

**Developing a Framework for Determining the Optimal  
Replacement Strategy for a Vehicle Fleet of a 3<sup>rd</sup> Party  
Logistics Service Provider (LSP), IMPERIAL  
Distribution**

**by**

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## EXECUTIVE SUMMARY

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This project is centred within the logistics and supply chain industry and is being monitored and supported by IMPERIAL Logistics and Volition Consulting Services, while being completed at IMPERIAL Distribution – a division of IMPERIAL Logistics. The project requires the use of Industrial Engineering techniques to create a framework that can be used by IMPERIAL Distribution, as a logistics service provider (LSP), to determine the most cost-effective fleet replacement policy for a specific client. This framework will need to take many different forms of inputs, while producing an optimal replacement strategy on request of the user. The scope includes the study of vehicle maintenance and size as well as capital outlay and risks. In the end, this framework aims to meet IMPERIAL Distribution’s client requirements as effectively as possible, while keeping the associated outbound logistics cost to a minimum.

This project will assist IMPERIAL Distribution in acquiring new contracts by means of tenders and by optimizing the fleets of current clients in terms of their replacement policy. This is important to them in the competitive industry of supply chain and logistics seeing as they will be able to provide an improved, more streamlined solution to their ever-increasing client base, while saving themselves money along the way. If implemented successfully, the proposed framework will result in potential savings by means of a decrease in variable cost per kilometre. This will remove volatility in addition to receiving better recovery on the vehicles within the IMPERIAL Distribution fleet.

## 1. Introduction and Problem Background

### 1.1 Background

IMPERIAL Distribution is a division of IMPERIAL Logistics, which is a wholly owned subsidiary of IMPERIAL Holdings (Pty) Ltd (Imperial Distribution, 2010), whose organogram is shown in Figure 1. IMPERIAL Holdings Limited is currently listed on the Johannesburg Stock Exchange (JSE) where it is included on the Top 40 All Share Index list for having a market capacity of over R20 billion. IMPERIAL Logistics is one of the five divisions within IMPERIAL Holdings Limited and is the leading supply chain management service provider in Africa (Imperial Logistics, 2010).

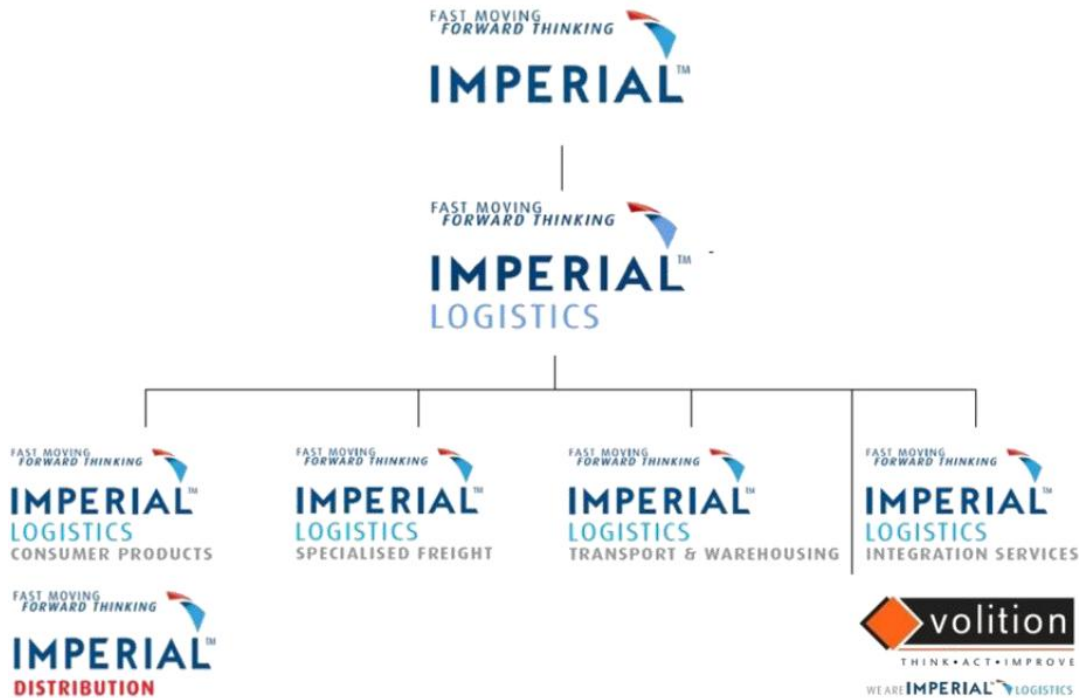


Figure 1: IMPERIAL Holdings' Corporate Structure

IMPERIAL Logistics owns many logistics and freight companies throughout Africa, including the company at which this project is conducted, IMPERIAL Distribution. Since 1978, IMPERIAL Distribution has specialised in providing dedicated logistics solutions for their customers, owning and operating warehouses and fleets across Southern Africa, allowing them to be a true supply chain partner as a third party logistics service provider.

All of IMPERIAL Distribution's clients are treated with the world class service quality which IMPERIAL Distribution is well known for, and are provided with generic solutions, specific to each company which meets their needs directly, while maintaining a high, world-class level of service.

IMPERIAL Distribution currently operates over eighty logistics contracts, resulting in an annual turnover approaching the R600 million mark. Owning a fleet in excess of 650 vehicles, managing more than 100,000m<sup>2</sup> of warehousing and employing approximately 1800 people makes them a true logistics leader. IMPERIAL Distribution's head office is situated in Spartan, Kempton Park, with regional offices in Cape Town, Durban and Port Elizabeth.

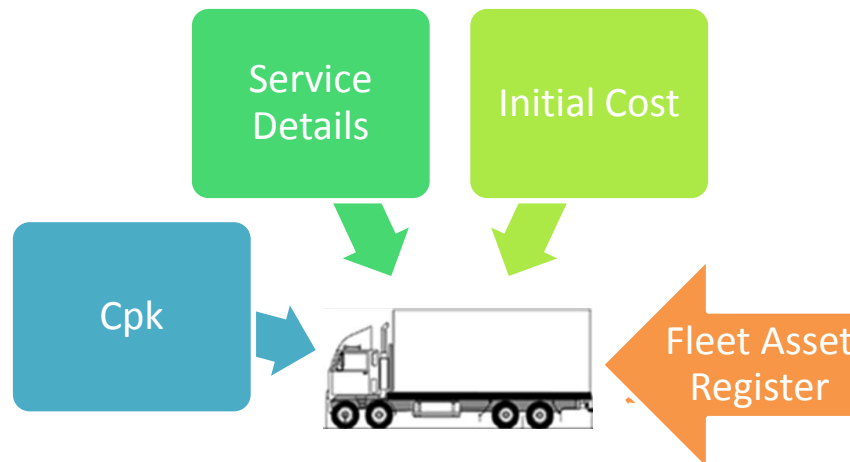
### 1.2 Problem Description

As a third party logistics service provider, IMPERIAL Distribution approaches a client, purchases their entire fleet and operates the client's entire distribution function for them. Given the vast number of contracts currently operated by IMPERIAL Distribution, trucks are assigned deliveries spanning the entire client base. As a result, trucks are utilized but not closely monitored as information on truck usage is few and far between. Truck ageing is a common issue in the logistics industry based on the various effects that ageing has on the productivity and cost of vehicles.

