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FRONT PAGE FOR FINAL PROJECT DOCUMENT (BPJ 420) - 2017

Information with regards to the mini-dissertation

Title [e.g. A Contingency framework for the after-sales inventory at Xxxxx Part Distribution Centre]	Forecasting transportation service demand for fleet optimization: the case of a third party logistics provider
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Keywords [Provide keywords from your project (for searching purposes). The first word of two words must always have a capital first letter and the rest of the words following must be lower case. In the event of an abbreviation, use as it is known, e.g. Economic recession, ABSA, ERP, Simulation modelling)]	Forecasting Optimization modelling 3PL Fleet optimization
Abstract [Provide an abstract of the mini-dissertation. An abstract is a short summary of the contents covered in the item.]	The aim of this project is to find the optimal fleet size for a 3PL by forecasting the anticipated service demand and applying an optimization model over a period of twelve months.
Category [Enter the category in which the project was done. E.g. Operations Research, Simulation, Logistics…]	Operations Research
Sensitive Parts [Indicate if there are sensitive parts that should not be published on UPSpace, e.g. Appendix A and H should not be published.]	

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FORECASTING TRANSPORTATION SERVICE DEMAND FOR FLEET OPTIMIZATION: THE CASE OF A THIRD PARTY LOGISTICS PROVIDER

Margo van Aarde

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2017/09/28

Interim Project Report Draft submitted in partial fulfilment of the requirements for the module

BPJ 420 Project

at the

Department Industrial and Systems Engineering
University of Pretoria

DECLARATION OF ORIGINALITY

I, Margo van Aarde, student number 14179254 hereby declare that this report is my own original work, and that the references listed provides a comprehensive list of all sources cited or quoted in this report.

EXECUTIVE SUMMARY

Outsourcing is becoming increasingly popular in today's age where customers have higher expectations from suppliers than ever before. Businesses are collaborating to aim to meet customer demand and stay competitive in the market. Some businesses turn to outsourcing. This industry is rapidly growing and faces a unique set of challenges. Customers value flexibility and punctuality in this service provided. In order to do this, logistics providers have to account for the stochastic nature of customer demand and thereby incur additional costs.

The focus of the project is on a transportation based logistics provider that provides transportation-, cross docking- and distribution services to a collection of retail clients. The company is a leveraged logistics provider, which means that it uses its own vehicles as well as vehicles hired from external companies to provide the service. This project aims to investigate ways to reduce the operating costs of a division in a logistics provider company specifically by suggesting the optimal fixed fleet size the company should maintain. This was done by forecasting the anticipated number of vehicles that will be required to meet customers' service demand for a period of twelve months and finding the optimal fleet size of the 3PL's fixed fleet. The primary challenge for the 3PL is to maintain their flexibility in the service they provide to clients while introducing stability in their own operations. The report gives a detailed plan that was followed to achieve this goal and outlines the tools and techniques that was applied to obtain the results. Furthermore, a literature study specifically aimed at forecasting and optimization models was done to broaden knowledge and understanding of these subjects.

The results suggests that the 3PL should maintain a fixed fleet size of 129 vehicles in order to meet the following twelve months of anticipated customer service demand. This was calculated as the optimal fixed fleet size that will ensure their customer service level is not affected and lead to a potential saving of almost R 40 000. This analysis will enable the 3PL to make informed decisions regarding the available options they have to reduce their operating expenses.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND NOTATION

ABBREVIATIONS AND ACRONYMS

3PL	Third party logistics provider. The acronym is used to refer to the company under investigation for this project.
DC	Distribution centre
SLA	Service level agreement
RMSE	Root mean squared error
MAD	Mean absolute deviation
MAPE	Mean absolute percentage error
MPE	Mean percentage error
LBQ	Ljung-Box Q

TERMINOLOGY

Client	The term is used to refer to the clients that require transportation services from the 3PL. There can be distinguished between two main categories of clients based on the service they require: 1) Local and 2) Regional.
Consignee	A consignee refers to the entity who will take possession of the delivered items. This is usually the end user but can also be a business. They can also be described as the customers of the 3PL's clients.
Consignment	Consignment refers to the goods to be delivered to a consignee.
Suppliers	Suppliers refer to the external companies where additional vehicles are hired from.
Fixed fleet	Refers to the delivery vehicles owned and managed by the 3PL.

FORECASTING TRANSPORTATION SERVICE DEMAND FOR FLEET OPTIMIZATION: THE CASE OF A THIRD PARTY LOGISTICS PROVIDER

1. GENERAL INTRODUCTION

Today's age can be referred to as the era of the buyer. Consumers have access to an abundance of information and can make well-informed decisions. This leads to consumers having very high expectations from suppliers concerning quality, price and availability of products and services. Globalization also plays a significant role in the competitive market as it reduces a product's life cycle and presents complex transportation challenges. These, along with other factors, contribute to the immense pressure suppliers are under to optimize every aspect of their business in order to compete in the market. Many suppliers turn to outsourcing as a solution to reduce operating expenses and improve productivity.

A third party logistics provider (3PL) is a business that provides outsourcing services specifically aimed at logistics services. These services include the physical movement of goods (WebFinance Inc., 2017). 3PLs have the ability to reduce logistics cost because they are specialists in the field, have more experience and can perform at economies of scale by, for example, combining smaller deliveries from multiple suppliers into one delivery. There can be distinguished between six types of 3PLs based on the service they provide (COYLE, 2016). Figure 1 illustrates the different types of 3PLs.

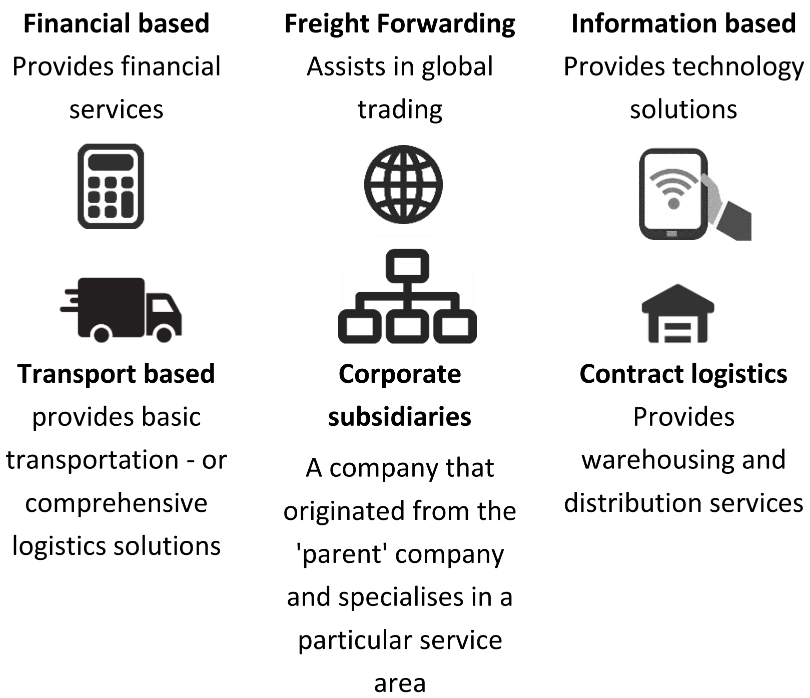


Figure 1: Types of 3PL providers

The 3PLs aim to provide flexible, agile, adaptable and timely delivery service. This introduces variability and uncertainty to the process that comes at a great expense due to the additional resources required to act as buffers.

2. COMPANY BACKGROUND

The company under investigation is a transportation based 3PL with hubs all over the country. The Gauteng based hub comprises of four main divisions, each with their own designated fleet. Each divisions services a range of customers with similar products to be transported. The services provided by the 3PL includes the collection, short-term storage and distribution of the consignments to the consignees. They are also responsible for reverse logistics i.e. when an end user returns the consignment to the supplier. Figure 2 below shows the size of the company by mentioning some key statistics.

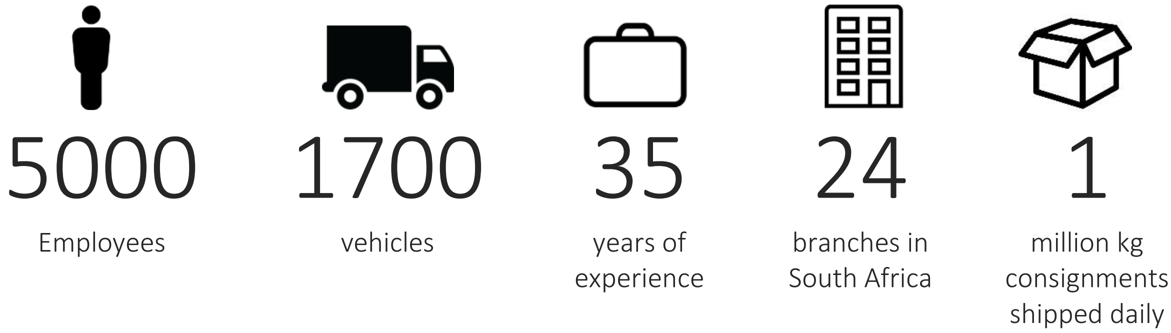


Figure 2: The company by numbers (CompanyX, 2017)

The 3PL's business model is set up with the focus on achieving excellent client satisfaction. They aim to remain flexible in the service they provide by having flexible cut off times for their clients to place orders. In practice, this also means that they are sometimes willing to operate at less-than-optimal vehicle capacity utilization in order to accommodate and retain a client.

One of the four divisions provides transportation services to clients with products that include consumer electronic devices, lifestyle and leisure related products. This division will be the focus of the project.

As mentioned earlier, the division has its own allocated fleet. This fleet consists of 122 vehicles. In addition to the allocated fleet, the division will hire supplemental vehicles from external suppliers when the allocated fleet's capacity is not sufficient to meet clients' demand for transportation services. These additional vehicles are hired primarily from one supplier, but other suppliers will be used if needed.

Division's operations

Figure 3 describes the typical procedure followed by the 3PL when a client requests service.

