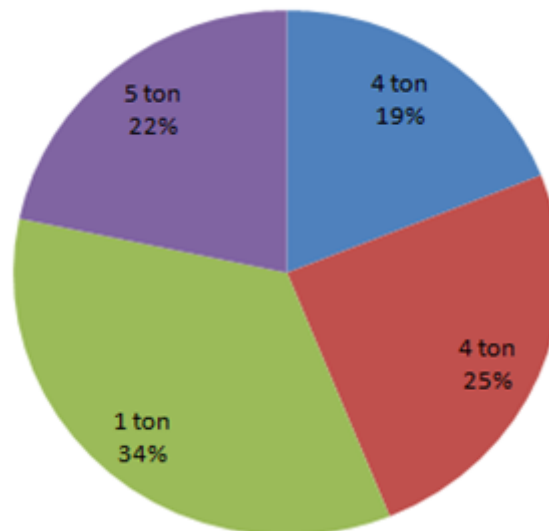


Figure 3.8: Pie Chart for Montague Gardens Truck Usage

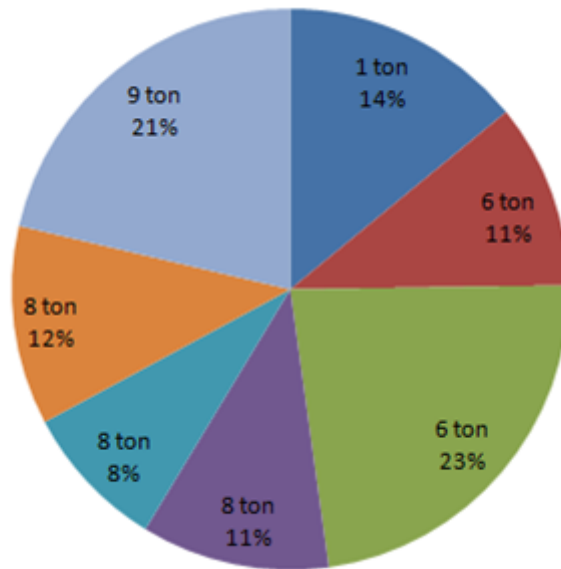


Figure 3.9: Pie Chart for Pretoria Truck Usage

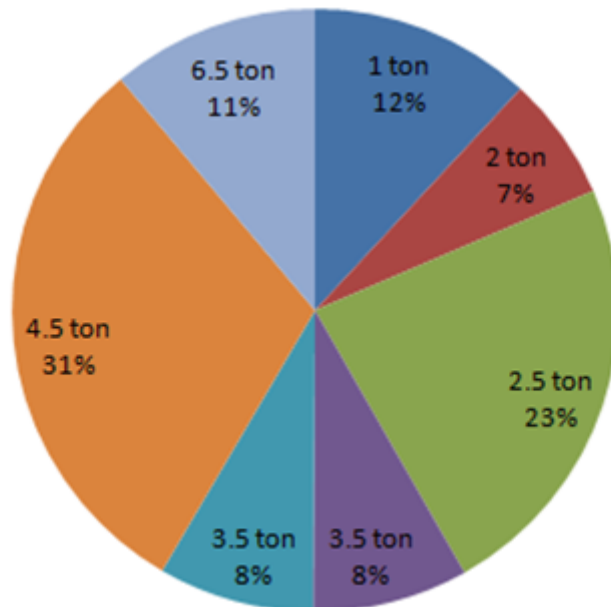


Figure 3.10: Pie Chart for Roodepoort Truck Usage

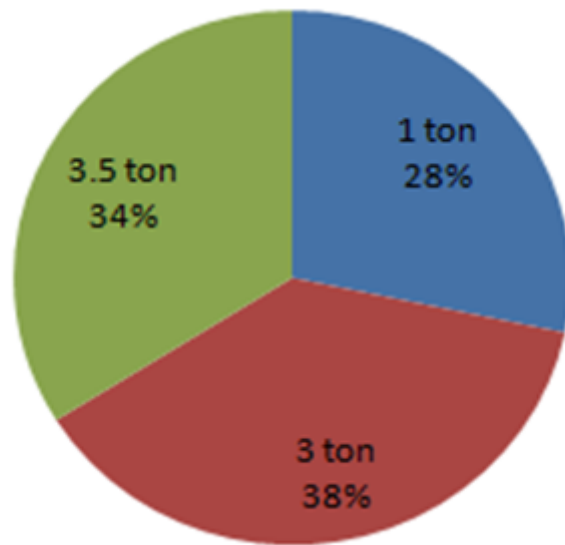


Figure 3.11: Pie Chart for Springs Truck Usage

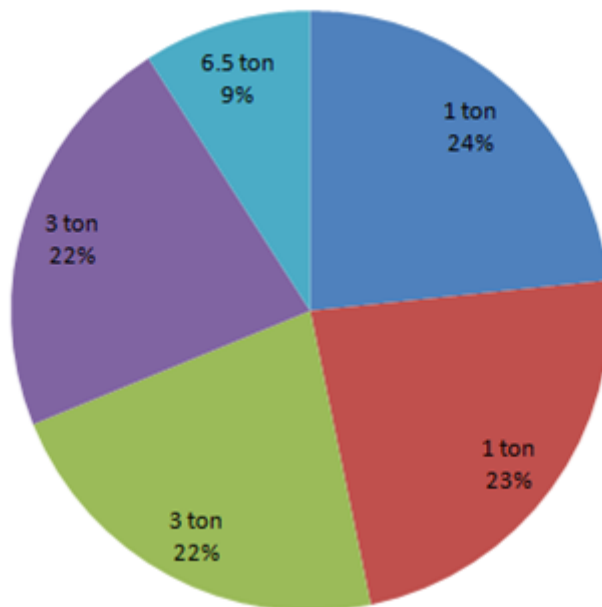


Figure 3.12: Pie Chart for Vereeniging Truck Usage

3.1.3 Costs Involved

For each vehicle, the estimated value for the cost per kilometre travelled was calculated. The RFA value for total annual operational cost was used, as calculated in the information gathering chapter, with the estimated kilometres travelled per month (data captured by IMPERIAL Distribution).

The formula used is as follows:

$$\text{Estimated Cost per Km} = \frac{\frac{\text{Total Annual Operational Costs}}{12}}{\text{Estimated Km per Month}} \quad (3.1)$$

The apportioned values for the cost per kilometre found for each vehicle are shown in the Appendix C.

3.2 Solution and Recommendations

When developing a solution two software programs were used. These programs were used to address the key supply chain metrics mentioned in the information gathering chapter. Since the most important contributor to any business is money and since supply chain cost is one of the key metrics for IMPERIAL Distribution, this issue was addressed first.

3.2.1 Distribution Model

Model

It will be the easiest to work with the variable costs as they are easier to manipulate than fixed costs due to their variability. The highest contributor to variable costs is fuel. Fuel costs depend on the kilometres travelled and vary accordingly.

Creating an optimisation model for the route travelled will address the cost and reliability metrics as it will ensure that all customers are serviced when required, will provide the shortest route to follow and recommend the vehicle that will service this trip the most efficiently.

In order to reduce the fuel costs the most logical solution is to reduce the kilometres travelled by each vehicle.