Minimizing the cost of operating a vehicle therefore holds great value to a third party logistics service provider. As a result, this project aims to optimize the replacement strategy of the IMPERIAL Distribution fleet in such a way that both the fixed and variable cost to IMPERIAL Distribution in managing this fleet is minimized. This problem is deeply rooted in the history of the management of logistics within the industry. Managers at logistics companies are constantly concerned with decreasing the route times, route costs and labour intensity within a contract, instead of going to the root of the service and decreasing costs where it matters: at the fleet management.

Fleet management includes the ever-important consideration of the fleet composition, which is a combination of the fleet mix and vehicle age. Within the context of this project, fleet mix refers to the number and combination of sizes of vehicles needed to fulfil the logistics requirements of all the clients, while vehicle age refers to whether the vehicle within the fleet is either new or used, and the age if it is used. This 'age' will be a combination of both years and kilometres travelled.

The problem that is encumbered in this dissertation is whether or not operating a vehicle for the next six months is economically viable. This project will need to define the replacement strategies for every vehicle within an optimized fleet, such that the financial benefits for IMPERIAL Distribution are at their highest. As can be seen in Figure 2, a specific vehicle from the fleet asset register has a lot of information linked to it. This information will be used by a tool to determine the course of action to be taken by IMPERIAL Distribution.



**Figure 2: Problem Description**

The tool that will be designed in this project, to be used by the business analysis department at IMPERIAL Distribution, is an optimization model, which should be able to determine the client's optimal replacement policies with great ease and efficiency. This model will need to combine all the variables that are important in making this decision, while considering user inputs and constraints specific to each client.

This problem can be called an optimization problem due to the fact that it involves achieving a specific objective while being subject to a set of constraints. In our case, this objective is to minimize the total cost (both fixed and variable) of operating a vehicle fleet for a given client, in the face of a set of variables defined by IMPERIAL Distribution.

### 1.3 Project Aim

The aim of this industrial engineering project is to develop a framework that will help determine whether or not a vehicle is financially suitable for operation. This framework will save IMPERIAL Distribution a lot of time and money in terms of determining their clients' fleet replacement strategies, as well as providing them with information that they need further down in their information chain.

At present, IMPERIAL Distribution determines the fleets by off-hand calculations and by using contract experience to tell them how much of what truck tonnage is required. Although this gets the clients products to site on time, most of the time, this method is not effective in reducing the costs involved for IMPERIAL Distribution. As far as the fleet mix (FSM) problem is concerned, IMPERIAL Distribution is looking to implement Plato software to calculate this for them, within the next six months. Therefore, this project's aim is to determine the optimal replacement strategies for the vehicles within a fleet, based on the input provided by the user.

The aim of the project can be described by the following objectives for the building of the framework:

- Design a user interface which allows IMPERIAL Distribution to assign values to defined variables
- Develop an optimization model which determines the optimal replacement policy for the vehicles within the optimized fleet mix
- Design an output interface which displays the optimal solution along with required outputs

If the aim of this project is met, the business analysis department at IMPERIAL Distribution will be able to use this framework to decrease unnecessary costs within contracts, such as maintenance and while decreasing the time required to produce the replacement strategies of the vehicles.

### 1.4 Project Scope

This project includes the developing of the framework which was discussed in the preceding section. The tools and techniques that can be used to build this framework will be discussed in the information study. However, when planning and executing a project it is imperative that project boundaries are fenced, so that time and resources are not spent on information that will not be useful in the solving of the particular problem. In the context of this problem, the boundaries, called scope, will be defined with respect to the variables required for the framework itself.

There are many factors and variables that can be included in a project and framework such as we have here. Therefore, according to IMPERIAL Distributions requirements as well as popular literature the following variables will be included in the project, framework and optimization model scope.

#### 1.4.1 Included In Project Scope

- Financial modelling
- Green miles (CO<sub>2</sub> emissions)
- Forecasted mileage
- Trucks
  - i. Vehicle Size
  - ii. Vehicle Age
  - iii. Replacement Strategies for each contract fleet
  - iv. Kilometres travelled
- Roads
  - i. Road Standard
  - ii. Road Class: normal, hilly and gravel
- Fixed and Variable Costs
- Model output statistics

### 1.4.2 Excluded From Project Scope

The following variables and factors have been excluded from the project scope either by request of IMPERIAL Distribution or based on ensuring that the project size does not swell past size requirements. The variables and factors that are excluded from the project scope include:

- The value of the product being shipped.
- Toll fees
- Branding cost
- Route optimization

### 1.5 Deliverables

The following is a list of the deliverables required for this project. Numbers 1 through 4 are required by IMPERIAL Distribution, whereas the final three are deliverables required by the University of Pretoria.

1. Framework
2. Training session
3. User manual
4. Full project report
5. Final document
6. Presentation
7. Poster

### 1.6 Chapter One Summary

Chapter One commenced by setting the environment within which this dissertation is situated which includes the company, IMPERIAL Distribution, as well as the problem which they are currently facing. The problem can be summed up as an optimal fleet replacement problem. This deals with the begging question of when a vehicle should be replaced so as to minimize the total contract cost for IMPERIAL Distribution.

Once the problem was laid out, it was possible to determine the aim for this project as well as deciding what was to be included and excluded from the project scope. The extent of the scope was determined only by IMPERIAL Distribution and the size limitations of a final year project set by the University of Pretoria. The deliverables of this project are set out in the final section of this chapter.

Now that the background environment has been clearly identified one can now proceed to eliciting relevant academic research, information and data on the subject matter which will help solving this problem.

## 2. Information Gathering

This information gathering chapter consists of two parts, firstly a literature review which researches academic papers on the dissertation topic, and secondly, an information study which focuses on the non-academic aspects of the said topic. The breakdown of the information-gathering phase into sections and relevant topics can be seen below in Figure 3.