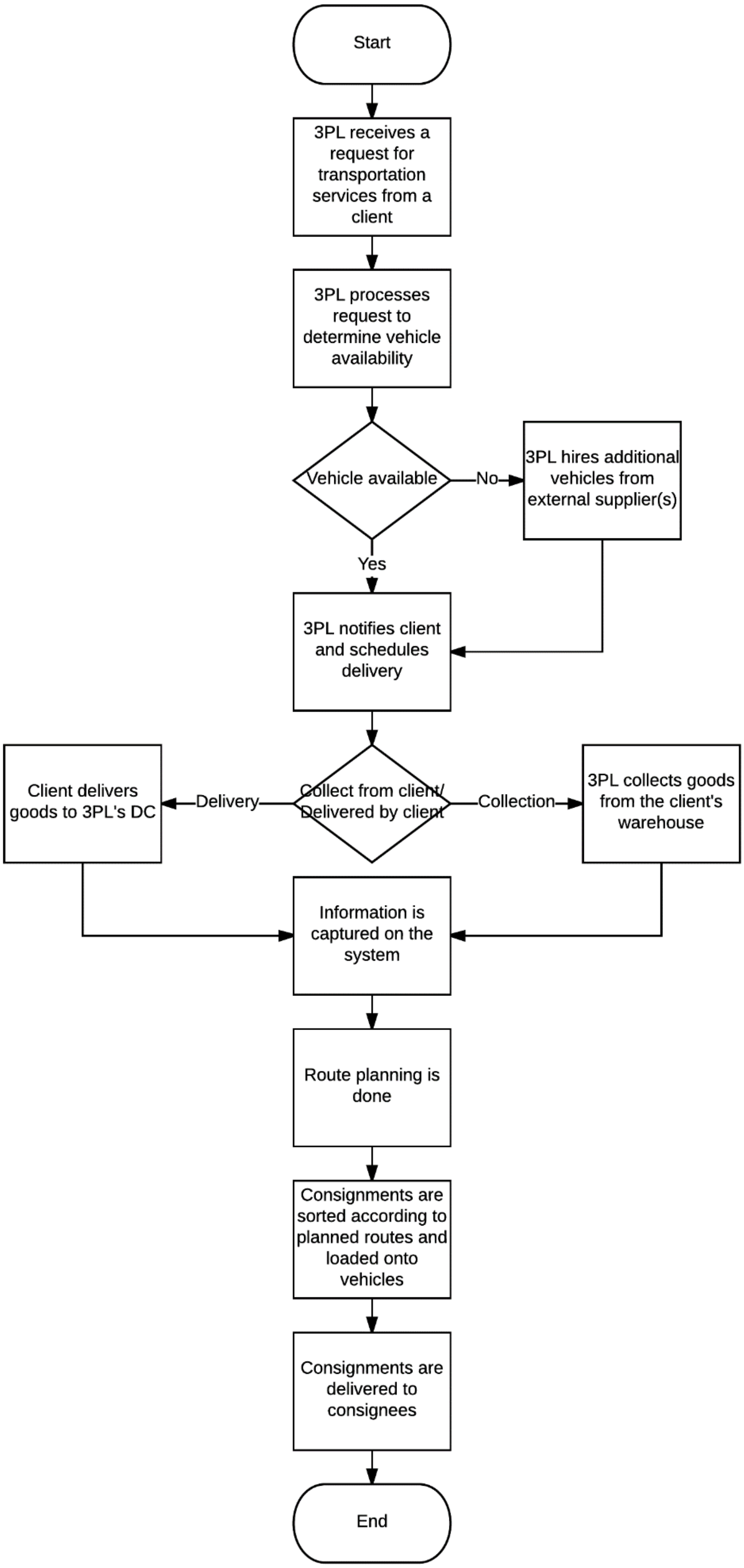


Figure 3: Standard operating procedures

Several stakeholders are involved in providing this service. What follows, is a holistic representation and discussion of the flow of operations and information amongst the stakeholders. The main stakeholders involved are the 3PL, clients of the 3PL, consignees and external vehicle suppliers.

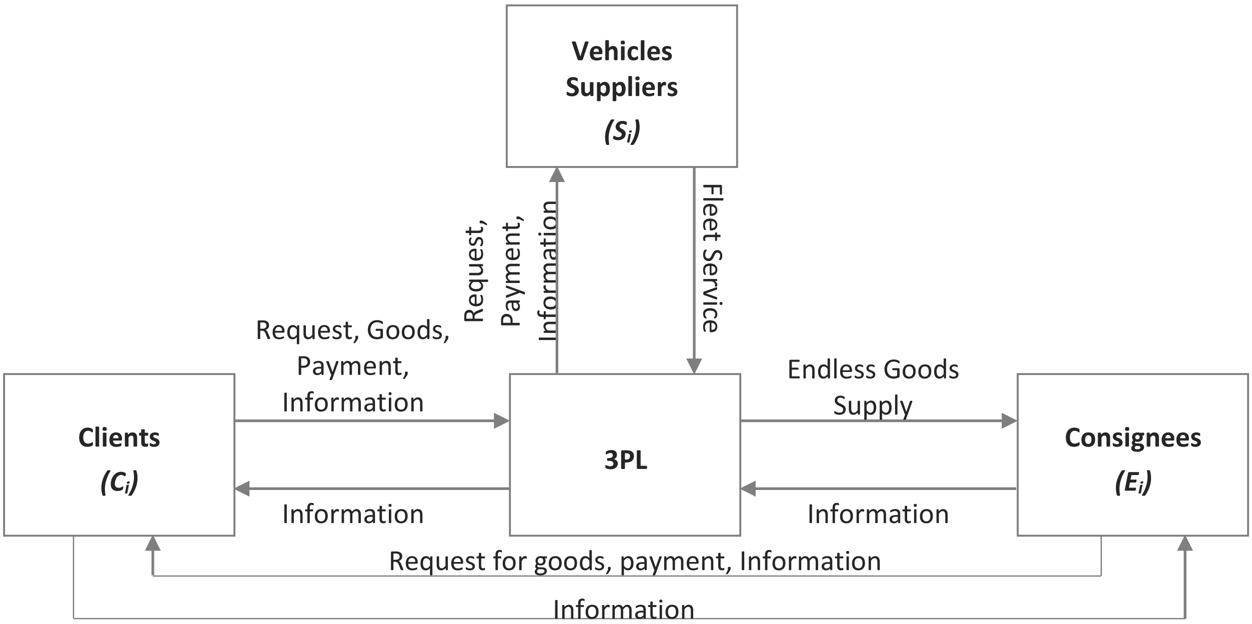


Figure 4: The flow of operations amongst the main stakeholders

Clients

Clients refer to the companies making use of the 3PL's transportation services. The first category of clients, also referred to as 'local clients', require transportation service within the Gauteng area. Within this category, there can further be distinguished between two types of clients namely 1) 'In house' clients and 2) 'Ad hoc' clients as illustrated in figure 5.

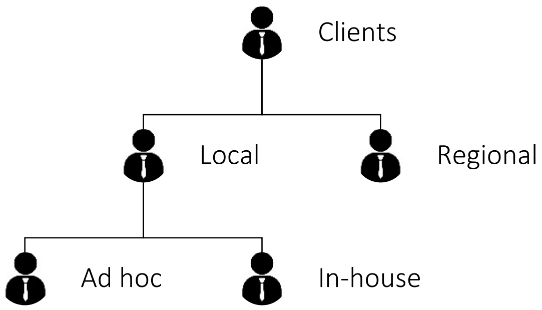


Figure 5 : Types of clients as distinguished by the division

The company's in house client base consists of approximately 250 large clients that require transportation services on a daily basis. These clients are referred to as 'in house' clients because of the level of integration between the 3PL and the clients. The 3PL will typically collect and deliver at least one load of consignments on a daily basis.

The second type of client is the ‘Ad hoc’ clients. These clients contribute significantly less to the annual deliveries because they do not require service on a daily basis. The clients will typically deliver their consignments to the distribution centre (DC) on a weekly or monthly basis where it is sorted according to routes and loaded onto delivery vehicles.

The second category of clients (called ‘regional’ clients) require transportation service on a national scale. This includes deliveries to other provinces such as KwaZulu-Natal, Mpumalanga, and North West. The 3PL has different service level agreements (SLAs) with each client, but the conventional delivery period is 48h. A separate fleet is used to serve regional clients and thus will not be considered for this project. This particular fleet also does inter branch transfers where goods are transferred from one branch to another before being delivered to the end user. The client base is relatively dynamic but can be controlled by the 3PL. The current trend is that the client base is expanding.

Consignees

Consignees are the end users of the delivered consignments. There are typically two types of consignees: 1) businesses and 2) individual customers. The number of consignees is dynamic and cannot be controlled by the 3PL.

Suppliers

The 3PL currently hires additional vehicles from one main supplier. However, additional suppliers may be used if the supplier cannot fulfil the request for additional vehicles. The supplier base is relatively fixed and can be controlled by the 3PL.

3. PROBLEM STATEMENT

The ultimate problem the division is experiencing is a high cost to serve local clients. This includes deliveries to in-house and ad hoc clients. These clients make up for the largest part of service provided by the division. The overall cost to provide transportation service is especially high during peak periods when their current fleet capacity is not sufficient to match clients’ transportation demand. In these months, additional vehicles are required to meet the demand for transportation. These vehicles are hired from external suppliers to complement the existing fleet.

Based on the volatile nature of the consignees’ demand the 3PL has to request vehicles at extremely short notice. The current operational agreement with suppliers allows them to request vehicles at short notice. However, this vehicle request service comes at a premium price, which is at a great disadvantage of the company. It is estimated that the cost of hiring additional vehicles is 30% higher than using the 3PL’s fixed fleet. During non-peak periods however, fleet utilization is much lower which also results in a higher cost to serve clients. The company is seeking a solution to reduce the cost to serve clients by operating with the optimal fleet size and reducing the cost to hire additional vehicles by being able to give relative long notice periods to external vehicle suppliers.

4. PROJECT AIM, OBJECTIVES AND RATIONALE

4.1 AIM

The aim of the project is to find the optimal fixed fleet size of the company with regards to the total operating cost by considering the future demand for transportation services and hiring rates of vehicles from external vehicle suppliers.

4.2 PROJECT OBJECTIVES

The execution of the project can be categorised into six main objectives. These objectives are listed in figure 6 below.

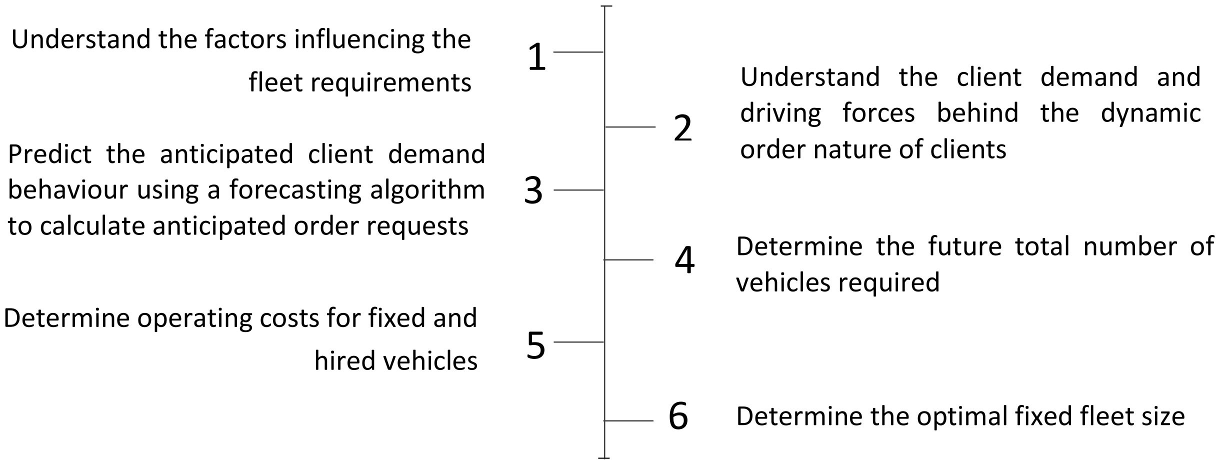


Figure 6: Objectives of the project

4.3 RATIONALE

The company is currently in the process of implementing dynamic routing by using an optimization tool called PLATO. The company is considering adjusting their fixed fleet size based on the model outputs but has to consider future demand trends and the hiring rates for additional vehicles. This project will aid the company in making an informed decision on adjusting their fleet size by calculating the anticipated demand and suggesting the optimal fixed fleet size the company should maintain.

5. PROJECT PLAN, SCOPE AND DELIVERABLES

5.1 PROJECT PLAN

The DMAIC principle (Define, Measure, Analyze, Improve, Control (DMAIC Approach) | ASQ, 2017) will be used as an approach to solve the problem the 3PL is facing. Tasks to be performed during the execution of the project is divided into the main phases of the problem solving technique.