The zones that were created in the information gathering phase were then used. The zones were created in the first place so that customers assigned to each one could be serviced together, thereby reducing the distance travelled. Thus it would make sense to use those zones here. This model will also help to plan and schedule the trips made by each vehicle. Planning of the trip will increase the reliability by reducing the chance of leaving out a customer along the way or making a delivery on the wrong day.

Using Google Maps, the distance between the depot and each zone and the distance from zone to zone were found. These distances may not be exact as each zone is fairly large, spanning a few kilometres in radius, but they can be used relative to each other to find average shortest distances.

Using the above information and linear programming, an optimisation model was developed. This model's aim is to minimize costs.

The code adapted for the model was taken from Joubert [3], for a vehicle transportation problem and takes into account the same factors that affect the system at hand.

The variables defined as inputs for the system are defined as follows:

Let

\mathbf{N} be the total number of zones that need to be serviced.

q_i be the demand for zone i , where $i = \{1, 2, \dots, N\}$.

d_{ij} be the distance travelled between zone i and j , where $i, j = \{1, 2, \dots, N\}$.

c_{ijk} be the cost associated with the distance travelled by vehicle k , between zone i and j , where $i, j = \{1, 2, \dots, N\}$ and $k = \{1, 2, \dots, K\}$.

\mathbf{K} be the number of vehicles in the fleet.

p_k be the capacity of vehicle k , where $k = \{1, 2, \dots, K\}$.

r_k be the cost per kilometre for vehicle k , where $k = \{1, 2, \dots, K\}$.

The decision variable that will determine whether a certain truck makes a trip and where, is as follows:

$$x_{ijk} = \begin{cases} 1 & \text{if vehicle } k \text{ travels from zone } i \text{ to } j, \text{ where} \\ & i, j = \{1, 2, \dots, N | i \neq j\}, k = \{1, 2, \dots, K\} \\ 0 & \text{otherwise} \end{cases} \quad (3.2)$$

The objective function which will determine the optimal route for each vehicle is defined as follows:

$$\min z = \sum_{i=0}^N \sum_{\substack{j=0 \\ j \neq i}}^N \sum_{k=1}^K (c_{ijk} x_{ijk}) \quad (3.3)$$

subject to

$$\sum_{j=1}^N x_{0jk} = \sum_{j=1}^N x_{j0k} = 1 \quad \forall k \in \{1, 2, \dots, K\} \quad (3.4)$$

$$\sum_{j=1}^N \sum_{k=1}^K x_{0jk} \leq K \quad (3.5)$$

$$\sum_{\substack{i=1 \\ i \neq j}}^N \sum_{k=1}^K x_{ijk} = 1 \quad \forall j \in \{1, 2, \dots, N\} \quad (3.6)$$

$$\sum_{\substack{j=1 \\ j \neq i}}^N \sum_{k=1}^K x_{ijk} = 1 \quad \forall i \in \{1, 2, \dots, N\} \quad (3.7)$$

$$\sum_{i=1}^N q_i \sum_{\substack{j=1 \\ j \neq i}}^N x_{ijk} \leq p_k \quad \forall k \in \{1, 2, \dots, K\} \quad (3.8)$$

$$c_{ijk} = r_k d_{ij} \quad \forall i, j \in \{1, 2, \dots, N\}, \\ \forall k \in \{1, 2, \dots, K\} \quad (3.9)$$

$$x_{ijk} \in \{0, 1\} \quad (3.10)$$

The constraints and functions are explained as follows:

(3.3) This is the objective function. It defines what the deciding factor is (minimising cost in this case) and how it is used.

(3.4) Since this problem requires the vehicles it uses to go out and return from their trips (it is not an open vehicle routing problem), this constraint is required to enforce this. It will make sure that the vehicles that leave the depot for deliveries will return.

(3.5) This constraint makes sure that the number of vehicles that the model uses in finding an optimal solution does not exceed those that are available.

(3.6) This constraint ensures that each zone is only visited once.

(3.7) This will make sure that each zone is left once only. Note that equations (3.5) and (3.6) work together so that all zones are only visited once.

(3.8) The vehicle capacity is not exceeded on a trip to a zone by adding this constraint.

(3.9) This equation is the formula for the program to calculate the cost that will be incurred when vehicle k travels from zone i to j .

(3.10) Ensures that a fraction of a vehicle is not used for a trip.

Validation and Testing

The model was tested using Lingo. The output shows that this model can be used to assign vehicles to trips that need to be made to fulfil the demand of each depot's customers. Using the inputs required, an optimal distribution plan is created. An example of the coding in Lingo is given in Appendix E. For this example, three zones and three vehicles were used. The demand for each zone, distance between zones, capacity of each vehicle and cost per kilometre is specified in the "data" section in the beginning of the model.

IMPERIAL Distribution has agreed that this model will provide them with a distribution plan that will minimise distances travelled, thus decreasing variable costs.

3.2.2 Support

Interactive Database

For the optimisation model developed, the distance between zones is required as an input. For this project Google Maps was made use of to find the distances between

each zone and customer. This process was extremely time consuming and tedious. As this project is based on Industrial Engineering which aims to make processes more efficient, it only made sense to develop a method so that the inputs for the optimisation model can be easily accessed.

When the distances between each zone were determined, the assumption was made that the distances between the zones are the same going in both directions.

Using Microsoft Office Access a database was created to support the distribution model and its inputs. Information required can be accessed and added quickly and easily. It can also be used to aid heuristic distribution modelling.

The database follows the layout shown in figure 3.13 and is described in further detail in Appendix D.

Validation and Testing

The database was tested using the program itself. The results and outputs of using the program are also described in Appendix D.

IMPERIAL Distribution agrees that the database is useful for reducing the amount of time spent finding inputs for the model. It is also user friendly, with a clear, visual interface and easy-to-use functionality.

Conclusion

The model developed will provide IMPERIAL Distribution with a method to obtain a global optimum for their distribution plan. It will address both of the KPI's. The reliability will be improved as all orders will be delivered on the day they are required as the model used with the database will help ensure that all deliveries for a day are completed.

The cost KPI will also be addressed and improved as the distance travelled will be reduced. This reduction in distance travelled is a result of the route for each vehicle being specified by the optimisation model.

3.2.3 New Fleet

Fleet Description

After determining the status on all the trucks in use at each depot and their usage, table 3.1 was created. In this table, vehicles in use at each depot were recorded as well as their general details. IMPERIAL Distribution had already completed an analysis on all vehicles, on their condition and whether they can be kept and refurbished or if they can no longer be used and need to be replaced. The decision to keep or replace the vehicles was stated as well as the cost of refurbishment. The truck usage obtained in the data analysis pie charts for each depot was added and the vehicles were ranked on this.

Ranking was used to compare the vehicles that are used to serve most of the depot's demand, thereby making it clear on which vehicles need to be replaced and which are not necessarily needed.