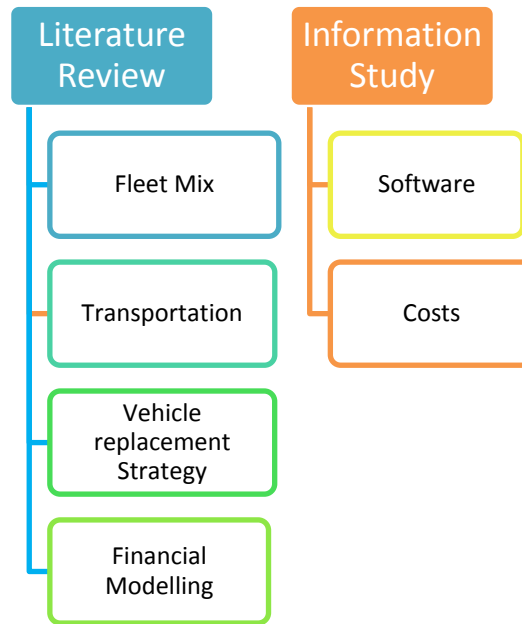


Figure 3: Information Study Breakdown

### 2.1 Literature Review

The academic problems in this project span the subjects of operations research and financial management. As there are three main aspects to this problem, they will be analyzed separately in the following sections.

#### 2.1.1 Fleet Mix Literature

Addressing the problem of which size and quantity of vehicles to acquire for a fleet, based on constraints, is done with a FSM (fleet size and mix) model. For the purpose of this project a variant of the FSM problem needs to be addressed in order to verify the optimality of a given vehicle fleet. However, throughout literature, the FSM problem has very rarely been analysed on its own. As Renaud and Boctor explain, fleet mix usually forms a part of a fleet size and mix vehicle routing problem, which is abbreviated to FSMVRP (Renaud & Boctor, 2002). IMPERIAL Distribution does not require such a solution based on the fact that they plan to have software installed which will calculate both the fleet mix and the optimal vehicle routes for them. Therefore, for the purpose of this project the optimal vehicle routes, fleet size and mix will be input computed by Plato. Literature on FSMVRP is included in

this literature review based on the need for understanding both the function and the output of such models such that replacement strategies can be determined and financial aspects understood and analyzed.

Sahli et al. were echoed by Brandao when he said that determining the optimal size of a fleet involves tactical, strategic and operational decisions (Brandao, 2009). Having an optimal fleet size ensures that a company does not spend unnecessary money on vehicles which are actually not needed. For globally competitive companies this has become increasingly important over the past decades. Brandao addresses these costs in his paper on creating a tabu-search algorithm for tackling the FSMVRP problem. It is Brandao's opinion that fixed costs are considered in tactical decision making, where decisions need to be taken as to vehicle choice and number, whereas variable costs are considered in daily planning. These two costs make up the objective function in this model, of which the objective is to minimize (Brandao, 2009).

FSMVRP are usually solved using heuristics and complex algorithms, although components of the problem can be broken down and solved separately. The most applicable model to the logistics industry is proposed by Etezadi and Beasley in their paper on vehicle fleet composition (Etezadi & Beasley, 1983), which calculates the optimal fleet composition for a contract in which a heterogeneous, multi-aged vehicle fleet services destinations from one depot. Etezadi and Beasley also supported the opinion that although depot location and vehicle routing has been widely discussed in literature, that the vehicle fleet composition optimization problem has received relatively little attention. This is astounding due to the fact that the costs involved in acquiring and managing vehicles represents a large portion of the cost of distribution in the first place (Etezadi & Beasley, 1983).

There are many variations which can be integrated into these FSMVRP optimization models. Not one of the models researched were identical, even though they are all based on very similar principles. The variations which occur in this kind of problem range between the inclusion and exclusion of certain fixed or variable costs, rental and purchase options, obsolescence, heterogeneous consideration, round trips, multiple deliveries in one vehicle, vehicle size constraints and so on.

The majority of articles in the available literature cannot cater for obsolescence within their models. However, Mole devised a model in which obsolescence is allowed. To allow for the obsolescence of these vehicles certain adaptations needed to be made to the model, which included the addition of a disposal policy. This disposal policy allows vehicles which are removed from service in a previous period to be subtracted from the available fleet in the current period, thus decreasing the amount of vehicles that can be assigned to contract in the period (Mole, 1975).

Mole did not, however, allow for a heterogeneous fleet or a varying demand. The first is vital to the model that needs to be developed for IMPERIAL Distribution, so although Mole is able to direct the model in the correct direction, his model in its entirety is not sufficient for the purpose of this study.

Repoussis and Tarantilis worked on developing models for heterogeneous fleets, where vehicles differ in capacity, cost and age. Homogenous fleets do not make any practical sense in the business world anymore, seeing as clients have various needs, delivery routes and schedules. Having a heterogeneous fleet gives a LSP the flexibility and accessibility that it needs to be an industry leader (Repoussis & Tarantilis, 2009).

Many researchers, including Wyatt, designed models on determining the fleet size where both rental and purchase of a vehicle are an option. Although these models are also not applicable in their entirety, they do highlight a valid point concerning minimization of transport costs. For a determined transport demand, minimization of transport costs represents only part of the minimization of distribution network costs (Wyatt, 1961). A further reduction in transport costs is possible without having to alter the fleet size, by oversupplying in periods of low demand. IMPERIAL Distribution also currently allow for both rental and purchase of machines for fleet contracts. This holds a high benefit for them, seeing as owning a fleet with spare capacity for the demand in period (t), could save on transport costs when the demand increases in period (t+1). This will be as a result of not needing to purchase new vehicles, which is extremely costly, but rather being able to use the spare capacity that is available in the already existing fleet.

It would be impossible to discuss the determination of fleet composition without mentioning Salhi, who is a front-runner in the field of operations research. His work on fleet distribution ranges from simple guidelines to intricate heuristics which solves VRP, depot location and FSM simultaneously (Salhi & Fraser, 1996). Components of his complex models can be used to solve the partial FSM problem that is described within this project.

### 2.1.2 Vehicle Ages and Replacement Strategies

Due to the nature of vehicles, although they are an asset they can never be considered an investment. Vehicles deteriorate with use and lose value with every kilometre over which they are operated.

#### 2.1.2.1 Vehicle Ageing

As vehicles get older there are a number of factors which are influenced. These factors are listed here as proof that it is important to monitor and control the age of vehicles within a fleet. If proper monitoring and control is implemented the owning company will be able to cut costs within their fleets, as well as being able to predict future changes and affects more accurately.