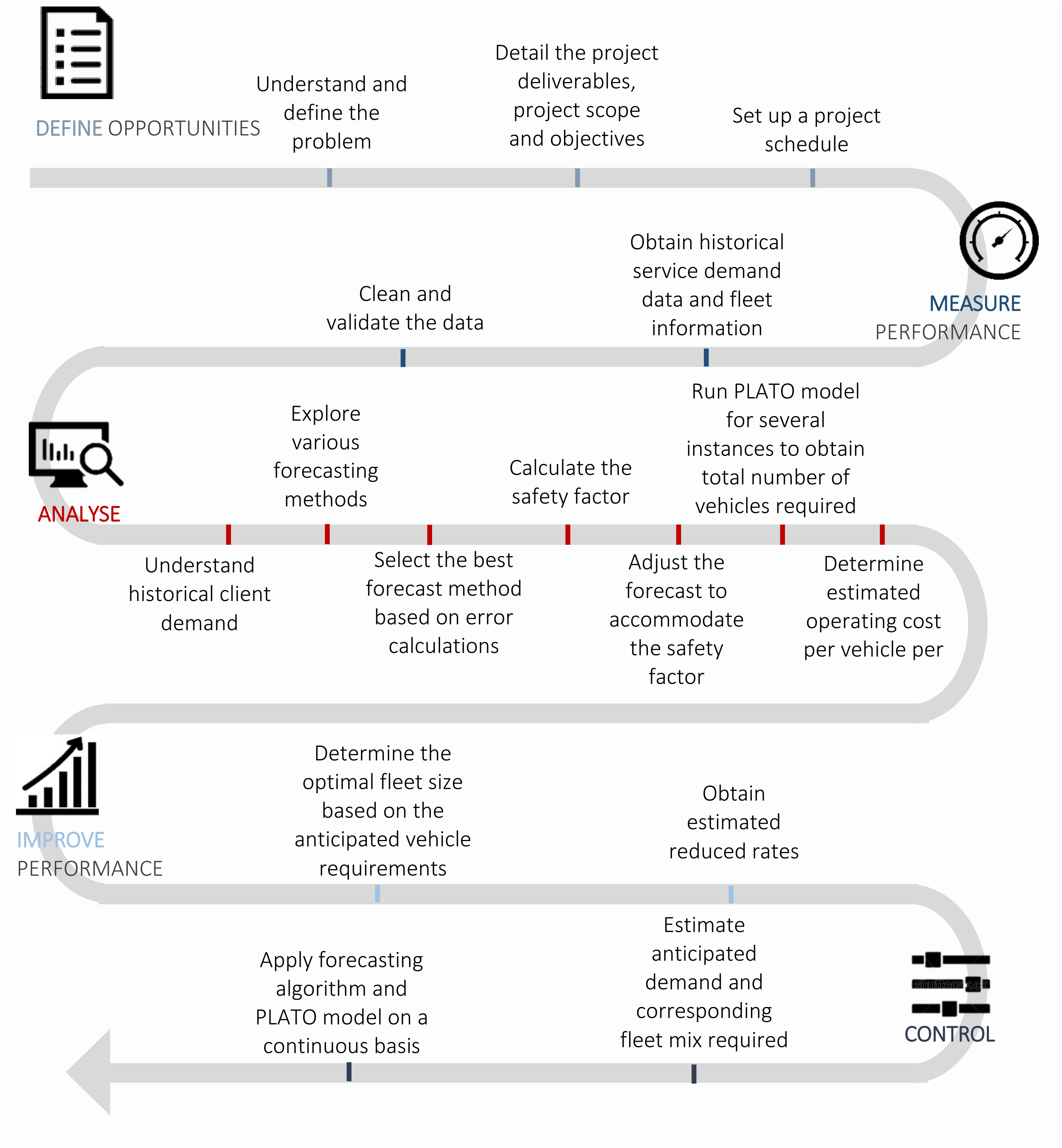


Figure 7: Project approach using the DMAIC principle

The safety factor referred to in the info graphic is used to compensate for the percentage error in the forecasted demand. It is expressed in terms of percentage additional consignments.

Several industrial engineering techniques will be applied throughout the project in order to address the problem the 3PL is experiencing. These techniques are listed in table 1 below. The table shows where these techniques will be applied and what the expected value of applying the techniques will be.

Table 1: Techniques and principles to be applied in the execution of the project

Objective	Technique / Principle	Reason for application
2	Forecasting	To enable the estimation of future anticipated demand for transportation services and a calculated safety factor
7	Optimization modelling principles	To apply an optimization model that will determine the optimal fixed fleet size based on several inputs

5.2 SCOPE

The scope of the project includes an investigation into the demand patterns for transportation services provided by the 3PL to local clients that include 'in house' clients as well as 'ad hoc' clients. Only demand data of customers who are served using the division's fixed fleet was considered. Any transportation service provided to regional clients was excluded from the scope as these clients are served with a separate allocated fleet of vehicles. The demand patterns was studied using two years' historical data to identify trends and seasonality to understand customer demand. Geographical areas such as Durban, Cape Town, and Port Elizabeth was excluded from the analysis.

Research was done on the different forecasting methods and software packages available in order to select the most appropriate forecasting instrument. The model was tested and the results were validated. Once an accurate forecast was obtained, the data was applied in a dynamic routing optimization model. This information was used to ultimately determine the expected total number of vehicles required to meet the forecasted demand. Lastly, the optimal fleet size required to meet the customer demand was determined by considering the obtained reduced vehicle hiring rates and the anticipated demand.

The scope of the project is limited to analysis and investigation phase and does not include the implementation and support phase.

5.3 DELIVERABLES

3.3.1 Company Expectations

The main deliverable of the project is a report containing the results of an investigation into finding the optimal fixed fleet size. This will aid the 3PL in making an informed decision on their plan forward to adjust the fleet size while also maintaining customer satisfaction.

3.3.2 Departmental Time-line

An overview of departmental related submission dates.

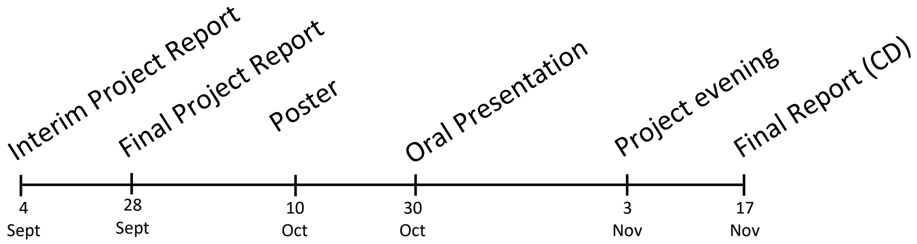


Figure 8: Departmental timeline of important submission dates

The main deliverable of the project, with regards to the department, is a comprehensive report discussing how industrial engineering techniques were applied to solve a complex problem.

6. LITERATURE REVIEW

The research required for this report covers an extensive scope, as there are two focus areas to be addressed. The first focus area is forecasting. This section discusses the methods, their applications and limitations available for making an accurate forecast. This section also includes research done on principles for selecting the best forecasting method for the application.

Because the future requirements for delivery vehicles is a function of the anticipated service demand, research was done on estimating the required fleet size and mix to determine the number of vehicles to meet the demand. However, because the 3PL is in the process of implementing a dynamic routing tool, the tool was also considered and selected as the best way to determine the required fleet size and mix to ultimately determine the future demand for delivery vehicles.

The second focus area is on optimization models. Under this section, the available resources for developing an optimization model was researched as well as considerations for hire or buy decisions.

Furthermore, optimization models were researched to gain an understanding of the factors that need to be considered to calculate the optimal fleet size.

SECTION 1: FORECASTING

Applications of different forecasting methods

Authors John C. Chambers, Satinder K. Mullick, Donald D. Smith published an extensive document in 2017 discussing the different forecasting methods and guidelines for selecting the right forecasting technique. The authors distinguished between three types of forecasting methods and discussed the application and limitations of each. (John C. Chambers, 2017)

The first forecasting method relates to qualitative techniques. This means that forecasts are based on current events (such as expert opinion) rather than historical events. Applicable techniques include a visionary forecast market research, panel consensus and the Delphi method. These techniques are especially useful when historical data is scarce or unavailable.

The second method discussed is casual models. Casual models are used when a system and the relationships of components within a system is studied. The application of this method is limited due to the extensive information needed to fully understand how components in a system interact. Forecasting methods that can be used include a regression model, input-output model, anticipation surveys and econometric models.

The third type of forecasting method recognised by the authors is time series projection. For this method, historical data is studied to identify patterns and trends. These techniques are ideal for cases where relatively long periods of historical data is available and cyclical trends can be identified fairly easily. These techniques are only valid under the assumption that current cycles and trends will continue in the future unless an external factor influences it.

Given the application of this type of method, it is the most applicable method to model and forecast the 3PL's service demand as sufficient historical data is available and a clear pattern was recognised.

The authors suggest five main techniques that can be applied:

1) Moving average

For this technique, the authors suggest a minimum of two years data is studied to identify the trends accurately. However, less data may be used if data is unavailable.

2) Exponential smoothing

The suggested minimum period of data required if trends are present is two years.

3) Box-Jenkins

According to the authors, this is the most time consuming and most accurate model to apply from a statistical point of view as it fits a mathematical model to a time series model. In doing such, a smaller error is assigned to history.

4) X-11

This technique identifies seasons, cycles and trends in time series data. The authors state that this technique is the best option when doing medium range forecasting. Medium range forecast is a forecast made over a three month to one-year forecasting horizon.

5) Trend projections

This technique focuses on identifying and projecting trends in data.

Forecasting techniques

Likewise, the authors of Supply Chain Management: A Logistics Perspective (COYLE, 2016) discuss four forecasting techniques that can be applied in a time series environment, each of which were further investigated.

1. Simple moving average

According to the authors, this is the simplest technique to apply. The forecast is calculated based on an average value of all the prior data (or the number of observations as specified). Therefore, this technique cannot track seasonality or trends and can only be applied when data is more or less constant.

$$A_t = \frac{D_t + D_{t-1} + \cdots + D_{t-n+1}}{n}$$

$D_t = Actual\ demand\ in\ period\ t$
$n = Total\ number\ of\ periods\ in\ the\ average$
$A_t = Average\ for\ period\ t$

2) Weighted average.

This technique is an improvement on the abovementioned technique as it assigns different weighting factors to different observations. The weighting factors are selected by the user.

$$A_t = w_t D_t + w_{t-1} D_{t-1} + \cdots + w_{t-n+1} D_{t-n+1}$$

$D_t = Actual\ demand\ in\ period\ t$
$n = Total\ number\ of\ periods\ in\ the\ average$
$A_t = Average\ for\ period\ t$

3) Exponential smoothing

This technique is similar to the weighted average method as different weights are also allocated to different observations. However, weighting factors are allocated according to the exponential function with the most recent observations carrying the most weight.

$$A_t = \propto D_t + (1-\propto) A_{t-1}$$

$D_t = Actual\ demand\ in\ period\ t$
$\propto = Smoothing\ constant, 0 \leq \propto \leq 1$
$A_t = Average\ for\ period\ t$

4) Exponential smoothing with a trend

This technique is suitable for applications where a trend is present in the data. The forecasted value is a combination of an overall smoothing factor and a trend-smoothing factor.

$$A_t = \propto D_t + (1-\propto)(A_{t-1} + T_{t-1})$$
$$T_t = \beta(A_t - A_{t-1}) + (1-\beta) T_{t-1}$$

$T_t = Trend\ estimate\ for\ period\ t$
$\beta = Smoothing\ constant\ for\ trend$
$\propto = Smoothing\ constant, 0 \leq \propto \leq 1$
$A_t = Average\ for\ period\ t$

Forecasting errors

Forecasting is often referred to as a combination of art and exact science. This may be due to the fact that there will always be a degree of uncertainty regarding a prediction. In the case of demand forecasting, multiple factors play a role. Factors such as such as the time of the year, the economic state of the country, advertisements, promotions etc. all play a role in the outcome and all contribute to the uncertainty of the forecast. This idea is perfectly summarized by the words of George E. P. Box: “All models are wrong; some models are useful”.

This begs the question: How does one compare forecasts if all forecasts are essentially wrong?

Over the time, experts in the field have developed multiple methods. Several of these are discussed in the journal by Strasheim (Strasheim, 1992). One of the most popular methods is to calculate the error value of a forecast. Several different calculations for the error value exists, each with their own strengths and limitations. The authors of Supply Chain Management: A Logistics Perspective (COYLE, 2016) discuss the following error calculations.