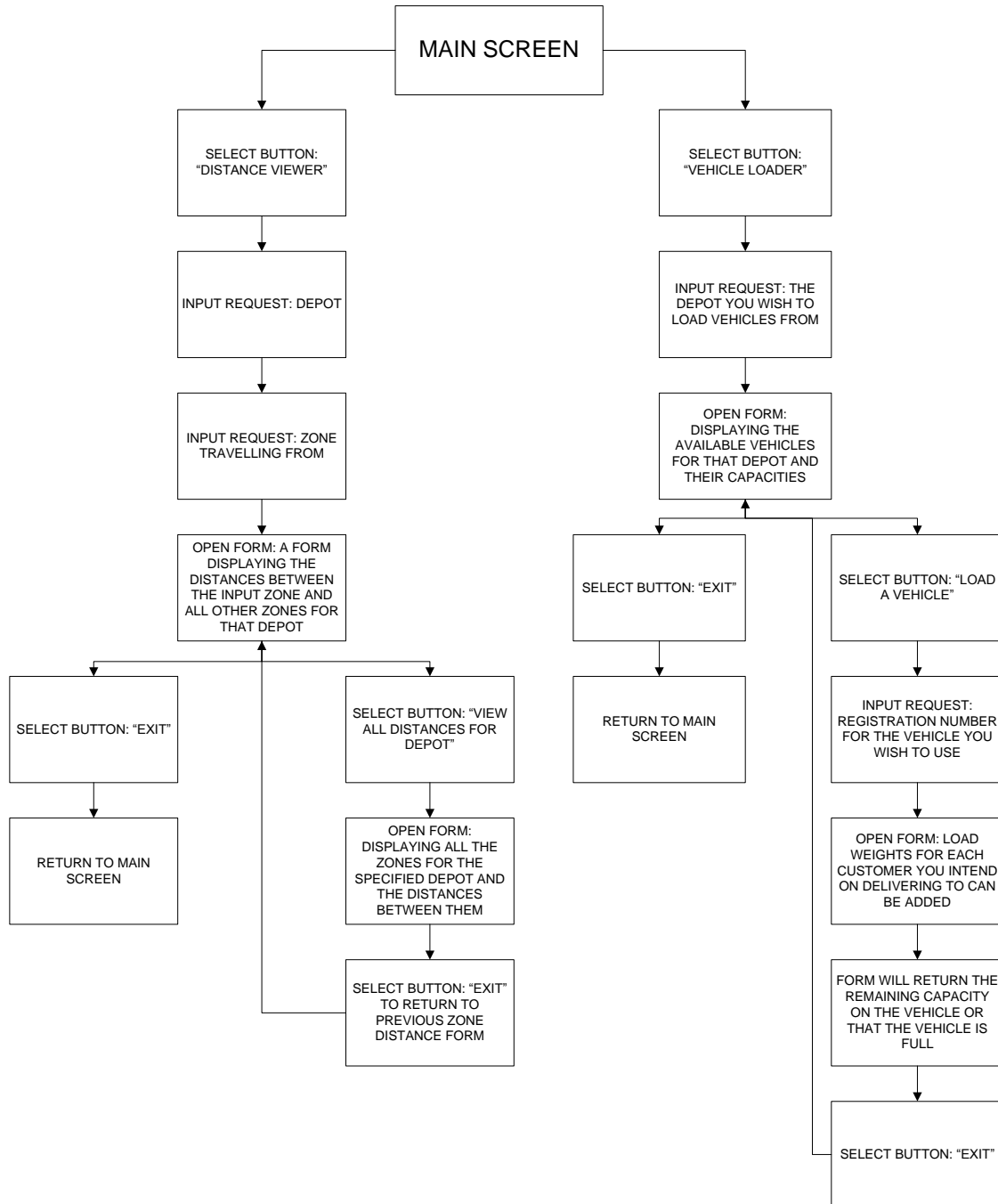


Figure 3.13: Flow Chart of Distance and Vehicle Loader Database

From this table, Meadowdale makes the most use of smaller, 1 ton vehicles, then 4 ton and lastly 8 ton vehicles. However, the use of 1 and 4 ton vehicles is very similar. According to the analysis done on the vehicles status by IMPERIAL Distribution, one of the 1 ton vehicles can no longer be used and needs to be replaced. Due to the high percentage that this vehicle is used, it is recommended that it be replaced. As two of the 8 ton vehicles are in need of refurbishment and are not used as extensively as the other vehicles, it may be more cost effective to sell one of the 8 ton vehicles and use that money to purchase a new 1 or 4 ton vehicle.

Looking at the vehicle status for Montague Gardens, their two most used vehicles are in need of replacement. Due to their importance for servicing demand, both of these vehicles should be replaced. The use of vehicles with respect to size difference is relatively well balanced, indicating that they have a good mix of what vehicles are required for their demand.

For Pretoria, their two most widely used vehicles will be costly to replace and fix. Since they have two 8 ton vehicles that are not used extensively, management may consider not replacing the 6 ton vehicle with another one, but instead making more use of the 8 ton vehicles to service the 6 ton vehicle's demand. The same could be done for the 9 ton vehicle as they are a similar capacity and thus can service similar demand.

Springs use of vehicles and fleet mix seems very efficient. They have three vehicles which are all well used. Clearly the 3 ton vehicle is used the most and the refurbishment cost will be well justified by its use. Since the 1 ton vehicle is used the least and is in need of replacement due to its mileage being too high, management may consider replacing it with a vehicle with a larger capacity, possibly a 2 or 3 ton vehicle. This will distribute the use of all vehicles more evenly thus making the purchase better justified.

At the Roodepoort depot, there are many options that can be considered for a replacement strategy. The two most used vehicles are in good condition and the refurbishment cost for CXL 050 GP will be well justified. It seems that the medium and smaller sized vehicles are used little in comparison. Since the two least used vehicles are need to be replaced, it may be more useful in serving demand to replace them with 4 ton vehicles or the same make and size vehicle as those that are used the most, depending on what the reason is that they are used the most. It also may be possible to not replace the 2 ton vehicle at all as this is used very little in comparison but instead purchase one vehicle that will service both the least used vehicles function.

Vereeniging generally has a well balanced use of their vehicles. Looking at the vehicles that are in good condition compared to those that need replacement and their respective usage, the replacement strategy for Vereeniging may be challenging. It seems that the vehicles that are needed the most are the smaller 1 and 3 ton vehicles but the vehicle that should be kept has a 6.5 ton capacity. While at least two of the vehicles requiring replacement should be replaced, it may be necessary to purchase a 1 ton and only one 3 ton vehicle and, by scheduling deliveries and servicing zones correctly, use the 6.5 ton to service the demand of other 3 ton vehicle as well as its own.

Validation and Testing

The effects of implementing the changes will be investigated in detail in the savings solution.