The following figure aims to illustrate the effect of vehicle age and time on operating costs, replacement costs, resale value and revenue.

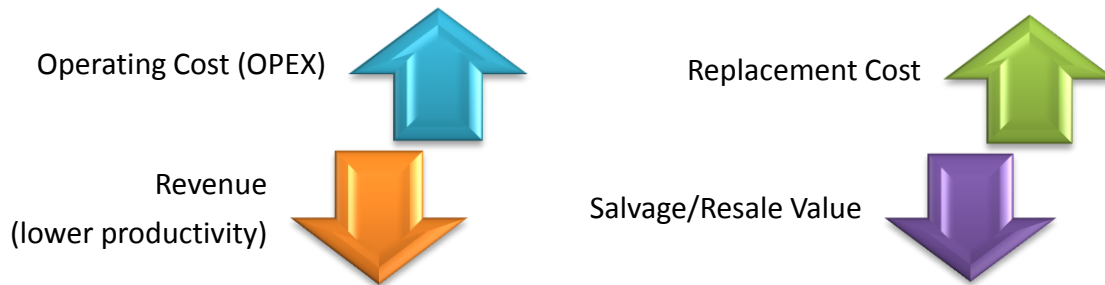


Figure 4: Effect of Vehicle Age on Factors

Operating costs of vehicles increase with age due to increasing maintenance costs (Wu et al., 2001). Replacement costs increase due to the initial vehicle prices increasing with at least inflation year on year. Lower productivity and an increased need for maintenance (downtime) are responsible for a decrease in the amount of income or revenue that a vehicle brings in. In addition, older vehicles have a lower book value and as such can be sold for less in year  $t+1$  than in year  $t$ .

An important aspect to note is that larger vehicles have a longer useful life than smaller vehicles. This will be reflected in both the salvage value and depreciation rate of these vehicle sizes, where larger vehicles depreciate at a slower rate than smaller vehicles, which results in a higher salvage value over a given period of time.

#### 2.1.2.2 Economic Life

The economic life of a vehicle is accepted as the cumulative number of hours or kilometres which has been worked by the vehicle when the total capital reaches a minimum. Some argue that the replacement of a vehicle should occur at this point. (Transvaalse Provinsiale Administrasie Tak Paaie, 1993).

The calculation of the economic life of a vehicle is based on the principle that the vehicle's capital costs decreases as the number of hours worked increases, while the maintenance costs increase.

Using economic life as an indication of a replacement point is useful because one can state economic life as a percentage. Once a vehicle has reached 100% of its economic life it does not become obsolete. The vehicle still functions, however, the cost to maintain it exceeds the capital which it brings in. As a result, we wish to replace the vehicle as close to 100% of its economic life as possible.

#### 2.1.2.3 Dynamic Programming

To be able to explore the theory behind replacement strategies one has to look at dynamic programming first. Dynamic Programming (DP) is used for the improvement of computational efficiency of optimization problems (Winston & Venkataramanan, 2003). This method takes a problem and decomposes it into sub-problems, each of which can be easily solved. To obtain a solution, the problems

are tackled from the end to the beginning of the problem. DP has been used extensively within the field of operations research to solve problems that include network, inventory, resource allocation and equipment replacement problems.

### *The Characteristics of Dynamic Programming:*

- The problem is decomposed into stages with a decision required at each stage
- Each stage consists of different states which contain valuable information necessary to make the decision
- The decision made at each stage determines how the state at the current stage is transformed into the state of the next stage
- The principle of optimality is applied in DP. If each individual stage is optimized, the total problem is considered optimized
- The recursive function connects the costs in one stage to the subsequent ones. (Winston & Venkataramanan, 2003).

### *Aspects to Consider in the Formulation of Recursions*

Aspect 1: The range of decisions that can be made for a given stage and state needs to be defined.

Aspect 2: The recursive function needs to specify how the cost of a given stage is influenced by the decision taken at that stage.

Aspect 3: Define how the decision that is taken at the current stage and state will influence the state at the stage which is to follow. (Winston & Venkataramanan, 2003).

### *2.1.2.4 Replacement Strategies*

In industries around the world managers are constantly faced with the dilemma of deciding when to replace equipment, and determining what effect their replacement decisions will have on the financial output of the company over time. Dynamic programming, and especially equipment replacement DP, can be used to solve these problems.

The general decisions that can be made regarding replacement policies are:

- Keep machine
- Overhaul machine
- Replace machine

To illustrate the use of equipment replacement problems, the following general example is used.

The only two decisions that are taken into consideration with the example is keeping the machine (K) or replacing the machine with a new machine (P).

“Define:

$F_t(i) \triangleq$  The maximum overall return from a machine of  $i$  years at the beginning of the year  $t, t+1, \dots, T$  when the principle of optimality is employed for the remainder of the process.

$R_t(i) \triangleq$  Revenue obtained from a machine of age  $i$  at the beginning of year  $t$ .

$U_t(i) \triangleq$  Maintenance cost of a machine of age  $i$  at the beginning of year  $t$ .

$G_t(i) \triangleq$  Replacement cost of a machine of age  $i$  by a new machine at the beginning of year  $t$ .

**Stages:** Years

**States:** Age of machine

**Decision:** When to replace machine

The following recursive function links these functions:

$$F_t(i) = \begin{aligned} & \max \quad P: [r_t(0) - U_t(0) - G_t(0) + f_{t+1}(1)] \\ & \max \quad K: [r_t(i) - U_t(i) + f_{t+1}(i+1)] \end{aligned}$$

*Using the recursive function will deliver an optimal replacement policy for any time horizon  $t, t+1, \dots, T$  for maximising the revenue obtained during the period” (Saksensa & Kumar, 1963).*

To improve the decision-making capabilities of an equipment replacement problem, one can add one or many factors to the dynamic program. These factors include the allocation of a weight given to vehicles based on predetermined rankings, or including the option of rentals or used vehicles. If a given equipment replacement problem requires the outsourcing of maintenance and servicing, the objective function will need to be altered in such a way to allow for the choosing of the maintenance option which bares the most benefit to the controlling company, at the lowest cost. These maintenance plans can be evaluated by means of a weighting system based on their attributes, and can be included directly into the objective function using these weightings. Attributes include service speed and distance from company, level of service and serviceability of equipment. The value of the weight allocation will increase or decrease the cost depending on relation of the packages or companies compared to one another (Lai & Li, 1997).