1) Cumulative Sum of Forecast Errors (CFE)

This is the simplest method to calculate the total forecast error because it is simply a sum of all the individual forecast errors. This calculation may not give a good indication of accuracy level as positive and negative values can balance out resulting in a low total error.

$$CFE = \sum_{t-1}^{n} E_t$$
$$E_t = Error\ for\ period\ t$$

2) Mean Squared Error (MSE)

This method for calculating the overall error is an improvement on the previous as it takes the square root of all the values before summing them. Therefore, positive and negative values do not cancel each other out. This method is however very sensitive to the sample size. Therefore, it is not a good measure to use when comparing data sets of different sizes.

$$MSE = \frac{\sum E_t^2}{n}, \sigma = \sqrt{MSE}$$
$$E_t = Error\ for\ period\ t$$
$$n = Number\ of\ periods$$

3) Mean Absolute Deviation (MAD)

This is a very popular measure as it is not affected by the positivity or negativity of values and the error is expressed as a proportion of the number of samples, which makes it possible to consider samples of different sizes.

$$MAD = \frac{\sum |E_t|}{n}$$
$$E_t = Error\ for\ period\ t$$

$$n = Number\ of\ periods$$

4) Mean Absolute Percent Error (MAPE)

This technique is similar to the MAD measure but expresses the error in terms of percentages.

$$MAPE = \frac{100 \sum \frac{|E_t|}{D_t}}{n}$$
$$E_t = Error\ for\ period\ t$$
$$n = Number\ of\ periods$$
$$D_t = Actual\ demand\ in\ period\ t$$

5) Tracking signal

The tracking signal is used to determine whether a forecast is bias. The larger the value, the more likely the forecast is to be bias.

$$Tracking\ Signal = \frac{CFE}{MAD}$$

Forecasting resources

ProForecaster comes as a free add-in for Microsoft Excel (ProBS, 2017) which allows the user to work on the same worksheet without having to export data to another system. The free version includes eight time series forecasting methods and four seasonal models to choose from and makes a recommendation based on the root mean square error (RMSE) amongst other metrics.

ProForecaster uses historical patterns and projects them into the future by using statistical forecasting and neural network technologies. The forecaster can perform most of the predictions automatically by determining the best-suited methods and neural networking architecture needed. The results are summarized for the user and certain parameters can be manually adjusted to obtain optimum results. The user can also easily compare the different methods and choose the most suited if the recommended is not the desired method.

This tool was applied by a company called Enesco Limited in 2013 to forecast demand in order to improve their production planning (Timberlake Consultants, 2017).

Identifying trends and cycles through data visualization

Data visualisation is a useful technique that is becoming increasingly popular as the amount of data that is available to be analysed becomes more. According to a statistical analysis company (SAS, 2017) it enables the user to represent large amounts of data in a manner that is not overwhelming by collapsing, grouping and condensing data to present information in the form of charts and graphs that can be used and easily understood by decision makers.

In a document with a similar topic, the authors also provide the following guidelines for when attempting to analyse data using visual techniques:

1) Understand the source of the data

This means that it is important to understand where the data comes from in order to know how reliable it is, how data should and can be cleaned and which filters to apply in order to extract useful information from the data without altering the results.

2) Determine what the goal of analysing the data is

In order to extract useful information from big data sets, it is important to know what information needs to be obtained from the data.

3) Select visuals that highlights the correct factors

It is crucial to use simple, yet useful visuals that are easy to understand and clearly conveys the important information that it was intended for.

Some of the basic visuals the authors suggested are:

- line charts: to show trends or relationships between variables
- bar charts: to compare the quantities in various groups
- scatterplots
- pie charts: the authors warn against this visual because it is not easy for the human eye to measure and quantify data represented in this manner. The donut-chart is an improvement on this visual.
- correlation matrixes
- network diagrams (Statistical Analysis Systems, 2017)

Data visualization resources

Capterra is an online resource that assists users in identifying the best Business Intelligence software. The table below is an extraction from this website (Capterra, 2017) that shows the top three software available based on the market score.

Software	Customers	Users	Total social score	Market Score*
Tableau	50000	6700000	146915 + 182371	95
Sap	34000	4556000	755618 + 909236	86
Qlik	40000	5360000	33392 + 74328	86

* The market score is calculated based on three factors each with a different weighting:

1) The number of customers (40%)
2) The number of users (40%)
3) Social score (20%)

This gives a good indication of what other users are using to analyse their business performance.

Tableau is a software solution that has many applications. Fraser applied it as a business intelligent solution after substantial research and comparison was done to compare similar resources. (Fraser, 2015)One of the areas the resources scored exceptionally well in was data visualization. According to Tableau's website (Tableau, 2017), Tableau enables the user to visually represent data and simplify complex ideas by enabling the user to create multi-faced views that highlight trends.

SECTION 2: OPTIMIZATION MODELS

Types of optimization models

The authors of the book Multi-Level Decision Making (Zhang, 2015) identify and discuss several types of optimization models. Some of which include the linear programming, non-linear programming, goal programming, multi-objective programming, , Stackelberg game theory and particle swarm theory.

The authors also suggest other methods to assist with decision making such as the Analytical Hierarchy process, Grid analysis and Decision tree. However, optimization models is a far more developed approach and is the most suitable when working with quantifiable data.

Optimization modelling usually uses mathematical programming to systematically select the best values for variables based on the specified objective function.

A linear programming problem is a model where the constraint and objective function is linear. A typical linear programming optimization model can be divided into four parts i.e. parameters, variables, objective function and constraints.

Parameters are used to represent the elements that cannot be controlled. The value of a parameter does not change during the solving process. A variable however takes on different values in order to find the optimal solution. A multi objective programming problem is a model where two colliding objectives need to be optimized simultaneously.

Lingo is a popular and relatively powerful optimization software that is often used to solve linear programming problems. (Lindo Systems Inc., 2017). Lingo can also be used to solve non-linear, quadratic, Second order, Quadratically constrained, and Stochastic models. A trial version is freely available online which makes it an easily accessible resource.

MS Excel also has an optimization add-in called Solver. The solver takes three user inputs into consideration when calculating the optimal solution: 1) the target which presents the objective, 2) changing cells (variables) and 3) the constraints.

Both these resources will be tested during the relevant phase of the project.

Optimization modelling

Rothlauf, 2011 highlights six steps that can be followed in finding a multi-step solution i.e. 1) Identify the problem, 2) Define the problem, 3) Construct the model, 4) Solve the model, 5) Evaluate the solution and 6) Implement the solution.

For the formulation of a model, the author suggests using the following notation to simplify modelling. Different alternative decisions can be represented by a combination of various decision variable e.g. {X1, X2, X3, …, Xn}.

Constraints can be used to define limitations for the decision variables and the objective function represents the goal or aim of the problem.

One problem can have multiple combinations of decision variables which is called a solution.

It is important to note that many assumptions have to be made when setting up a model. There is a trade-off between tractability (the ability to solve the optimization model) and validity (the resemblance between the model and reality).

In order to evaluate the balance between this trade off, the authors suggests using a sensitivity analysis to evaluate the optimal solution by considering the effect different factors have on the solution. The aim is to ensure that small changes in the input to the model do not result in excessive changes to the suggested solution.

Another method suggested by the author is the use of retrospective testing which is the comparison of historical data and the model output with the aim of determining whether the model output was realistic for that period. (Rothlauf, 2011)

7. SIMULATION DATA INPUT

Historical Service Demand Data

In the historical data obtained from the 3PL the service demand is represented by two different metrics i.e. the number of consignments to be delivered and the kilograms of each consignment. For the purpose of this project, a consignment is defined as a single delivery to a customer. Since the service demand is primarily driven by the number of consignments, it was decided to base the forecast on this metric.

The number of consignments delivered by the 3PL was plotted over 24 periods to gain a better understanding of the nature and cycles of customers' demand for transportation services. Data was obtained for a two-year period starting in July 2015 and ending in June 2017.

First, an average number of consignments per day was calculated for each month using the formula below.

$$Average\ number\ of\ daily\ consignments = \frac{C_t}{W_t}$$

$C_t = Total\ consignments\ to\ be\ delivered\ in\ the\ period\ t, t\ \in \{1,2,3,\dots,24\}$
$W_t = number\ of\ working\ days\ in\ the\ period\ t, t\ \in \{1,2,3,\dots,24\}$

The first graph in figure 9 shows the total number of consignments for each month. The second graph in figure 9 takes the number of working days into consideration and displays the average consignments to be delivered per day. Figure 9 clearly show a seasonal pattern that is repeated every 12 months. There are two peak periods in a year i.e. the primary peak period during September to November and the secondary peak period during April.

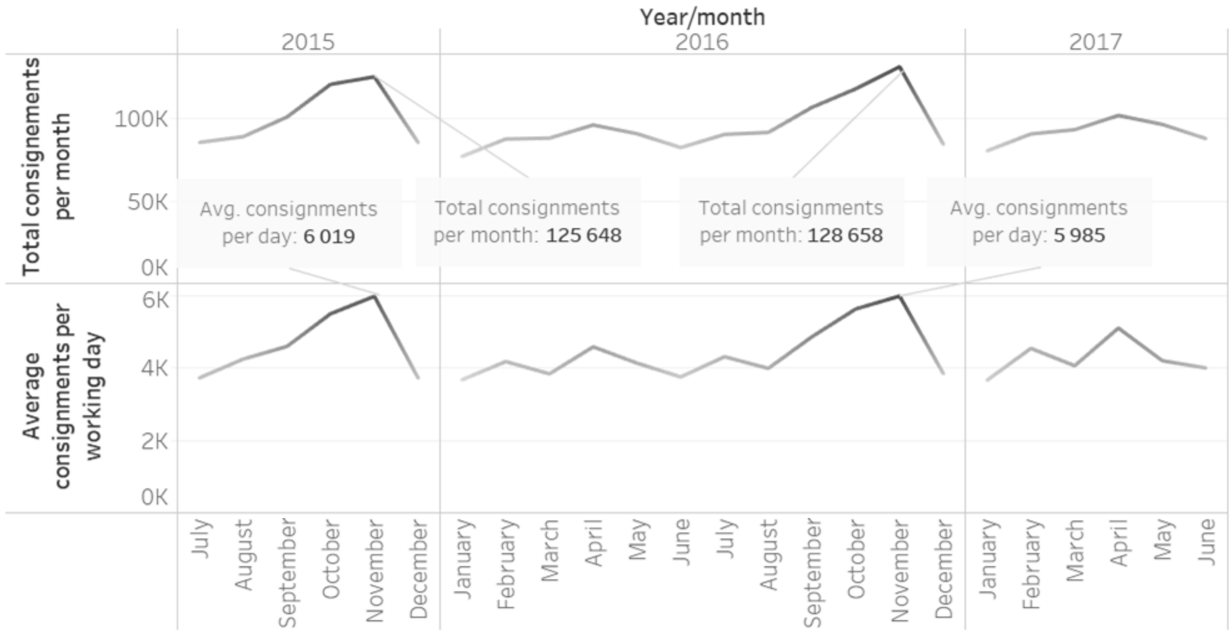


Figure 9: Historical service demand data

Current Fixed Fleet Information

Table 2 shows a summary of the critical fleet information that was needed for this project. This information was obtained from observations and discussions with managers at the 3PL.

Table 2: Fixed Fleet Information

Total fixed fleet size	122 vehicles
Total fleet capacity	504 300 kg
Fixed cost component per vehicle	R1011.00/day
Variable cost component per vehicle	R11.00/km

8. PROJECT APPROACH

8.1 CONCEPTUAL DESIGN

The block diagram in figure 10 describes the execution of the project by distinguishing between five main phases and highlighting the different tools used in the phases of the project.