Depot	Vehicle	Current Odometer Reading	Capacity (tons)	Owned By	Comments	Usage	Replace/ Keep	Refurbishment Cost
Meadowdale	NWT 857 GP	416 173km	1	GSA	Km very high	17	Replace	0
	WCS 696 GP	182 955km	1	Imperial		17	Keep	0
	XMP 489 GP	138 988km	4	GSA	Good condition	16	Keep	15 000
	XSZ 560 GP	234 742km	4	GSA	Good condition	16	Keep	15 000
	WPR 255 GP	144 606km	8	Imperial		12	Keep	0
	SLN 658 GP	173 540km	8	GSA	Good condition	11	Keep	15 000
	SPZ 253 GP	172 673km	8	GSA	Godd condition	11	Keep	15 000
	CY 132 043	499 950km	1	GSA	Km very high	34	Replace	0
Montagne	GSG 371 FS	652 372km	4	GSA	Km very high	25	Replace	0
	CA 241 456	239 167km	5	GSA	Good condition	22	Keep	15 000
	CY 212 456	211 762km	4	GSA	Good condition	19	Keep	15 000
	LHR 368 GP	1 146 424km	6	GSA	Odo clocked over	23	Replace	0
	BG 42 DG GP	202 624km	9	GSA	A frame broken	21	Keep	35 000
Pretoria	ZMP 422 GP	33 454km	1	GSA	Good condition	14	Keep	5 000
	WWK 051 GP	136 124km	8	GSA	Rear bumper dented	12	Keep	15 000
	NCW 721 GP	252 969km	6	GSA	Badly maintained	11	Replace	0
	WLM 502 GP	226 785km	8	Imperial		11	0	0
	TVK 931 GP	415 633km	8	Imperial		8	0	0
	XSZ 560 GP	67 036km	3	GSA	Good condition	38	Keep	15 000
	TCK 939 GP	248 322km	3.5	Imperial		34	0	0
	NRW 587 GP	438 861km	1	GSA	Km very high	28	Replace	0
Roodepoort	SGG 253 GP	157 909km	4.5	GSA	Good condition	31	Keep	0
	CXL 050 GP	135 192km	2.5	GSA	Good condition	23	Keep	15 000
	WCS 696 GP	157 702km	1	Imperial		12	0	0
	WLT 105 GP	176 635km	6.5	Imperial		11	0	0
	XKX 774 GP	128 758km	3.5	GSA	Good condition	8	Keep	15 000
	CAW 1077	400 847km	3.5	GSA	Km very high	8	Replace	0
	TTZ 294 GP	351 000km	2	GSA	Km very high	7	Replace	15 000
Vereeniging	WDF 639 GP	235 000km	1	GSA	Good condition	24	Keep	10 000
	PKX 795 GP	700 000km	1	GSA	Poor Condition	23	Replace	0
	MMW 909 GP	520 000km	3	GSA	Km very high	22	Replace	0
	RCZ 122 GP	351 000km	3	GSA	One more year of use	22	Replace	0
	ZSB 213 GP	21 000km	6.5	GSA	Good condition	9	Keep	15 000

Table 3.1: Fleet Decisions

3.3 Savings

There are two areas where savings can be made for this project, namely in the variable costs being incurred by each vehicle and in the purchasing and refurbishment strategy used for the fleet. These areas are where costs are currently being incurred or will be incurred in the near future.

The areas where the savings will affect the income statement are shown in red in figure 3.14.

3.3.1 Variable Costs

Variable costs increase as a function of the kilometres travelled by the vehicle. For this reason, use of the optimisation model with the allocated zones for each depot is key to increase savings made by IMPERIAL Distribution.

Using the optimisation model, a global optimum can be obtained for daily distribution functions. Using the distances between each destination and incorporating the variable and fixed cost per kilometre for each vehicle, a distribution plan will be obtained so that variable costs will be minimised.

Quantitative values for the savings on variable costs will be obtained through further testing stages of the model developed.

3.3.2 Fixed Costs

Reducing the kilometres travelled by each vehicle will not reduce the fixed costs involved. A thoroughly considered vehicle replacement strategy, taking into account all requirements, will have a contribution to the fixed costs. It will reduce or even eliminate the fixed costs for each vehicle. Table 3.2 gives a possible replacement strategy and the outcomes for the suggestions previously made that will result in reduction of money spent.

The return on investment equation is a good indicator of the performance of money spent on investments, in this case, on vehicles. A high ROI indicates that the company's profits are higher than the money spent on assets. This is an important indicator as no profit seeking organisation wants to own assets that are not making them profit. Using the formula for return on investment, as shown below, it is obvious that the more operating assets that are invested in, the lower the return on investment. Following a strategy where fewer vehicles will be purchased will increase the return on investment.

$$ROI = \frac{NetProfit}{OperationAssets} \quad (3.11)$$

From the proposed recommendations for the replacement and refurbishment of vehicles, a saving of R1 142 000 can be made from the fixed costs incurred alone.

The costs for the purchase of new vehicles was investigated and used where replacement was suggested. The amounts shown for replacement of vehicles are

Income Statement	
Revenue	
Net Sales	XXX
Cost of Goods Sold	
Beginning Inventory	XXX
Goods purchased or manufactured	XXX
Total Goods Available	XXX
(Less ending inventory)	(XXX)
Cost of Goods Sold	XXX
Gross Profit (Loss)	XXX
Expenses	
Advertising	XXX
Bad debts	XXX
Commissions	XXX
Depreciation	XXX
Employee benefits	XXX
Equipment	XXX
Insurance	XXX
Maintenance	XXX
Office Equipment	XXX
Payroll taxes	XXX
Rent	XXX
Research and development	XXX
Salaries and wages	XXX
Software	XXX
Travel	XXX
Utilities	XXX
Total Operating Expenses	XXX
Operating Income (Loss)	XXX
Non-operating revenues	XXX
(Less interest expense)	(XXX)
Income before tax	XXX
(Less operating expense)	(XXX)
Net Income	XXX

Figure 3.14: Affect on Income Statement

those for the purchase of new vehicles of the same make and model that are currently in use. IMPERIAL Distribution may decide to purchase second hand vehicles or vehicles of a different make and/or model. In this case these amounts may change.

3.3.3 Validation and Testing

The suggested changes are validated by the difference in total spending in table 3.2. It is possible for IMPERIAL Distribution to save a great deal of money by carefully considering what costs are necessary and which can be avoided.

Depot	Vehicle	Capacity	Usage	Replace/ Keep	Refurbishment Cost	Option	Recommendation	Original	
Meadowdale	NWT 857 GP	1	17	Replace	0	Replace	(200 000)	(200 000)	
	WCS 696 GP	1	17	Keep	0	-	0	0	
	XMP 489 GP	4	16	Keep	15 000	-	(15 000)	(15 000)	
	XSZ 560 GP	4	16	Keep	15 000	-	(15 000)	(15 000)	
	WPR 255 GP	8	12	Keep	0	-	0	0	
	SLN 658 GP	8	11	Keep	15 000	-	(15 000)	(15 000)	
	SPZ 253 GP	8	11	Keep	15 000	Sell	150 000	(15 000)	
	CY 132 043	1	34	Replace	0	Replace	(180 000)	0	
Montague	GSG 371 FS	4	25	Replace	0	Replace	(197 000)	0	
	CA 241 456	5	22	Keep	15 000	-	(15 000)	0	
	CY 212 456	4	19	Keep	15 000	-	(15 000)	0	
	LHR 368 GP	6	23	Replace	0	Use 8ton already owned	280 000	(280 000)	
	BG 42 DG GP	9	21	Keep	35 000	Use 8ton already owned	35 000	(35 000)	
Pretoria	ZMP 422 GP	1	14	Keep	5 000	-	(5 000)	(5 000)	
	WWK 051 GP	8	12	Keep	15 000	-	(15 000)	(15 000)	
	NCW 721 GP	6	11	Replace	0	Replace	(280 000)	(280 000)	
	WLM 502 GP	8	11	-	0	-	0	0	
	TVK 931 GP	8	8	-	0	-	0	0	
	XSZ 560 GP	3	38	Keep	15 000	-	(15 000)	(15 000)	
	TCK 939 GP	3.5	34	-	0	-	0	0	
	NRW 587 GP	1	28	Replace	0	Replace	(210 000)	(210 000)	
Roodepoort	SGG 253 GP	4.5	31	Keep	0	-	0	0	
	CXL 050 GP	2.5	23	Keep	15 000	-	(15 000)	(15 000)	
	WCS 696 GP	1	12	-	0	-	0	0	
	WLT 105 GP	6.5	11	-	0	-	0	0	
	XKX 774 GP	3.5	8	Keep	15 000	-	(15 000)	(15 000)	
	CAW 1077	3.5	8	Replace	0	Replace	(200 000)	(200 000)	
	TTZ 294 GP	2	7	Replace	15 000	Do not replace	180 000	(180 000)	
	WDF 639 GP	1	24	Keep	10 000	-	(10 000)	(10 000)	
Vereeniging	PKX 795 GP	1	23	Replace	0	Replace	(175 000)	(175 000)	
	MMW 909 GP	3	22	Replace	0	Replace	(240 000)	(240 000)	
	RCZ 122 GP	3	22	Replace	0	Do not replace	197 000	(197 000)	
	ZSB 213 GP	6.5	9	Keep	15 000	-	(15 000)	(15 000)	
	Total Spendings							(1 005 000)	(2 147 000)