Equipment replacement is one of the many tools of dynamic programming. To fully utilize the benefits of this technique the user will need to design a model that succumbs to all the characteristics of a DP model as discussed above. This will result in an effective recursive function and the optimal solution being found.

The one and only objective of an equipment replacement problem is to minimize the cost of owning and maintaining equipment. The output of the model is a replacement policy which is based on supplying the user with the decision between keeping or replacing a given vehicle at the beginning of a stage. Considering other factors, including maintenance costs, salvage value and weight allocation, can influence the final values being obtained as well as the optimal decision. It is of great importance to include all relevant aspects to attain a feasible solution (Winston & Venkataramanan, 2003).

### *Consideration of used machines*

Using the previous example by Saksensa and Kumar, the replacement of the current machine by another of age  $x$  is considered (Saksensa & Kumar, 1963). The formulation will be altered by including a replacement cost of a vehicle of a certain age at the beginning of the period. The recursive function would then be reduced by this replacement cost (Saksensa & Kumar, 1963).

#### *2.1.2.5 Replacement Point*

The begging question then, is when does one need to replace a vehicle? At what point does a vehicle start costing a company too much in terms of maintenance and/or efficiency loss? The New Zealand Transport Agency provides great insight and valuable experience in finding the answer to these questions. They refer to the point in time when a vehicle should be replaced as the ‘replacement point.’ (NZ Transport Agency, 2005) The graph shown in the next figure illustrates the costs over time for a heavy vehicle, which includes the consideration of depreciation, maintenance costs, obsolescence and operations downtime (as a result of a service or breakdown).

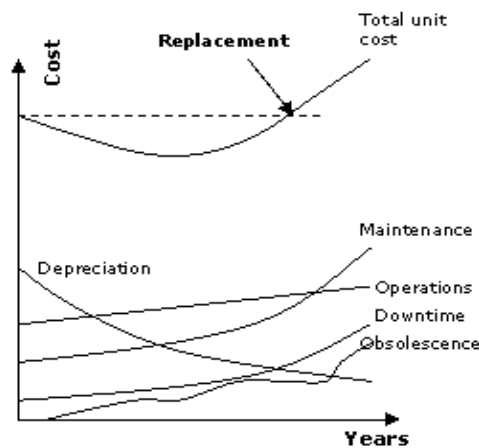


Figure 5: Replacement Point (NZ Transport Agency, 2005)

The top curve on the graph is the total cumulative cost of all the bottom costs, excluding the initial cost of purchasing the vehicle. The point marked with an arrow as ‘replacement’ is the optimal point in time to replace the vehicle; after which the cost of operation exceeds the replacement cost. As can be seen in Figure 5, we do not replace the vehicle at the minimum total cost but rather where the line surpasses the initial cost point. Over time, the cost graph will appear as a series of U-shapes with the apex representing the acquiring of a replacement vehicle, as shown in the figure below.

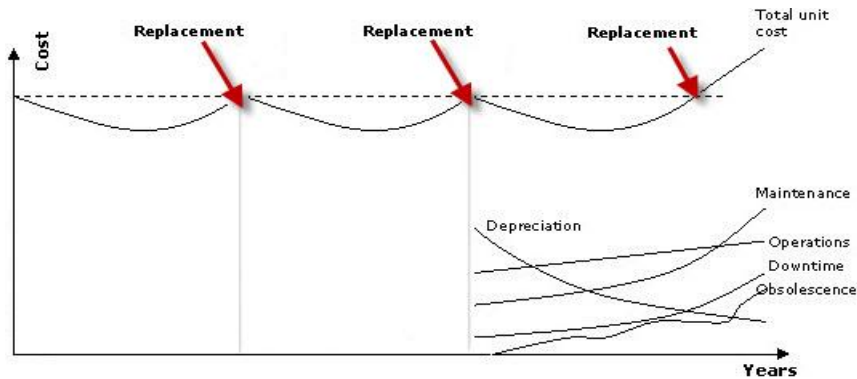


Figure 6: Replacement over long time period (NZ Transport Agency, 2005) - adapted

The question about the exact replacement point is answered by the following figure. We do not replace the vehicle at the minimum cumulative cost (Red Arrow) due to the fact that if we do, for the time indicated by the purple arrow on the graph we will be incurring more cost than if we replaced vehicle at the green arrow (Figure 7). This is illustrated in the following figure.

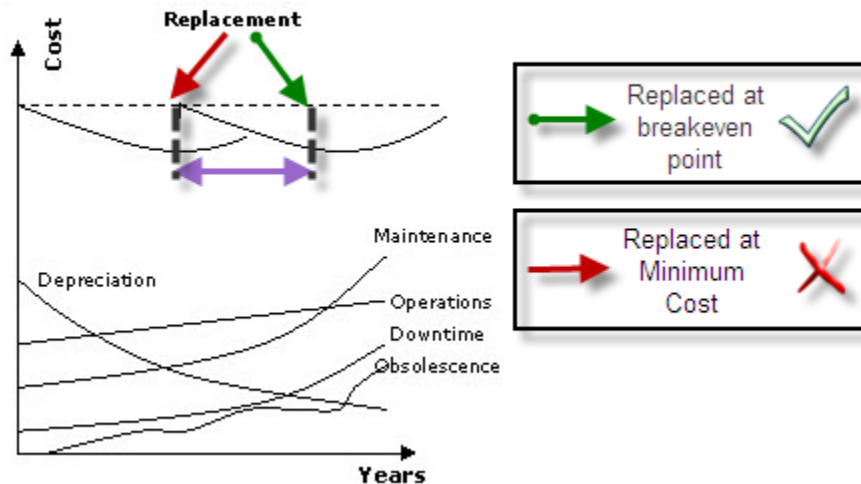


Figure 7: Replacement Point versus minimum cost

Due to the high initial cost of vehicles, most companies attempt to buy the cheapest model on the market at the time of purchase. However, time has proven that the more reliable a vehicle is, the less expensive it ends up being due to the lower maintenance cost. In addition, if a cheap vehicle is purchased and then completely stops working after a couple of years then effectively double the cost is incurred. Therefore, it is important for a company to weigh both the initial purchase price and the lifecycle cost of the vehicle at purchase (NZ Transport Agency, 2005).

### 2.1.3 Financial Modeling

The purpose of this project is to find the most cost effective solution for the fleet design problem. The cost associated with a fleet includes both initial and running costs. The initial cost, to procure the vehicles, should obviously be minimized while still reaching the desired service requirements. Running costs include those of depreciation, maintenance and labour. The vital part of performing a financial analysis is having the necessary indicators in place to help determine whether a said solution is more or less beneficial to a company. For this reason, we now look at financial indicators that could aid the decision-making in this project, as well as the basic financial terms which define those indicators.