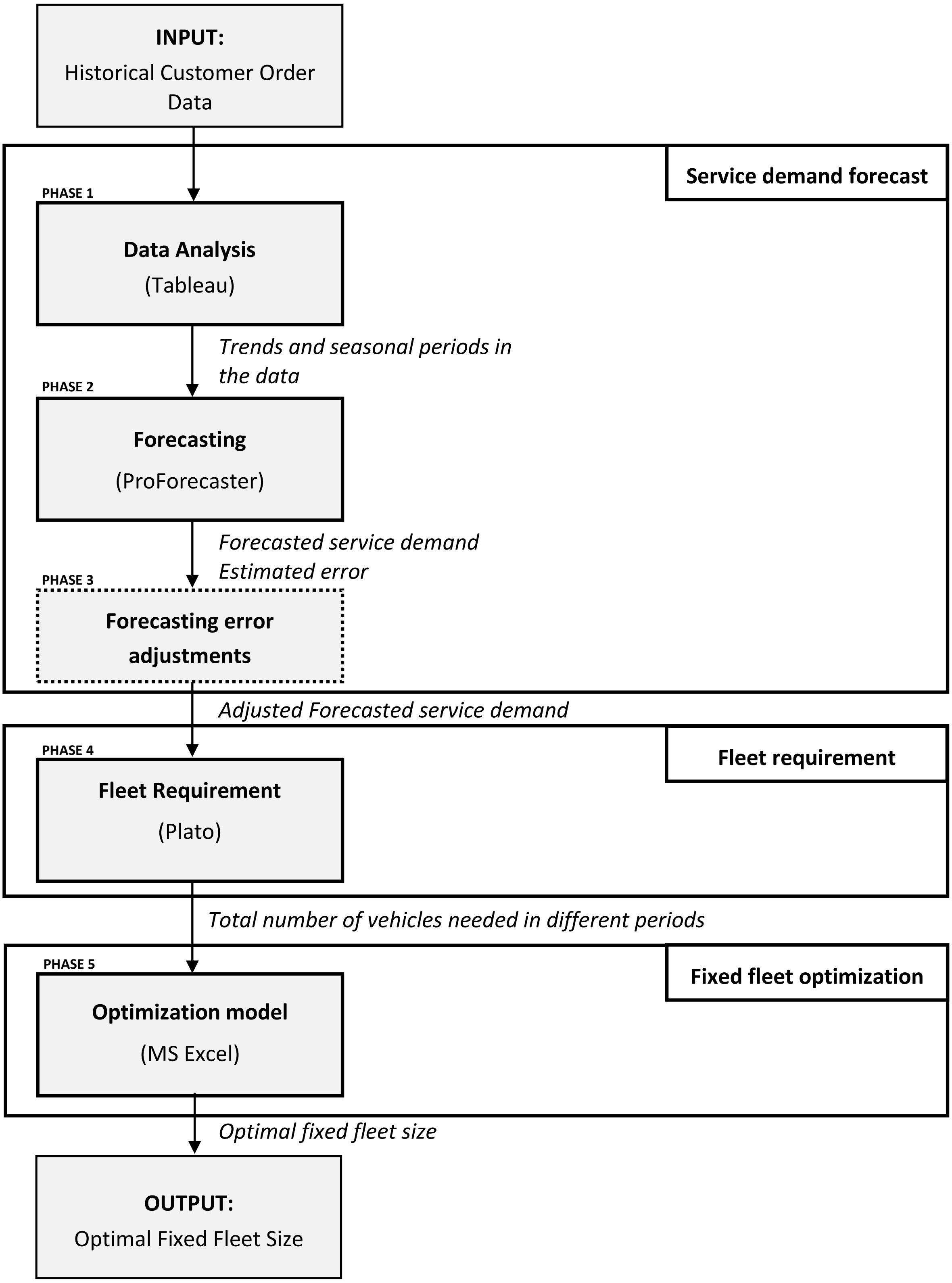


Figure 10: Conceptual design

Phase 1

A software called Tableau was used to visually represent the historical customer order demand data for the 24-month period in order to understand the trends and seasonality in customers' order nature.

Output: *Identified trends and seasonality in the data.*

Phase 2

ProForecaster was used to determine the most accurate forecasting technique as well as the percentage error associated with the forecasting technique. Finally, the most accurate forecast was obtained for the following 12 months using the prior 24 months' customer order demand data.

Outputs:

- *Accurate 12 month forecast*
- *Expected percentage error in the forecast*

Phase 3

The results obtained in phase two was adjusted to compensate for the expected error in the forecasted quantities due to the nature of the data and the fact that it represents the estimated customer demand. The 3PL has to plan for the maximum expected demand because they cannot afford to have too few delivery vehicles available especially with their business plan's main focus being on customer satisfaction.

Output: Adjusted 12 month forecast of the transportation service demand

Phase 4

Several Plato models was run to determine the number of vehicles required to meet the anticipated customer demand throughout the 12 month period.

Output: Expected total number of vehicles needed to meet the forecasted customer demand for transportation services over the 12 month period

Phase 5

The optimization model required the vehicle hiring rates from external vehicle suppliers (Total cost/vehicle) as well as the fixed and variable cost component of the fixed fleet in order to find the optimal number of vehicles to have in the 3PL's fixed fleet.

Output: Optimal fixed fleet size

8.2 ALTERNATIVE SOLUTION METHODS

Alternative approaches to forecasting

Several approaches were considered for making the forecast for the anticipated demand levels. One approach that was considered was to develop a forecasting model using a programming language such as Python. Python has several libraries that could aid the user in building a forecasting model such as SciPy, NumPy, Matplotlib, Pandas, scikit-learn and statsmodels (Brownlee, 2017).

A python based forecasting model will require a complex and multi-step algorithm to obtain accurate forecasting results. The model should be capable of calculating a forecast using multiple forecasting techniques, each of which has to be programmed and validated individually. The program will also have to make several error calculations and select the most appropriate forecast based on the outcomes. While it is possible to develop this program, it would require a great deal of effort and time while giving limited results.

Another approach was to make use of an already developed forecasting software such as GMDH Shell or ProForecaster. Both these softwares were briefly tested. ProForecaster was easy to install and had a user friendly interface whereas GMDH Shell required more time and effort to master.

Further investigation into ProForecaster

Proforecaster is used for time series forecasting. In short, the software operates by applying different models to find the model that best fits the data patterns such as trends and seasonality. The software applies both statistical models and neutral networks. Statistical models are suited best for linear data patterns while neutral network models perform best on non-linear patterns.

The software calculates hundreds of combinations for parameters in each model. The models are then ranked in order of forecasting accuracy. This ranking is done based on several statistical properties that measures the model's performance.

The software gives the user the choice between a manual mode and an automatic mode. If the manual mode is selected, the user can specify the models and ranking methods that should be applied. The software then distinguishes between data with and without trends as well as data that show damped trends. A further differentiation is made between data with no seasonal effect, data with additive seasonal effect and data with a multiplicative seasonal effect as illustrated in the image below (figure 11). This image is a screenshot of the ProForecaster Professional Edition Software and shows some of the forecasting methods that can be selected by the user.

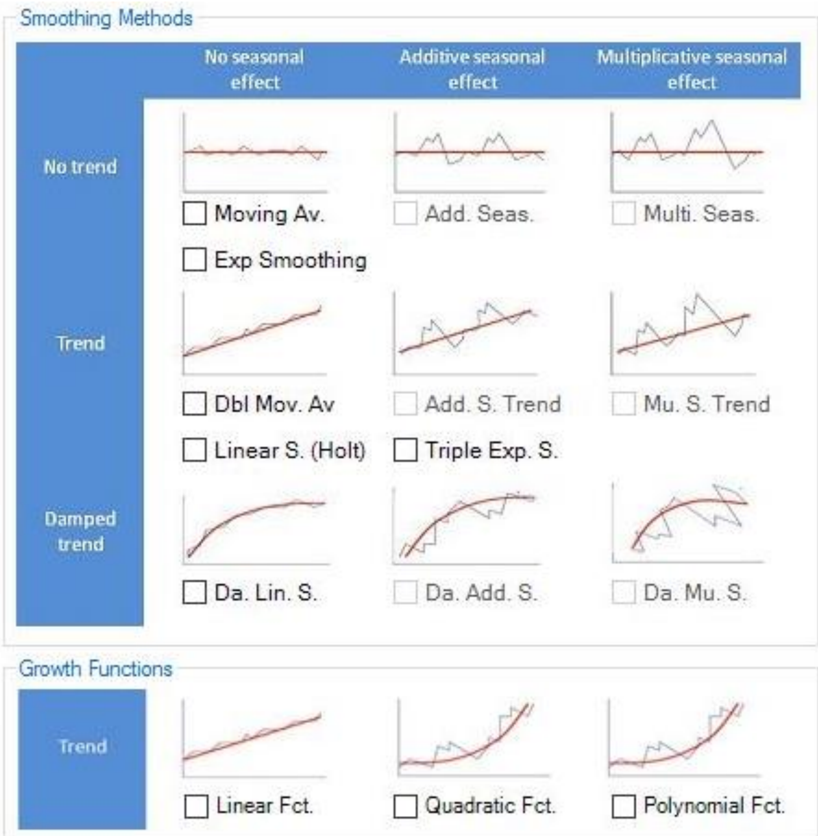


Figure 11: ProForecaster smoothing methods

In order to make an accurate forecast it is important for the user to understand the data and the factors driving the trend and seasonality. For example, data can either have additive or a multiplicative seasonality. Additive seasonality is observed in cases where the seasonality factor is determined by the absolute difference between consecutive readings. In this case the amplitude remains relatively constant. However, when the seasonality factor is determined by the proportion difference between consecutive readings, it is called multiplicative seasonality (Kourentzes, 2014).

The main difference in calculation is that with the additive seasonality technique, the seasonality is added to the forecast whereas with the multiplicative technique the seasonality factor is multiplied.

The equations below illustrate the difference between the calculations using the holt-winter's model (Rob J Hyndman, 2017).

Additive seasonality:

$$L_t = \alpha(y_t - S_{t-s}) + (1-\alpha)(L_{t-1} + b_{t-1})$$
$$b_t = \beta(L_t - L_{t-1}) + (1-\beta)(b_{t-1})$$
$$S_t = \gamma(y_t - L_t) + (1+\gamma)S_{t-s}$$
$$F_{t+k} = L_t + kb_t + S_{t+k-s}$$

Multiplicative seasonality:

$$L_t = \alpha\left(\frac{y_t}{S_{t-s}}\right) + (1-\alpha)(L_{t-1} + b_{t-1})$$
$$b_t = \beta(L_t - L_{t-1}) + (1-\beta)(b_{t-1})$$
$$S_t = \gamma\frac{y_t}{L_t} + (1-\gamma)(S_{t-s})$$
$$F_{t+k} = (L_t + kb_t)\,S_{t+k-s}$$

However, if the automatic mode is selected, the software runs through all the model combinations to find the optimal solution. The software considers a total of seventeen different forecasting techniques that can be seen in figure 12. This image is a screenshot taken while using the ProForecaster Professional Edition Software.

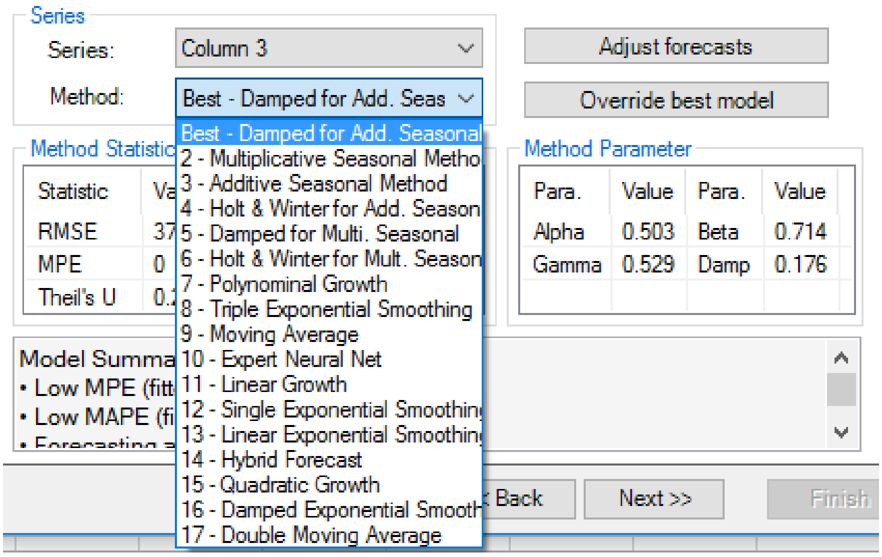


Figure 12: Seventeen different forecasting techniques considered

The software determines the most accurate forecasting method based on a ranking method that can be specified by the user. Options include:

1) Expert rank – check for goodness of fit on validation data
2) RMSE – Root mean squared error
3) MAD – Mean absolute deviation
4) MAPE – Mean absolute percent error

Theil's U is a comparison of the actual forecasted values and values forecasted with minimal historical data. This metric serves as a measure of forecasting uncertainty. A Theil's U value of less than one indicates an accurate forecast (EPM Information Development Team, 2013).