Table 3.2: Fleet Savings

3.4 Conclusion

Completing an analysis on the options for a replacement and refurbishment strategy shows that R1 142 000 of savings are possible. Further consideration would be required by those at IMPERIAL Distribution with regard to the final decisions. Experience of each vehicles usefulness at each depot will provide an important input for the replacement strategy with regard to which vehicles should replace those that need it and what refurbishment is necessary for each vehicle.

Chapter 4

Conclusion

From the analysis done using AS-IS data, the system can be improved by implementing the optimisation model, to reduce the variable costs, and the vehicle replacement recommendations (some or all) to reduce the capital investment required to bring the fleet in line with IMPERIAL Distributions standards.

Evaluating the vehicles required to meet each depots demand will be a beneficial exercise. It will have a large impact on the capital expenditure and fixed costs (insurance, licence, administration, operation, depreciation) for IMPERIAL Distribution. It is managements decision on what recommendations will be taken into account, and while not all the options may be implemented, table 3.2 shows the impact that individual considerations will make.

4.1 Implementation

The distribution plan using zones can be implemented right away as it does not rely on the optimisation model alone. It can be done using heuristics and experience of traffic, roads and general conditions. The model described can also be implemented by someone with programming knowledge using different software options such as Microsoft Excel and Matlab.

Implementation of the new fleet will depend on decisions made by fleet managers and the finance department. Considerations will have to made on bounds on costs to upgrade and maintain the fleet.

4.2 Benefits

The benefits of this project include:

- Reduction on variable costs
- Reduction on fixed costs
- More efficient use of vehicles to serve demand
- More control over fleet and customer network

- User friendly database
- More reliable scheduling of deliveries
- Lower distances travelled by vehicles can decrease maintenance costs

4.3 Future Improvements

This project aimed to implement continuous improvement into the logistic process. Use and maintenance of the zone system by adding new customers to an appropriate zone and updating the distances between the zones, the system will keep their logistics functions running at a reliable level.

Every time the model is run, it will provide a different optimum according to the demand needs and keep costs to a minimum. Experience may show that similar routes are followed as customers may place similar weekly orders. As there are often new or once off customers, these can easily be incorporated into the system and a new optimal distribution plan can be found.

Keeping the database up to date with the relevant information will also contribute to keeping costs to a minimum and facilitate reliability of the orders delivered with the right orders being delivered at the right time.

The truck utilisation will also be maximised using the optimisation model. From the ROI formula, better use of fewer assets will help IMPERIAL Distribution increase their profits and decrease their expenses at the same time.