The first term that one needs to be acquainted with is depreciation. Depreciation is the spreading of the cost of a vehicle or asset over its useful life (Seal et al., 2006). This cost is a result of wear and tear or obsolescence. Depreciation is an important factor to consider as it decreases the book value of the vehicle and therefore the vehicle's salvage value. It is important to note, however, that the depreciation of vehicles should be calculated but can only be an input into a financial model. Depreciation is what it is and there is no way to change the value thereof (Horngren & Harrison, 2005). The only way in which depreciation will affect the optimal replacement strategy is by weighing in on the salvage value, which if decreases, decreases the advantage of having the said vehicle.

When capital is spent on an activity or product that will increase an assets capacity or efficiency and extend its useful life it is known as capital expenditure (Horngren & Harrison, 2005). An example of capital expenditure is an engine overhaul (as opposed to a general service, which is not a capital expense), adding to the capacity of a vehicle or the refurbishing of a vehicle. In the consideration of the scope of this project, this financial term is important because this is not an expense but rather an increase in the worth of a vehicle. Therefore, instead of diminishing a company's profit margin, capital expenditure increases the salvage value and operational worth of a vehicle.

A company's shareholders essentially have money invested in that company, and for this reason 'charge' the company for the use of their money. This is called capital charge. The return to the company's shareholders and creditors should be larger than the company's capital charge. The equation (Horngren & Harrison, 2005) for capital charge is:

#### Equation 1

$$\text{Capital Charge} = \left( \frac{\text{Notes Payable} + \text{Loans Payable} +}{\text{Longterm Debt} + \text{Stockholders Equity}} \right) \times \text{Cost of Capital}$$

The first financial indicator to consider is Return on Investment (ROI), which is the ratio of net operating profit to average operating costs, or the product of the margin and turnover (Seal et al., 2006). Obviously, the higher the ROI is for a company, the better, due to their profits exceeding their assets. It would be a waste of money for a company to own assets that cost more than what they generate in terms of income.

## Equation 2

$$ROI = \frac{Net\ Profit}{Operating\ Assets}$$

Secondly, Return of Investment Capital (ROIC) should be noted as it is closely related to ROI, however it includes the consideration of dividend payouts to stakeholders. ROIC assesses a company's efficiency in allocating all capital under its control to investments that yield profit (Investopedia). The following equation is that for ROIC and helps one determine how well a company is using its money to generate income.

## Equation 3

$$ROIC = \frac{Net\ Income - Dividends}{Total\ Capital}$$

Total capital includes common and preferred shares, as well as long-term debt. ROIC is a ratio which is normally stated as a percentage.

Profit before interest and tax (PBIT) is simply a calculation of total income minus operating expenses. As the acronym states, this calculation excludes the consideration of taxes and interest.

## Equation 4

$$PBIT = Income - Operating\ Expenses$$

PBIT is also referred to as EBIT (Earnings before Interest and Tax), operating income, operating profit or even operating earnings (Foo, 2009) and can be seen clearly by the perusal of a company's income statement. Foo described the importance of using PBIT as follows,

*"For companies with minimal depreciation and amortization activities, profit before interest and taxes (PBIT) is monitored closely by the creditors since it represents the amount of cash that the companies can earn to pay off creditors." (Foo, 2009)*

We can use a combination of all the above financial indicators to analyse the effect of certain actions and decisions on a system. In this way, we can make decisions from the financial perspective and as a result will be able to minimize the costs involved.

## 2.1.4 Costs

Due to the high level of intensity within the logistics industry, money being spent on logistics every year is increasing at an alarming rate. It is virtually inconceivable to run a company without the use of transportation, and as a result, American companies spent \$554 billion in 1999 on transportation costs alone (Coyle et al., 2003). IMPERIAL Distribution spends approximately R36 million per annum on

transportation. Therefore, being able to reduce transportation costs by even a couple of percent will save IMPERIAL Distribution hundreds of thousands of Rand.

Transportation of goods or the delivery of services to customers is a very important task which can prove to be very expensive without correct management. Effective distribution logistics is therefore, one of the main aims of modern companies who wish to provide a high level of customer service with minimal investment and cost. Most researches normally overlook the fact that vehicles form a large part of logistics costs. Repoussis and Tarantilis cited Toth and Vigo to explain that fuel, maintenance and wages are all vehicle factors that affect daily logistics costs (Repoussis & Tarantilis, 2009). Optimizing routes to expend as little fuel and time as possible is one thing, but being able to reduce the total cost of vehicles (with better service plans, fuel consumption and ageing) will take the logistics costs into another dimension. Just making small changes in fleet choices and management can have a substantially positive effect on the profit margin at the end of the day.

The following pie chart (RFA, 2008) illustrates the breakdown of vehicle costs over five years, as researched by the Road Freight Association. As can be seen, the total cost consists of both fixed and variable cost items. The largest part of the total cost comes from fuel and oil costs, which is the main cause for many organisations to argue that a vehicle cannot be considered an investment, but merely an asset.

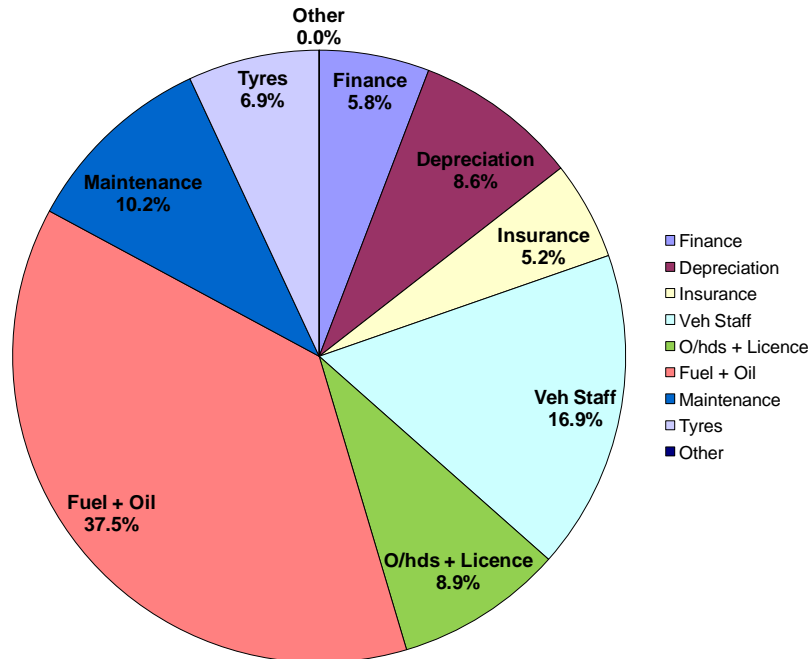


Figure 8: Vehicle Cost Pie Chart (RFA, 2008)

Vehicles are expensive due to three main reasons; their initial cost is elevated, they depreciate over time and they have unavoidable maintenance costs. In addition, not only do these three costs exist, but they also increase by at least the inflation rate every year. As a result, it is not enough for a company to merely budget enough for the initial purchase of the vehicle, but rather to ensure that they have the available cash flow to maintain the vehicle too.