ProForecaster was selected as the best alternative software to be used as it provides a well-rounded and thorough comparison, takes multiple forecasting techniques into consideration and can be downloaded for free.

Approach to calculating fleet requirements

The division is currently in the process of implementing dynamic routing. The software they are using is called Plato. Plato is a dynamic routing tool that is unique in the sense that it aims to minimise the total operating expenses (Opsisystems, 2017) unlike other similar tools such as Road Show that aims to minimize the total kilometres travelled (Descartes, 2017). Some of the factors taken into account are listed in table 3 below.

Table 3: PLATO inputs and outputs

INPUTS	**OUTPUTS**
Fleet information	Route plan
· Available number of vehicles · Vehicle capacity (kg, m^3) · Fixed cost (R) · Running cost (R/km) · Average travel speed during normal traffic hours (km/h) · Average travel speed during peak traffic hours (km/h)	· Number of vehicles required per day · Optimal route and drop sequence · Estimated delivery timeline
Other costs	KPIs
· Labour rate (R/hr) · Overtime rate (R/hr) · Sleep out costs (R/day)	· Total operating costs · Fleet utilization
Order Data	
· Consignments to be delivered (number of parcels, kg, volume) · Collection and delivery addresses	

Client information

- Nominated days (and times) of delivery
- Expected turnaround times (min/kg)
- Expected wait time
- Service level agreement

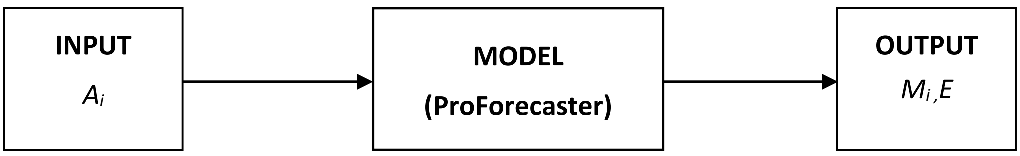
The output is a prescriptive model that suggests a route plan. This plan includes detail regarding the best routes the various vehicles should take, what consignments should be delivered by which vehicles and what drop sequence should be followed on a daily basis. This tool gives a very realistic output due to the number of input factors considered in the model. Considering that this tool is what will be used by the 3PL to plan future deliveries, it was selected as the resource to be used to determine the fleet requirements for this project.

8.3 MODEL DEVELOPMENT

ProForecaster

Step I: Determine the most accurate forecasting technique and calculate the expected error

An initial forecast was for each period using the data for the first twelve months. The forecasted service demand level for the next twelve months was then be compared to the actual service demand level during that same period. This was done so the percentage error could be calculated over the different periods. This type of model validation is sometimes referred to as retrospective testing.



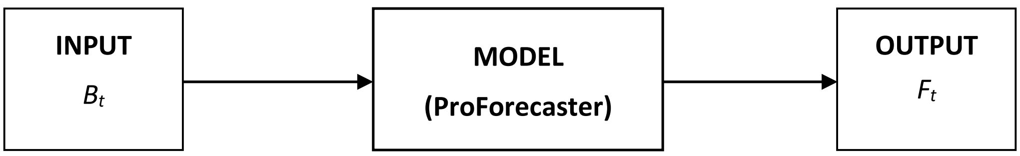
A_i : Historical transportation demand data for the first twelve months where i refers to the different months, i = {1,2,3,…,12)

M_i : The most accurate forecasting method

E: The estimated expected error

Step II: Forecasting transportation service demand for the third year

In the second phase both the first - and second year data sets will be used to forecast the demand for the third year.



B_t : Historical transportation demand data for the first - and second year where i refers to the different periods, i = {1,2,3,…,24}

F_t : The forecasted service demand for each period t, t = {1,2,3,…,12}

Optimization Model

This model aims to minimize the total cost of meeting the forecasted fleet requirements over the next 12-month period by finding the optimal combination of number of owned and hired vehicles.

$\boldsymbol{Objective\ function}$:

$$Min((N_{hired} \times C_h) + (N_{idle} \times C_i))$$

$\boldsymbol{Subject\ to}$:

$R = \{129, 116, 147, 150, 158, 119, 115, 137, 129, 138, 130, 128\}$

$n = \{120, 121, 122, \dots, 139, 140\}$

$$N_{hired} = \sum_1^{12}(R - n) \qquad For\ all\ r > n$$

$$N_{idle} = \sum_1^{12}(n - R) \qquad For\ all\ r < n$$

Where:

N_{hired}:	*refers to the number of additional vehicles to be hired for a given period.*
N_{idle}:	*refers to the number of vehicles that won't be needed during a given period.*
C_i:	*the total cost of an idle vehicle per day, where C_i = R 2460.64*
C_h:	*the total cost of a hired vehicle per day, where C_h = R 1489.20*
R:	*refers to the total number of vehicles required during a period i.e. the total anticipated fleet requirement for each period*
n:	*refers to the number of vehicles in the fixed fleet for different scenarios.*

The model runs through different fixed fleet sizes and calculates the total cost for each period. The cost is calculated as follows:

- If the number of vehicles in the fixed fleet is more than the required vehicles, then some vehicles will be idle. Therefore, the total cost of the idle vehicles is applied for that period.
- If the number of vehicles in the fixed fleet is less than the required vehicles, then some additional vehicles have to be hired at an increased price. Therefore, the total cost of the hired vehicles is applied for that period.

9. RESULTS AND DISCUSSION

9.1 MODEL SOLUTION AND RESULTS

What follows is a systematic summary and discussion of the results obtained during the execution of the model. This section follows the structure of the five phases of the model as identified in the conceptual design diagram (figure 10) earlier in the report.

PHASE 1: Data Analysis

The results of the data analysis phase is summarised in table 4 below. This table shows the average number consignments per working day during the 24-month period starting in July 2015. This information was used as input to the next phase, which is forecasting.

Table 4: Data analysis results for periods 1 to 24

Period (t)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Date	Jun 2015	Jul 2015	Aug 2015	Sept 2015	Oct 2015	Nov 2015	Dec 2015	Jan 2016	Feb 2016	Mar 2016	Apr 2016	May 2016
Average cons. per working day	3720	4239	4588	5491	5971	3715	3668	4172	3834	4579	4129	3747

Period (t)	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
Date	Jun 2016	Jul 2016	Aug 2016	Sept 2016	Oct 2016	Nov 2016	Dec 2016	Jan 2017	Feb 2017	Mar 2017	Apr 2017	May 2017
Average cons. per working day	4305	3983	4858	5623	5977	3836	3658	4535	4056	5096	4195	3994

PHASE 2: Forecasting

ProForecaster Professional Edition was used to determine the estimated service demand for the following twelve months. According to the model outputs seen in table 5, the Holt Winters method for Additive seasonality was selected as the most accurate forecasting method. The software compares the actual values with the forecasted values for the periods 13 to 24 in order to determine these metrics. Table 5 shows the summary of the statistics of the seventeen different forecasting techniques that were tested before selecting the most accurate forecasting method. The summary statistics include the Root mean squared error, mean absolute deviation, mean percentage error, Theil's U and The Ljung-Box Q statistic.

Table 5: Summary of forecasting techniques performance

Method	Expert Ranking	RMSE	MAD	MAPE	MPE	Theil U	LBQ
Holt & Winter for Add. Seasonal	1	203.006	172.473	0.038	-0.009	0.264	11.01369
Damped for Add. Seasonal	2	202.574	170.905	0.038	-0.01	0.264	11.59444
Additive Seasonal Method	3	210.412	173.981	0.038	-0.014	0.278	13.61757
Multiplicative Seasonal Method	4	209.175	176.081	0.039	-0.015	0.276	13.63193
Holt & Winter for Mult. Seasonal	5	201.771	171.071	0.038	-0.01	0.261	11.05326
Damped for Multi. Seasonal	6	201.141	169.626	0.038	-0.01	0.261	11.56795
Polynominal Growth	7	707.286	570.052	0.126	0.023	0.842	29.51151
Single Exponential Smoothing	8	755.17	584.153	0.123	-0.015	0.884	28.78563
Triple Exponential Smoothing	9	768.921	598.347	0.126	-0.01	0.883	21.33644
Linear Exponential Smoothing	10	750.378	589.661	0.125	-0.006	0.879	29.47126
Expert Neural Net	11	634.136	542.319	0.121	0.035	0.732	16.8932
Linear Growth	12	711.765	581.648	0.128	0.023	0.851	29.88111
Hybrid Forecast	13	750.378	589.661	0.125	-0.006	0.879	29.47126
Quadratic Growth	14	711.003	580.301	0.128	0.023	0.856	29.0427
Moving Average	15	933.546	760.166	0.176	0.033	1.096	27.06258
Damped Exponential Smoothing	16	773.996	640.306	0.14	0.012	0.921	29.43033
Double Moving Average	17	1116.516	824.291	0.189	0.001	1.502	28.64807

The Holt Winters method for Additive seasonality performed the best overall. The forecasting method showed a relatively low RMSE, MAD, MAPE, MPE and LBQ. The Theil's U value is 0.264 which is far less than 1. This is an indication of an accurate forecast. The forecasting results are summarised in table 6 below, which contains the forecasted number of consignments for the following 12-month period.

Table 6: Forecasting results for periods 25 to 36

Period (t)	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**
Date	Jun 2017	Jul 2017	Aug 2017	Sept 2017	Oct 2017	Nov 2017	Dec 2017	Jan 2018	Feb 2018	Mar 2018	Apr 2018	May 2018
Average cons. per working day	4678	4453	5313	6128	6532	4407	4277	5124	4669	5658	4808	4592

PHASE 3: Adjustments for forecasting error

An adjustment had to be made due to the nature of the data that was forecasted. Because the data is representing service demand, which will directly affect the number of vehicles used to make the deliveries, the 3PL will have significant direct- and indirect cost implications should they not have sufficient vehicles available. These implications include redelivery cost and loss of clients. The summary of the calculations can be seen in appendix C.

The MAPE was used as the error adjustment factor as it is a good indication of the overall difference in the actual and forecasted numbers and is not sensitive to sample size. The MAPE was calculated as 3.8%. The initial- and adjusted forecast is shown in figure 13 below.

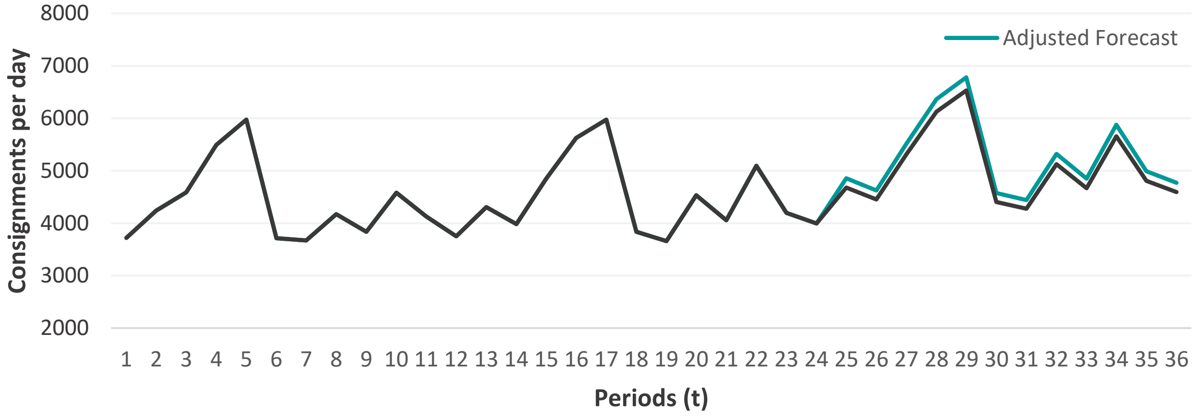


Figure 133: Initial versus adjusted forecast

PHASE 4: Fleet Requirement

The adjusted forecast was used as input to the dynamic routing optimization software. A model was run for each period to determine the number of vehicles that would be required to make the deliveries. The model was set up to minimise the lateness on deliveries and to minimise the number of vehicles used to complete all the deliveries. This enabled the user to get an accurate indication of the minimum number of vehicles needed.