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Chapter 5

Addendum

Appendix A: Graphs of Demand

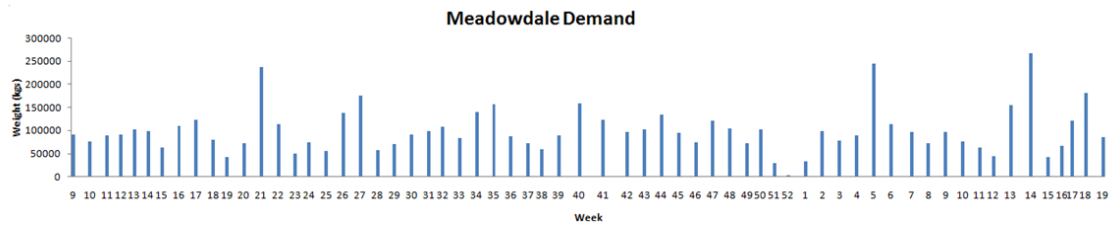


Figure 5.1: Graph of Meadowdale’s Demand

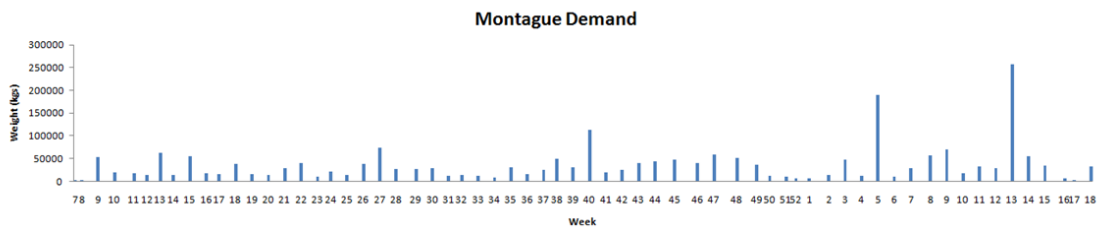


Figure 5.2: Graph of Montague Gardens’s Demand

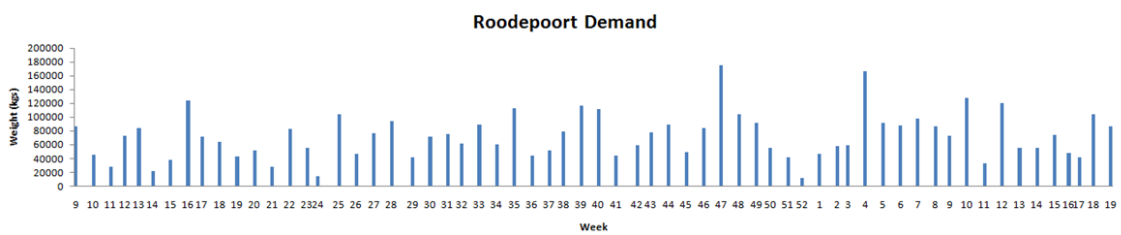


Figure 5.3: Graph of Roodepoort’s Demand

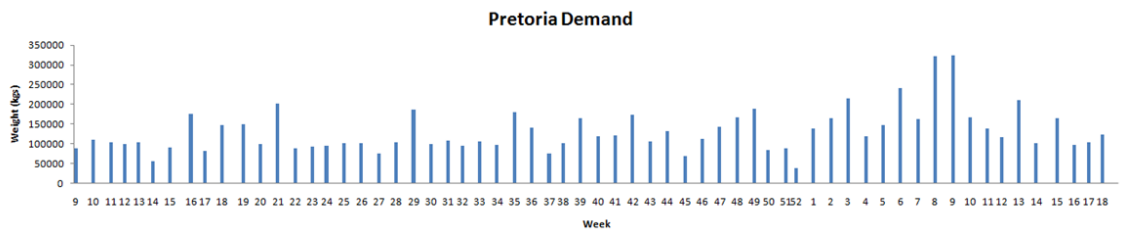


Figure 5.4: Graph of Pretoria’s Demand

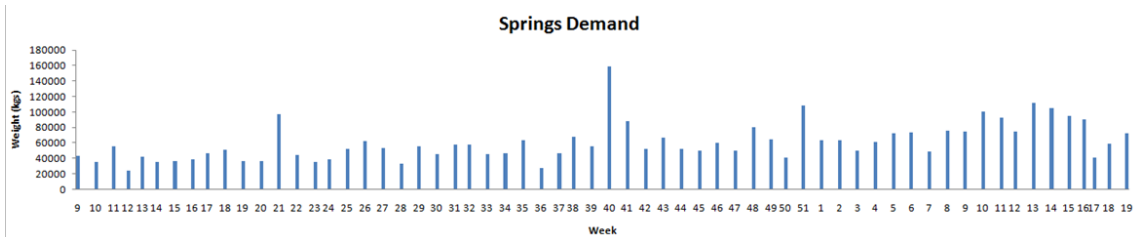


Figure 5.5: Graph of Spring’s Demand

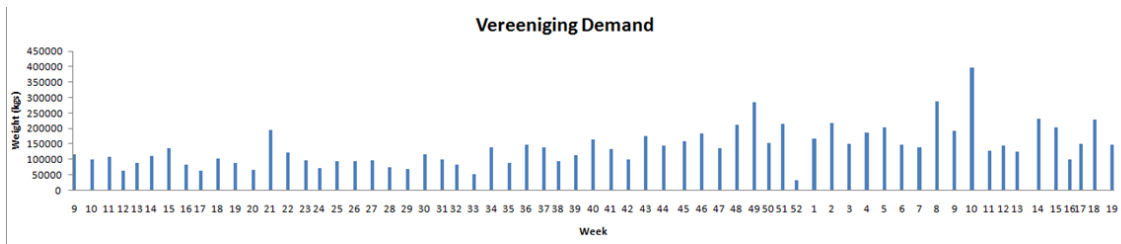


Figure 5.6: Graph of Vereeniging's Demand

Appendix B: Allocated Zones for Each Depot

5.0.1 Meadowdale Zones

- A. Kya Sands, Fourways, Sundowner, Randburg, Rivonia, Woodmead, Cresta, Kramerville, Marlboro, Robertville, Strijdom Park.
- B. Roodepoort, Industria West, Newlands, Greenhills.
- C. Edenvale, Thornhill Estate, Greenstone Hill, Sebenza, Spartan, Kempton Park, Norkem Park, Bredell, Modderfontein, Olifantsfontein, Meadowdale.
- D. Bramley, Kew, Highlands North, Glenhazel, Bagleyston, Sydenham, Senderwood, Orange Grove.
- E. Bruma, Bedfordview, Malvern East, Malvern, Primrose, City Deep, Heriotdale.
- F. Hillbrow, Johannesburg CBD, Booysens, Rosettenville, Winchester Hills, Benrose, Doornfontein, Jeppes Town.
- G. Germiston, Wadeville, Alberton, Alrode, Boksburg, Benoni, Raceview, Springs, Nigel, Beyerspark, Rondebult.
- H. Centurion, Midrand.
- I. Lenasia, Carltonville, Fochville, Vereeniging, Vanderbijlpark.
- J. Outliers: Botswana, Polokwane, Nelspruit, Zambia.

5.0.2 Montague Gardens Zones

- A. East London, Port Elizabeth, George, Hermanus.
- B. Piketberg, Vredenburg, Langebaan, Darling, Vredendal.
- C. Bergvliet, Tokai, Muizenberg, Noordhoek, Kommetjie, Retreat, Capricorn Crescent.
- D. Matroosfontein, Blackheath, Kuils River, Mitchells Plain.
- E. Lansdowne, Claremont, Athlone, Salt River, Woodstock, Observatory, Ottery, Cape Town.
- F. Montague Gardens, Killarney Gardens, Chempet, Saxenburg.
- G. Durbanville, Kraaifontein, Brackenfell, Oakglen, Bellville, Sanlamhof, Parow, Parow East, Beaconvale, Epping, Panorama.
- H. Outliers: Worcester

5.0.3 Pretoria Zones

- A. Hammanskraal, Babelegi, Mabopane, Soshanguve.
- B. Wapadrand, Silver Lakes, Mooikloof, Garsfontein, Elarduspark, Faerie Glen.
- C. Atteridgeville, Sunderland Ridge, Valhalla, Wierdapark, Hennops Park, Centurion.
- D. Halfway House, Bryanston, Randburg, Honeydew, Benrose, Meadowdale, Kyalami, Midrand.
- E. Booyens, Mayville, Gezina, Villeria, Pretoria, Arcadia, Klerksoord, Wonder Park.
- F. Doornpoort, Sinoville, Montana, Kameeldrift, Montana Park, Zambezi.
- G. Silvertondale, Silverton, Weavind Park, Jan Niemand Park, Koedoespoort Industrial.
- H. Hebron.
- I. Postmasburg.
- J. Phalaborwa, Broederstroom, Naboomspruit, Polokwane, Mahweling, Modimolle, Settlers.
- K. Bronkhorspruit.
- L. Brits.

5.0.4 Roodepoort Zones

- A. Chartwell, Fourways, Kya Sands, Northriding, Rivonia, Kyalami, Hennops Park.
- B. Breaunanda, Krugersdorp, Boltonia, Chamdor, Lindhaven, Grobler Park, Muldersdrift.
- C. Honeydew, Ferndale, Randburg, Strubens Valley, Fairland, Northcliff, Linden, Parkhurst, Blackheath, Albertskroon, Blairgowrie, Fonteinebleau, Roosevelt.
- D. Horison, Discovery, Roodepoort, Florida, Weltevreden Park.
- E. Robertville, Industria North, Newclare, Westdene, Industria, Riverlea, Maraisburg, Johannesburg CBD, Fordsburg, Ophirton, Stafford, Berea, Booyens.
- F. Germiston, Kensington, City Deep, Benrose, Denver, Heriotdale, Jet Park, Steeledale.
- G. Dobsonville, Glenanda, Eldorado Park, Soweto, Lenasia, Westonaria, Kocksoord, Azaadville, Randgate, Randfontein.

5.0.5 Springs Zones

- A. Nigel, Balfour.
- B. Etwatwa, Delmas.
- C. Springs, Strubenvale, Geduld, Langaville, Geluksdal, Tsakane, Kwa-Thema.
- D. Brakpan, Actonville, Benoni, Elsburg, Boksburg, Anderbolt, Driehoek.
- E. Tembisa, Bapsfontein, Midrand, Olifantsfontein.
- F. Kempton Park, Edenvale, Industria, Modderfontein.
- G. Katlehong, Vosloorus, Rondebult.