### 2.1.4.1 Variable Costs

Variable costs are those costs that vary in direct proportion to the activity level (Seal et al., 2006). Each unit variable cost is always constant, resulting in an increased sum for an increased level of activity. In transportation, variable costs include:

- Fuel (due to different consumption levels)
- Maintenance: makes up between 5 and 10% of a vehicle's operating costs (NZ Transport Agency, 2005). In addition, maintenance costs increase with vehicle age and operation intensity. For IMPERIAL Distribution, maintenance is considered by means of the maintenance  $C_{pk}$  which varies with age and road conditions
- Lubricants, Oil
- Tyres

Maintenance makes up between 5 and 10% of a vehicle's operating costs in New Zealand (NZ Transport Agency, 2005). In addition, maintenance costs increase with vehicle age and operation intensity. This percentage will increase as the delivery distances and weights increase, as is the case in South Africa, where maintenance costs are much higher than in New Zealand, reaching between 25 and 35% of operating costs.

### 2.1.4.2 Fixed Costs

Fixed costs are costs which do not fluctuate with the activity level (Coyle et al., 2003), in other words they are constant regardless of usage. In the case of transportation, fixed costs include:

- Initial purchase price
- Depreciation
- Interest
- Insurance (Transportation Cost and Benefit Analysis II - Vehicle Costs)

### 2.1.4.3 Depreciation

IMPERIAL Distribution depreciates their vehicles using straight-line depreciation with varying percentages for different vehicle types. The residual value of the vehicle is not taken into account when calculating the depreciation of a vehicle. The information pertaining to depreciation of the vehicle fleet can be found on the CY grid, which contains a column which records the depreciation value for the vehicle type. The CY grid will thus be linked to the model as a vital input.

An excerpt of the CY grid displaying some vehicle type’s depreciation percentage is shown below in Table 1.

Table 1: Depreciation percentages from CY grid

CY code	Model	depreciation %
111	Dyna,7-105,Freighter	10%
112	Dyna,7-145,Freighter	10%
113	Dyna,7-145,Freighter	10%
114	Dyna,8-145,Freighter	6.25%
115	Dyna,8-145,Freighter	6%

As can be seen in the table above, most vehicles are depreciated at either 10% or 6.25% although other values exist too. An example of how depreciation is calculated for a single vehicle is now shown for clarity.

Equation 5

$$\begin{aligned}
 \text{Depreciation} &= \frac{\text{Cost of Vehicle} * \text{Depreciation Percentage}}{12 \text{ months}} \\
 &= \frac{750\,000 * 0.0625}{12} = R3\,906.25 \text{ per month per vehicle}
 \end{aligned}$$

Depreciation is included in the model because depreciation costs vary depending on the vehicle cost. Therefore, if one was to replace a vehicle with a cheaper model, the depreciation costs would decrease. By including depreciation in the model, we are assessing the impact of a large expense on the vehicle replacement choice.

2.1.4.3 Income

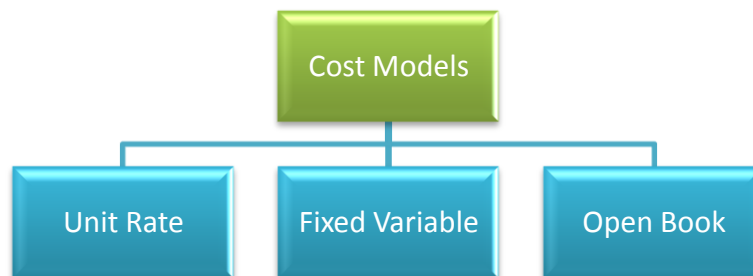


Figure 9: IMPERIAL Distribution Cost Models

As with any company, IMPERIAL Distribution’s income is generated by clients paying their accounts. IMPERIAL Distribution has three cost models that are used to determine the pricing on a contract or

tender. Firstly, there is the unit rate model, with which IMPERIAL Distribution quotes and invoices a client based on the logistics cost per unit. Secondly, the fixed-variable cost model has both an overhead (fixed) cost and a variable cost which increases as delivery volume increases. Lastly, the open book cost model works on the principle of communicating all exact costs to client, increased by a suitable mark-up. With this model, clients pay for what is actually spent, which can be both advantageous or not.

## 2.2 Information Study

An information study is an essential part of a successful project as it includes the obtaining of information that is vital to the project itself but that is not found by the perusal of academic papers. This information includes the considering of software, data and costs, each of which were researched and will be discussed below.

### 2.2.1 Software

There are many software options that can be considered within the context of this project. Firstly, the various software packages available on the market need to be investigated, following which they can be directly compared to one another based on various criteria using a decision matrix in Section 2.3.

For the purpose of the project the following functions need to be fulfilled by means of computer software, as illustrated in Figure 10.

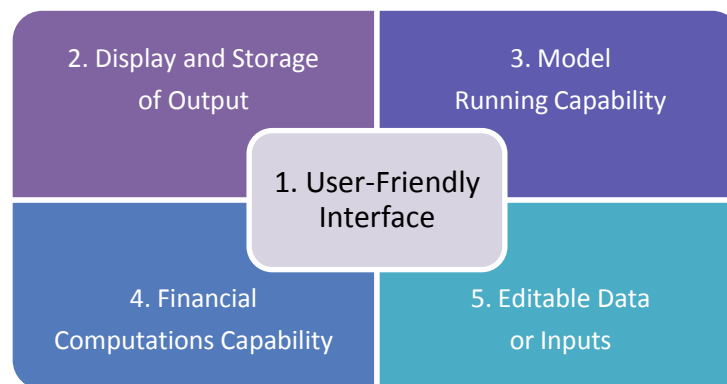


Figure 10: Software Requirements

There are a number of software options available on the market that could fulfil one or more of the above requirements. The research of these software packages was broken up into relevant sections so as to have a basis to compare packages on. Firstly, we look at databases that comply with requirements one and two. Secondly, Microsoft Excel is investigated on the assumption of compliance with requirements one and three through five. The model running capability is also investigated in its own right seeing as it is probably the most vital of the software requirements.