Throughout the process of running the models, all the settings were kept the same and a controlled set of addresses were used. For example, the model run time was kept constant throughout all the iterations. This ensured that an accurate comparison could be done to measure the number of vehicles required between the periods. The diagram below shows an example of different proposed route configurations tested by the software in search of the optimal route delivery plan for one of the model runs. The screenshots in figure 14 were taken by the user while using OPSI Plato Dynamic Routing Software. The different customer locations are represented by the points and the lines connecting the points represent the sequence of drops. Different configurations were used to determine the number of vehicles required.

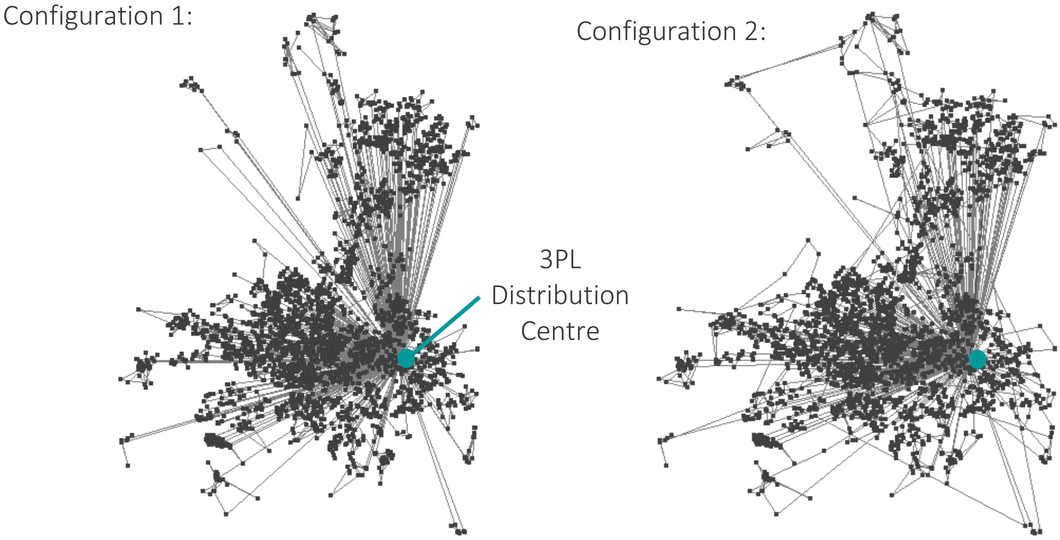


Figure 14: Different route configurations tested by the software

The results of the series of models is shown in table 7 below. This information was used as input to the optimization model.

Table 7: Summary of Plato modelling results

Period (t)	25	26	27	28	29	30	31	32	33	34	35	36
Number of unique consignments per day	4858	4625	5517	6364	6783	4576	4442	5321	4848	5875	4993	4768
Number of vehicles required per day	129	116	147	150	158	119	115	137	129	138	130	128

The graph in figure 15 summarises the relationship between number of consignments and total number of vehicles required for each period.

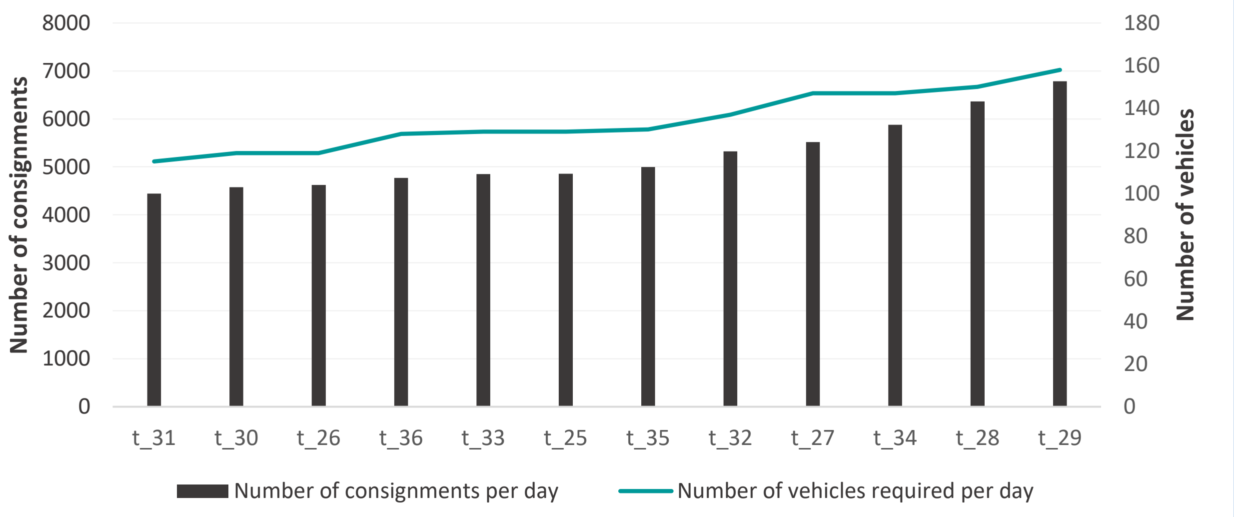


Figure 15: Relationship between number of consignments, number of vehicles and total kilograms

PHASE 5: Optimization

Optimization model inputs:

1) Average km/vehicle/day

Obtained from Plato modelling exercise: 131.8 km/vehicle/day

2) Vehicle costing information

	Fixed cost (per day)	Variable cost (per km)	Total cost per day	Total cost (per 12 instances)
Owned Vehicle	R1011/day	R 11 / km	R 1011 + R 11(131.8) = R2460.6	R2460.6 x 12 = R29527.7
Hired Vehicle	-	R 11.33 / km	R 11.33(131.8) = R14989.2	R1489.2 x 12 = R17870.2

3) Required number of vehicles for each for each period that was forecasted

PERIOD (T)	25	26	27	28	29	30	31	32	33	34	35	36
VEHICLE REQUIREMENT (R - number of vehicles)	129	116	147	150	158	119	115	137	129	138	130	128

Optimization model results:

Two modelling iterations were done. The purpose of the first iteration was to roughly determine where the optimal solution would lie. The exact solution was found by doing the second iteration. The graphs in figure 16 and 17 below show the total cost for different fixed fleet sizes (N). The summary table of the calculations can be seen in appendix D. It was concluded that the optimal solution would be between 120 and 140 vehicles after completing the first iteration.

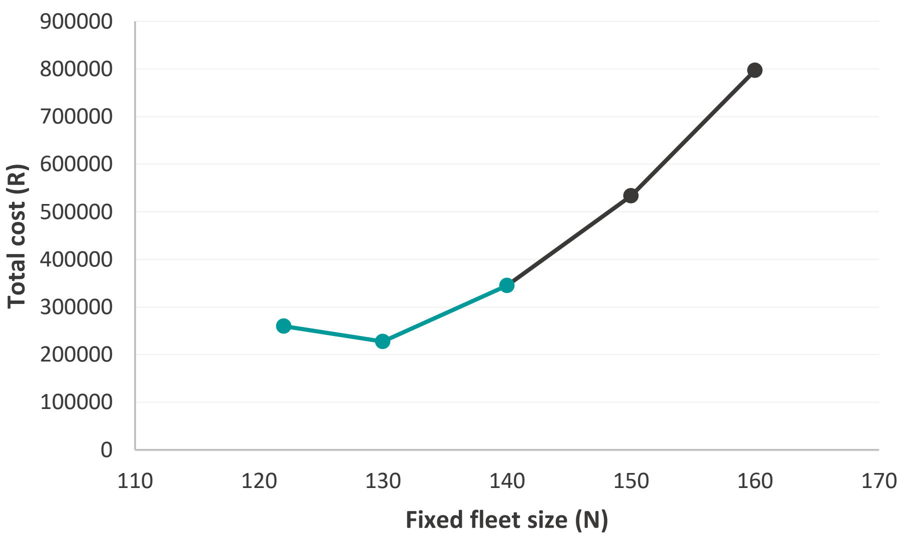


Figure 146: Iteration 1 results of the optimization model

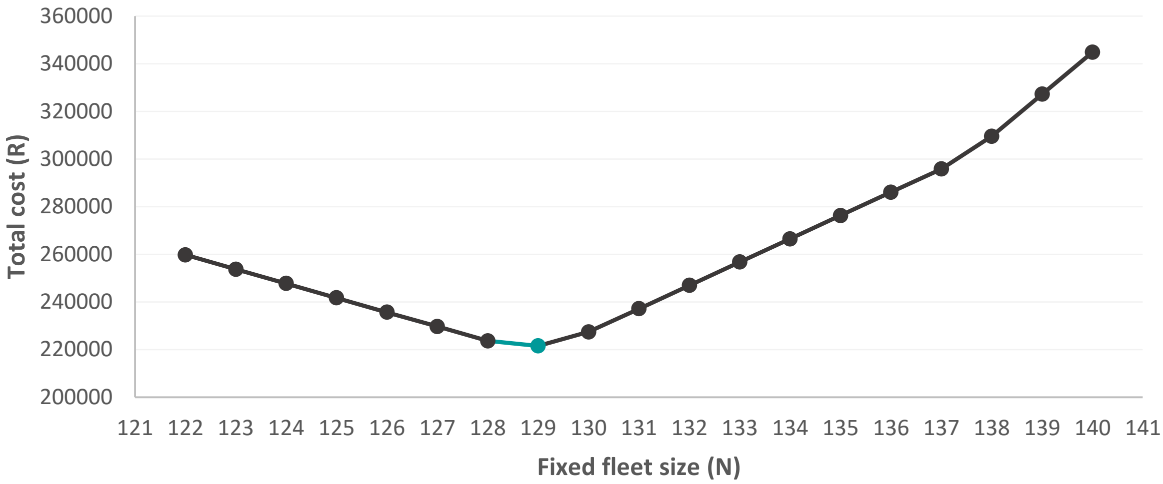


Figure 157: Iteration 2 results of the optimization model

The optimal solution was found to be 129 vehicles. Therefore, the model suggests that the company should maintain an owned fleet with 129 vehicles and hire in additional vehicles only when needed.

9.2 MODEL VALIDATION

Model Validation Approach

A thorough model validation will have to be completed before implementing the model results. In order to validate the model, a technique called "Retrospective validation" can be applied. This is the process of comparing modelling outputs for historical events to the actual performance during that same period. I.e. the number of vehicles used over the previous 12 months can be compared to modelling outputs made for the same period. However, the 3PL does not have the data of the number of vehicles used over the last 12 months available; therefore this approach could not be followed.

Sections of the model has already been validated for example the forecast that was validated over a 12 month period. A sensitivity analysis was done to measure the effect of changing input values on the optimization model.

Sensitivity analysis

Three factors were considered: 1) The cost of hiring additional vehicles 2) The average kilometres travelled per vehicle per day and 3) The number of vehicles required.

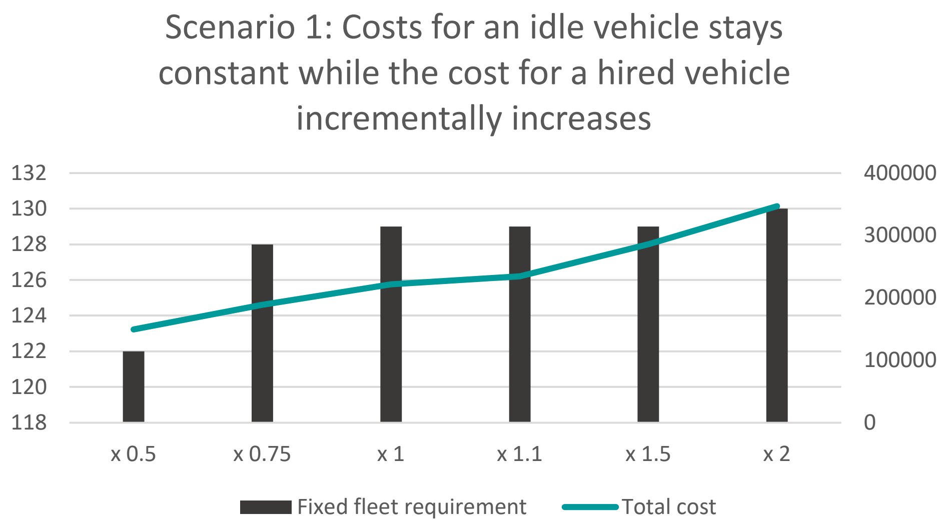


Figure 18: Effect of changing vehicle hiring rates

The chart in figure 19 shows what the impact would be on the results if suppliers cost would drastically change. The total cost increases from R 221574 to R 346537 when the cost of hiring a vehicle doubles. This is a 56.4% increase in the total cost. The total cost decreases by 48.1% when the cost of hiring a vehicle is reduced by 50%. These changes are significant and should be considered for further evaluation.