5.0.6 Vereeniging Zones

- A. Outliers: Postmasburg, Matatama.
- B. Bothaville, Viljoenskroon, Klerksdorp, Potchefstroom, Parys, Nortbrug, Potchindustria.
- C. Heilbron, Frankfort, Sasolburg, Deneysville, Reitz.
- D. Standerton, Balfour, Heidelberg.
- E. Secunda, Trichardt, Bethal, Kriel, Delmas, Emzinoni.
- F. Randburg, Johannesburg CBD, Germiston, Wadeville, Industrial Park, Evander.
- G. Fochville, Oberholzer, Carltonville.
- H. Randfontein, Lenasia, Lenasia South, Orange Farm, De Deur.
- I. Evaton, Sebokeng, Meyerton, Rothdene, Vereeniging, Three Rivers, Powerville, Rosahof, Matsoheng, Vanderbijlpark.

Appendix C: Average Kilometres Travelled by each vehicle per month

Capacity	Vehicle Registration	Fixed Costs	Variable Costs	Total Costs	Estimated per Month	Km	Estimated Cost per Km
1 ton	NWT 857 GP	143 268	64 701	207 969	1 500		R11.55
1 ton	WCS 696 GP	143 268	64 701	207 969	1 500		R11.55
4 ton	XMP 489 GP	286 581	130 465	417 046	1 400		R24.82
4 ton	XSZ 560 GP	286 581	130 465	417 046	1 400		R24.82
8 ton	WPR 255 GP	345 069	201 760	546 829	1 000		R45.57
8 ton	SPZ 253 GP	345 069	201 760	546 829	1 000		R45.57
8 ton	SLN 659 GP	345 069	201 760	546 829	1 000		R45.57

Table 5.1: Meadowdale Fleet Costs

Capacity	Vehicle Registration	Fixed Costs	Variable Costs	Total Costs	Estimated per Month	Km	Estimated Cost per Km
1 ton	CY 132 043	143 268	64 701	207 969	4 209		R 4.12
4 ton	GSG 371 FS	267 438	93 270	360 708	3 055		R 9.84
4 ton	CY 212 456	286 581	130 465	417 046	2 311		R15.04
5 ton	CA 241 456	286 581	130 465	417 046	2 649		R13.12

Table 5.2: Montague Gardens Fleet Costs

Capacity	Vehicle Registration	Fixed Costs	Variable Costs	Total Costs	Estimated per Month	Km	Estimated Cost per Km
1 ton	ZMY 422 GP	143 268	64 701	207 969	2 788		R 6.22
6 ton	LHR 368 GP	340 412	161 019	501 431	2 108		R19.82
6 ton	NCW 721 GP	340 412	161 019	501 4331	4 549		R 9.19
8 ton	WWK 051 GP	345 069	201 760	546 829	2 159		R21.11
8 ton	TVK 931 GP	345 069	201 760	546 829	1 673		R27.24
8 ton	WLM 502 GP	345 069	201 760	546 829	2 268		R20.09
9 ton	BG 42 DG GP	345 069	201 760	546 829	4 221		R10.80

Table 5.3: Pretoria Fleet Costs

Capacity	Vehicle Registration	Fixed Costs	Variable Costs	Total Costs	Estimated per Month	Km	Estimated Cost per Km
1 ton	WCS 696 GP	143 268	64 701	207 969	2 139		R 8.10
2 ton	TTZ 294 GP	267 438	93 270	360 708	1 200		R25.05
2.5 ton	CXL 050 GP	267 438	93 270	360 708	4 200		R 7.16
3.5 ton	CAW 1077	286 581	130 465	417 046	1 500		R23.17
3.5 ton	XKX 774 GP	286 581	130 465	417 046	1 500		R23.17
4.5 ton	SGG 253 GP	286 581	130 465	417 046	5 500		R 6.32
6.5 ton	WLT 696 GP	340 412	161 019	501 4331	2 000		R20.89

Table 5.4: Roodepoort Fleet Costs

Capacity	Vehicle Registration	Fixed Costs	Variable Costs	Total Costs	Estimated per Month	Km	Estimated Cost per Km
1 ton	NRW 587 GP	143 268	64 701	207 969	1 500		R11.55
3 ton	XSZ 560 GP	267 438	93 270	360 708	2 000		R15.03
3.5 ton	TCK 939 GP	286 581	130 465	417 046	1 800		R 19.31

Table 5.5: Springs Fleet Costs

Capacity	Vehicle Registration	Fixed Costs	Variable Costs	Total Costs	Estimated per Month	Km	Estimated Cost per Km
1 ton	WDF 639 GP	143 268	64 701	207 969	4 500		R 3.85
1 ton	PKX 795 GP	143 268	64 701	207 969	4 500		R 3.85
3 ton	MMW 909 GP	267 438	93 270	360 708	4 250		R 7.07
3 ton	RCZ 122 GP	267 438	93 270	360 708	4 250		R 7.07
6.5 ton	ZSB 213 GP	340 412	161 019	501 431	1 750		R23.88

Table 5.6: Vereeniging Fleet Costs

Appendix D: Access Database for Distance Viewing and Loading of Vehicles

On opening the database, the screen shown in figure 5.7 will be displayed. From here the user can select the “Distance Viewer” or “Vehicle Loader” buttons.

When the Distance Viewer button is pushed a request for the depot required is opened as shown in figure 5.8. For this example the Springs depot was entered.

The zone the vehicle will be travelling from is then requested as an input similar to figure 5.8. Since the zones for each depot were named alphabetically and with the same letters, these had to be differentiated for the database. This was done by abbreviating the depot name, followed by the alphabetical letter assigned to the zone, shown in table 5.7. An example is given for each case.

For this example the zone travelling from was requested as A, thus the input was “S A”. Note that the database is not case sensitive to inputs so if “s a” was entered the same result would be given. The Distance Viewer form is opened, displaying the distances from the zone given as an input to the rest of the zones for that depot.

The distances displayed here can be used when providing input distances for the distribution model. If “EXIT” is selected the form will close and go back to the main screen. If “VIEW ALL ZONES AND DISTANCES FOR DEPOT” is selected a similar form will open that shows the distances between all the zones for that depot.

On selecting “EXIT” on this form it will return to the Distance Viewer form where the user can continue there or exit back to the main screen.