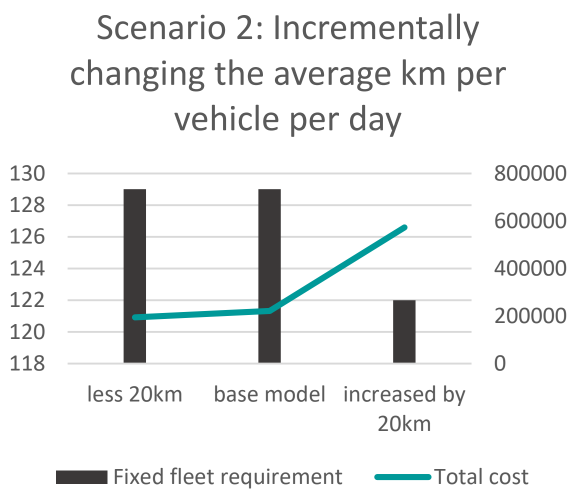


Figure 19: Effect of changing kilometres travelled

Figure 20 shows that the model is very sensitive to an increase in kilometres travelled. The total cost increased by 158.1% when the kilometres was increased by 20 km. This will be an important factor to consider as kilometres travelled is a volatile metric and is likely to change over the forecasted period. Kilometres travelled depends on the customer locations, specific routes and customer orders for a particular day.

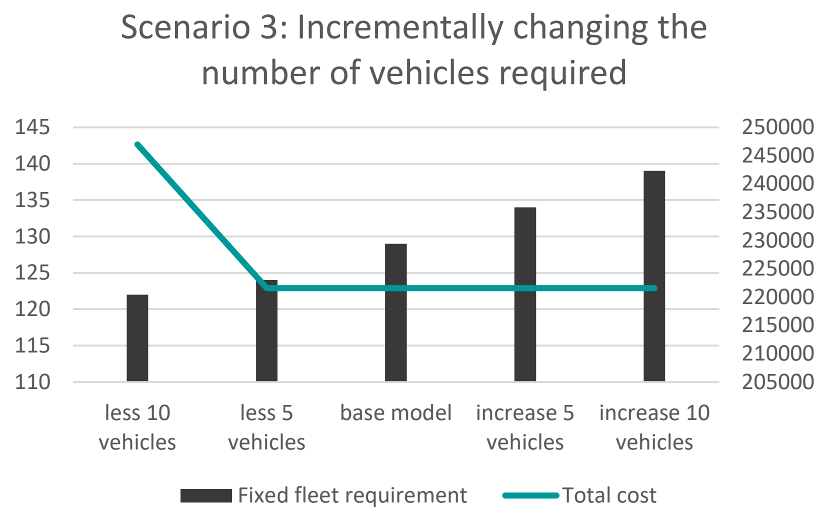


Figure 160: Effect of changing vehicle requirements

Figure 20 shows the effect of increasing (or decreasing) the number of vehicles required for each period. From this graph, it is clear that the model is relatively sensitive to changing customer demand. This is another factor to take into consideration when implementing the model as the fleet requirements may vary slightly on a daily basis during each period.

9.3 RECOMMENDATIONS FOR IMPLEMENTATION

It should be noted that the model is relatively sensitive to some factors that might change or deviate slightly over the course of the next 12 months. Due to the high stakes involved when making changes to fixed fleet sizes (i.e. the high cost of purchasing new delivery vehicles) this model should only be used in conjunction with other analyses and not be the sole decision driver. Other factors such as labour cost, training cost, available storage, business strategy, inflation, interest etc. should also be considered when making a decision regarding the 3PL's fixed fleet size.

10. CONCLUSION

The operating costs of a company can be minimised by implementing the optimal fleet size that is required. This can be done by first using various forecasting methods to determine the customer service demand and then using the information to determine the amount of vehicles that will be used. Analysing data from the logistics company shows trends that can be used to effectively forecast future transportation needs.

The model results show that the optimal owned fleet size the company should operate with is 129 vehicles with a total cost of R 221 534. Should the 3PL continue to operate with 122 vehicles during the following 12 months, the total cost would amount to R 259 732. Therefore the 3PL could potentially save R 38 198 by increasing their fixed fleet size with an additional seven vehicles.

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Appendix A: Sponsorship Form

Department of Industrial & Systems Engineering
Final Year Projects
Identification and Responsibility of Project Sponsors

All Final Year Projects are published by the University of Pretoria on *UPSpace* and thus freely available on the Internet. These publications portray the quality of education at the University and have the potential of exposing sensitive company information. It is important that both students and company representatives or sponsors are aware of such implications.

Key responsibilities of Project Sponsors:

A project sponsor is the key contact person within the company. This person should thus be able to provide the best guidance to the student on the project. The sponsor is also very likely to gain from the success of the project. The project sponsor has the following important responsibilities:

1. Confirm his/her role as project sponsor, duly authorised by the company. Multiple sponsors can be appointed, but this is not advised. The duly completed form will considered as acceptance of sponsor role.
2. 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 from the company's perspective.
3. Review the Final Project Report (delivered during the second semester), ensuring that information is accurate and that the solution addresses the problems and/or design requirements of the defined project.
4. Acknowledges the intended publication of the Project Report on UP Space.
5. Ensures that any sensitive, confidential information or intellectual property of the company is not disclosed in the Final Project Report.

Project Sponsor Details:

Company:	SIZWE AFRICA BUSINESS CONSULTING
Project Description:	STATISTICAL FORECASTING TOOL FOR A THIRD PARTY LOGISTICS PROVIDER
Student Name:	MARGO VAN AARDE
Student number:	141 792 54
Student Signature:	
Sponsor Name:	ADRIAAN VAN WYK
Designation:	BUSINESS ANALYST CONSULTANT
E-mail:	adriaan.vanwyk@sizweafrica.co.za
Tel No:	
Cell No:	+27 82 467 0425
Fax No:	
Sponsor Signature:	

Appendix B: Summary of forecast adjustments calculations

t (period)	Actual consignments per day	Forecasted consignments per day	Absolute Error	Absolute Error / Actual Demand	Adjusted forecast
14	3983.16365	4239.28571	256.122065	0.06430117	
15	4858.04284	4545.99585	312.046988	0.06423307	
16	5623.32138	5479.35117	143.970205	0.02560234	
17	5976.74334	5987.27081	10.5274719	0.00176141	
18	3836.23636	3745.59584	90.6405212	0.02362746	
19	3657.87	3729.42343	71.5534235	0.0195615	
20	4534.81519	4244.26792	290.547264	0.06407036	
21	4056.17414	3970.91314	85.261001	0.02102005	
22	5096.20822	4770.81558	325.392632	0.06384995	
23	4195.09397	4422.11053	227.016562	0.05411477	
24	3993.97957	4078.10721	84.1276421	0.02106361	
25		4678.48502			4858.48152
26		4453.3858			4624.722
27		5312.77487			5517.17456
28		6128.48327			6364.26591
29		6531.76488			6783.06307
30		4406.69445			4576.23429
31		4277.43522			4442.00203
32		5124.31293			5321.46188
33		4668.51212			4848.12493
34		5657.68153			5875.3509
35		4807.98659			4992.96544
36		4591.78741			4768.44837

MAPE	Error factor
0.03847325	1.03847325

Appendix C: Summary of optimization model calculations

Iteration 1:

t	1	2	3	4	5	6	7	8	9	10	11	12
R	129	116	147	150	158	119	115	137	129	138	130	128

Suggested number of owned vehicles	**Calculations**											
122	7	-6	25	28	36	-3	-7	15	7	16	8	6
130	-1	-14	17	20	28	-11	-15	7	-1	8	0	-2
140	-11	-24	7	10	18	-21	-25	-3	-11	-2	-10	-12
150	-21	-34	-3	0	8	-31	-35	-13	-21	-12	-20	-22
160	-31	-44	-13	-10	-2	-41	-45	-23	-31	-22	-30	-32

N	**Hire**	**Cost**	**Total hire cost**	**Idle**	**Cost**	**Total Idle cost**	**BALANCE**
122	148	1489.179	220398.5	-16	2460.643	-39370.3	259768.79
130	80	1489.179	119134.3	-44	2460.643	-108268	227402.63
140	35	1489.179	52121.27	-119	2460.643	-292817	344937.82
150	8	1489.179	11913.43	-212	2460.643	-521656	533569.81
160	0	1489.179	0	-324	2460.643	-797248	797248.43

Iteration 2:

R	129	116	147	150	158	119	115	137	129	138	130	128
t	1	2	3	4	5	6	7	8	9	10	11	12

N	**Calculations**											
122	7	-6	25	28	36	-3	-7	15	7	16	8	6
123	6	-7	24	27	35	-4	-8	14	6	15	7	5
124	5	-8	23	26	34	-5	-9	13	5	14	6	4
125	4	-9	22	25	33	-6	-10	12	4	13	5	3
126	3	-10	21	24	32	-7	-11	11	3	12	4	2
127	2	-11	20	23	31	-8	-12	10	2	11	3	1
128	1	-12	19	22	30	-9	-13	9	1	10	2	0
129	0	-13	18	21	29	-10	-14	8	0	9	1	-1
130	-1	-14	17	20	28	-11	-15	7	-1	8	0	-2
131	-2	-15	16	19	27	-12	-16	6	-2	7	-1	-3
132	-3	-16	15	18	26	-13	-17	5	-3	6	-2	-4
133	-4	-17	14	17	25	-14	-18	4	-4	5	-3	-5
134	-5	-18	13	16	24	-15	-19	3	-5	4	-4	-6
135	-6	-19	12	15	23	-16	-20	2	-6	3	-5	-7
136	-7	-20	11	14	22	-17	-21	1	-7	2	-6	-8
137	-8	-21	10	13	21	-18	-22	0	-8	1	-7	-9
138	-9	-22	9	12	20	-19	-23	-1	-9	0	-8	-10
139	-10	-23	8	11	19	-20	-24	-2	-10	-1	-9	-11
140	-11	-24	7	10	18	-21	-25	-3	-11	-2	-10	-12

N	**Hire**	**Cost (for 12 days)**	**Total hire cost**	**Idle**	**Cost**	**Total Idle cost**	**BALANCE**
122	148	17870	2644782	-16	29528	-472444	3117225
123	139	17870	2483951	-19	29528	-561027	3044977
124	130	17870	2323119	-22	29528	-649610	2972729
125	121	17870	2162288	-25	29528	-738193	2900481
126	112	17870	2001457	-28	29528	-826776	2828233
127	103	17870	1840625	-31	29528	-915359	2755985
128	94	17870	1679794	-34	29528	-1003942	2683736
129	86	17870	1536833	-38	29528	-1122053	2658886
130	80	17870	1429612	-44	29528	-1299220	2728832
131	75	17870	1340261	-51	29528	-1505914	2846175
132	70	17870	1250910	-58	29528	-1712608	2963518
133	65	17870	1161560	-65	29528	-1919302	3080861
134	60	17870	1072209	-72	29528	-2125996	3198205
135	55	17870	982858.2	-79	29528	-2332690	3315548
136	50	17870	893507.4	-86	29528	-2539384	3432891
137	45	17870	804156.7	-93	29528	-2746078	3550235
138	41	17870	732676.1	-101	29528	-2982300	3714976
139	38	17870	679065.6	-110	29528	-3248049	3927115
140	35	17870	625455.2	-119	29528	-3513799	4139254