Back at the main screen, if the “VEHICLE LOADER” button is selected, a request for the depot appears. After specifying the depot required, which in this

Depot	Abbreviation	Example
Meadowdale	MD	MD A
Montague	M	M D
Pretoria	P	P H
Springs	S	S C
Roodepoort	R	R B
Vereeniging	V	V G

Table 5.7: Depot Abbreviations

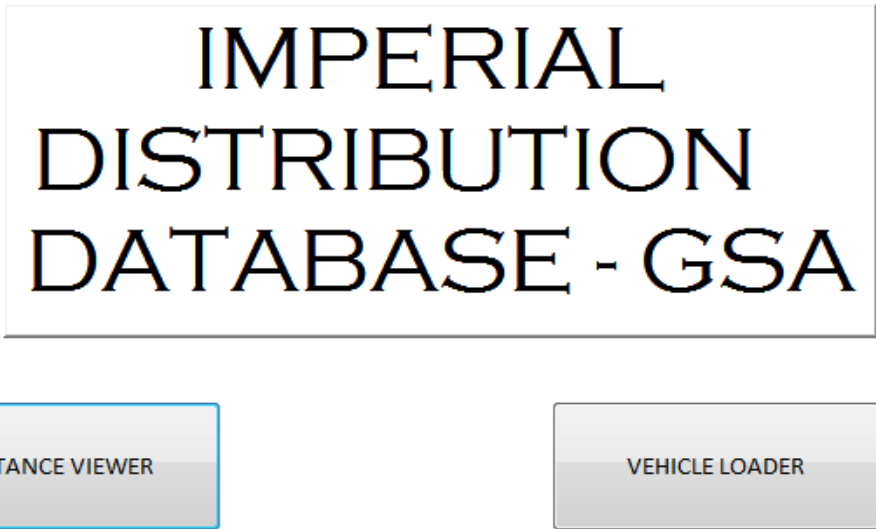


Figure 5.7: Main Screen of Database

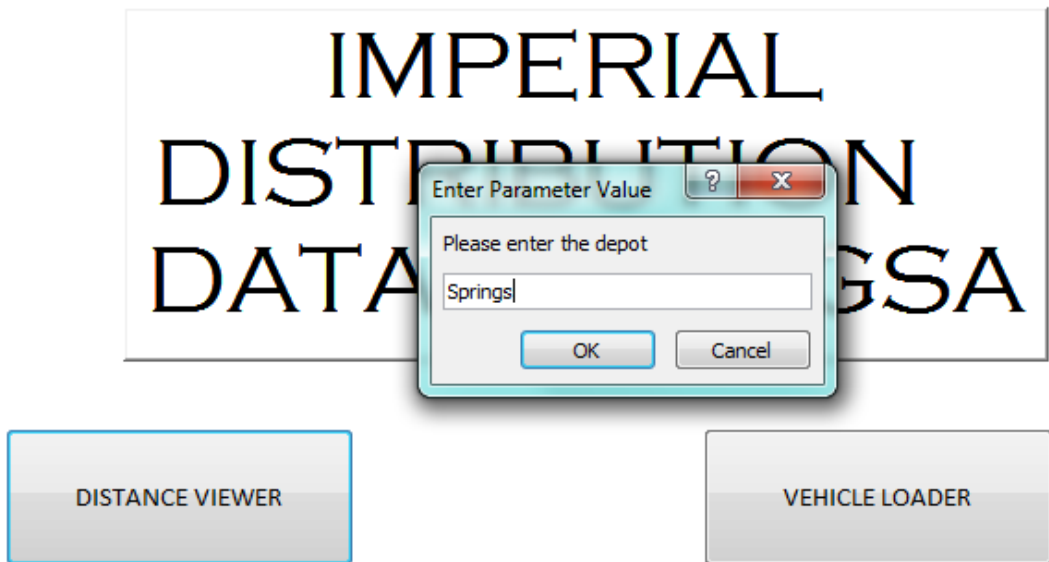


Figure 5.8: Depot Input Request

Distance Viewer				
	Depot	Zone From	Zone To	Distance (km)
▶	Springs	S A	S B	80
	Springs	S A	S C	58
	Springs	S A	S D	78
	Springs	S A	S E	115
	Springs	S A	S F	105
	Springs	S A	S G	67
*				

EXIT

VIEW ALL ZONES AND DISTANCES FOR DEPOT

Figure 5.9: Distance Viewer Form

All Zones Distances

	Zone From	Zone To	Distance
▶	S A	S B	80
	S A	S C	58
	S A	S D	78
	S A	S E	115
	S A	S F	105
	S A	S G	67
	S B	S C	22
	S B	S D	28
	S B	S E	45
	S B	S F	69
	S B	S G	50
	S C	S D	25
	S C	S E	52
	S C	S F	71
	S C	S G	40
	S D	S E	36
	S D	S F	47

EXIT

Figure 5.10: Distinces between all zones

case was Roodepoort, a form will open showing all the vehicles available at that depot as well as their capacities.

This form is used to view which vehicles are available and use their registration numbers for the next step.

On selecting the “LOAD A VEHICLE” button, a request for the vehicle registration number will appear and the user will be required to enter which vehicle they would like to use. For this example, CAW1077 was selected. The next form that opens allows the user to add the weight of each customer order as an input and receive the remaining capacity as an output. Provision has been made for four different customer entries only as previous records show that it is very rare that a vehicle services more than three customers in one trip. If the load added to the truck exceeds the capacity available, the output will be a message saying “Not Enough Space” as opposed to the remaining capacity.

On selecting the “EXIT” button the form will close and return to the Available Vehicles form where the user can select “EXIT” to return to the main screen.

Available Vehicles		
Depot	Registration	Capacity (tons)
▶ Roodepoort	SGG253GP	4
Roodepoort	CXL050MP	2
Roodepoort	WCS696GP	1
Roodepoort	WLT105GP	6
Roodepoort	XKX774GP	4
Roodepoort	CAW1077	4
Roodepoort	TTZ294GP	2
* <input type="text"/>	<input type="text"/>	<input type="text"/>

EXIT

LOAD A VEHICLE

Figure 5.11: Available Vehicles Form

Vehicle Loader

Registration	CAW1077
Capacity (Tons)	4
Customer 1 Load (kg)	2400
Remaining Space (kg)	1600
Customer 2 Load (kg)	1000
Remaining Space (kg)	600
Customer 3 Load (kg)	1200
Remaining Space (kg)	Not enough space
Customer 4 Load (kg)	
Remaining Space (kg)	

EXIT

Figure 5.12: Vehicle Loaded to Capacity

Appendix E: Lingo Example

```

sets:

zonefrom/1..3/:q;
zoneto/1..3/;
vehicles/1..3/:p,r;
zones(zonefrom, zoneto):d;
travel(zonefrom, zoneto, vehicles):c,x;
endsets

data:
q=1000 2000 3000;
d=5 10 20
10 5 40
20 40 5;
p=400 500 400;
r=1.5 3 2.5;
enddata

min=@sum(travel(i,j,k):x(i,j,k)*c(i,j,k));

@for(vehicles(k):
@sum(zoneto(j):
x(0,j,k))=@sum(zoneto(j):x(j,0,k)));

@for(vehicles(k):
@sum(zoneto(j):
x(0,j,k))=1);

@sum(travel(i,j,k):
x(0,j,k))<= 3;

@for(zoneto(j):
@sum(travel(i,j,k)|i #NE# j:
x(i,j,k))=1);

@for(zonefrom(i):
@sum(travel(i,j,k)|j #NE# i:
x(i,j,k))=1);

@for(vehicles(k):
(@sum(zonefrom(i):
q(i)))*(@sum(zoneto(j)|j #NE# i:x(i,j,k)))<=p(k));

@for(travel(i,j,k):
c(i,j,k)=r(k)*d(i,j));

@for(travel(i,j,k):
@bin(x(i,j,k)));
end

```