2.2.1.1 Databases

Databases are extremely useful software packages which have the ability to store a vast amount of information and, upon query, to display a certain category of this information. This will be useful within the context of this project in terms of storing contract’s fleets together, as well as being able to access full reports on fleets as required. These lists of fleets and query outputs will then be used as inputs to an optimization model, which will need to determine the replacement strategy, which will result in an update of information on the database pertaining to the newly developed replacement strategy.

According to the Independent Oracle Users Group (IOUG) the leading database products on the market are Oracle and Microsoft’s SQL. The IOUG recently conducted a survey to determine which databases are leaders in providing internal (within companies) and external access (to clients via a website). The results of the survey are shown below in Table 1 (IOUG).

Table 2: Software Options

Software	Internal Use	External Access
Oracle 9i	86%	69%
Microsoft SQL	57%	34%
Oracle 10g	54%	32%
Oracle 8i	50%	23%
Microsoft Access	26%	5%

The first Database we consider is Microsoft’s Access. Access is mentioned for completeness’ sake, even though IMPERIAL Distribution has eliminated it as a possible software package. The functions and design of Access make the program inconsistent, unstable and therefore unreliable. The software would be able to do the job required of it, but not without glitches that could otherwise be avoided with alternative software packages.

Secondly, we consider Microsoft’s most successful database, Microsoft SQL. The basic structure of this software package is shown in Figure 11 below.

Figure 11: Microsoft SQL Function (Symtex, 2010)



The SQL package assists a company in managing data at any time and place (Symtex, 2010). Everything from images to raw data can be stored within SQL with ease, and can be accessed and processed just as easily. Database developers from across the globe have praised SQL as an exciting release for increasing productivity and functionality. SQL costs between \$4 000 and \$25 000 depending on the package size and details. Depending on the extent to which this database will be used by IMPERIAL Distribution, it can be argued that this relatively high cost is justified. As revealed by Microsoft, some of the new features of SQL 2008 include:

- Data compression
- Resource governing
- Database encryption
- Extendible keys
- Extended events

So what is the difference between Microsoft's two products? Many experts believe that SQL is in a very different league from Access. Access has many bugs and faults, which SQL does not exhibit. The reasons why Access is not a prime candidate include:

1. It is unreliable in multiple user environments
2. It is not client-server architecture
3. It is not scalable
4. Network and performance are not consistent
5. Maintainability is labour-intensive

Even Microsoft admits the shortfalls of Access (Symtex, 2010), which illustrates the insufficiency of Access to service IMPERIAL Distribution for the function of this project.

### *2.2.1.2 Optimization Software*

The aim of this project is to determine the optimal fleet replacement strategy for one of IMPERIAL Distribution's clients. As a result, the optimization software is the most important aspect to software choice. There are three available options for this: Microsoft Excel and Lindo's Lingo and What's Best.

Microsoft Excel was not designed as optimization software, however if the spreadsheets are designed in the right manner, using VBA, Solver and macro's, then the software can be manipulated in such a way that it can act as optimization software.

The leader in optimization software is Lindo, who produced both Lingo 7.0 and What's Best? software packages. Lindo's software is highly regarded due to its speed and ease of use, and as such has been used across the world.

*"Our linear, non-linear and integer programming solvers have been used by thousands of companies worldwide to maximize profit and minimize cost on decisions involving production planning,*

*transportation, finance, portfolio allocation, capital budgeting, blending, scheduling, inventory, resource allocation and more.” (Lindo, 2010)*

What’s Best? is an Excel add-in, which can be used to build large-scale optimization models (Lindo, 2010). This is particularly handy in this project due to the interface still being Excel, which every educated employee will have sufficient knowledge in to understand. The only negative aspect of this program is that the base cost of What’s Best?, without any trimmings, runs at \$2 995 per single user (Lindo Systems Inc., 2010). What’s Best? was used successfully by Cunha and Mutarelli to determine the production and distribution of weekly magazines in a developing country (Cunha & Mutarelli, 2007).

Lingo 7.0 is optimization software that runs within its own program (Lindo, 2010). The models are written in simple programming language, with outputs given in the form of matrices and equations. Lingo is highly reputed around the world and is used in numerous tertiary educational institutions to aid teaching of operations research. Lingo is pricey however, costing approximately \$2 995 for a single user utilizing the industrial package.

The disadvantages of using Lingo is that it is very expensive (one needs a licence for every computer, not just for institution), programming knowledge is required and that it does not have any more capabilities than Excel.

### *2.2.1.3 User Interface*

The requirements set out by IMPERIAL Distribution for this project require variable inputs from the program user. This means that a user interface is necessary, and that this user interface will need to be user-friendly. Users should be guided through the use of the framework and model such that the model can produce the optimal solution. There are a couple of viable software solutions with acceptable user interfaces.

Microsoft Excel is one of the most widely used software packages in the world. Practically every single working-man has at least basic knowledge of Excel. Thus, a user interface in Excel would be familiar to the user and easier to navigate through, rather than expecting a user to suddenly acquaint himself with new software. This would require minimal training in software capabilities for the user. Excel is a very stable program and can be used by multiple users at a time.

Secondly, we mention the fact that, as a concept, Access would be sufficient in terms of a user interface. However, the programming involved in creating what is required in Access is extensive and not desirable. In addition, the shortfalls of Access mentioned in the section above apply here as well and as a result; Access is not a viable software solution for a user interface.

Being an Excel add-in makes What’s Best? a software option for the user interface. What’s Best? has all the trimmings that optimization software has and yet holds all the benefits of Excel too.

### 2.2.1.4 Software Combination Possibilities

The following diagram depicts the possible combination of software packages that would as a unit adhere to all the requirements set out in Section 2.2.1 above.

Assessing the diagram below exposes the very common trait of Microsoft Excel as a leading choice in software solution for this problem. Excel is superior because it can act as model, input and output interface. Lingo’s What’s Best? also appears to be a viable solution, in connection with Excel. However, Excel does not cost anything apart from being part of the Microsoft Office Suite (which most computers automatically have installed on them before purchase and is thus included in the purchase price) whereas What’s Best? tends to be on the pricey side.

To choose between all the various software packages which have been introduced in this section, we use the decision matrix as part of the selection of techniques in the subsequent section.

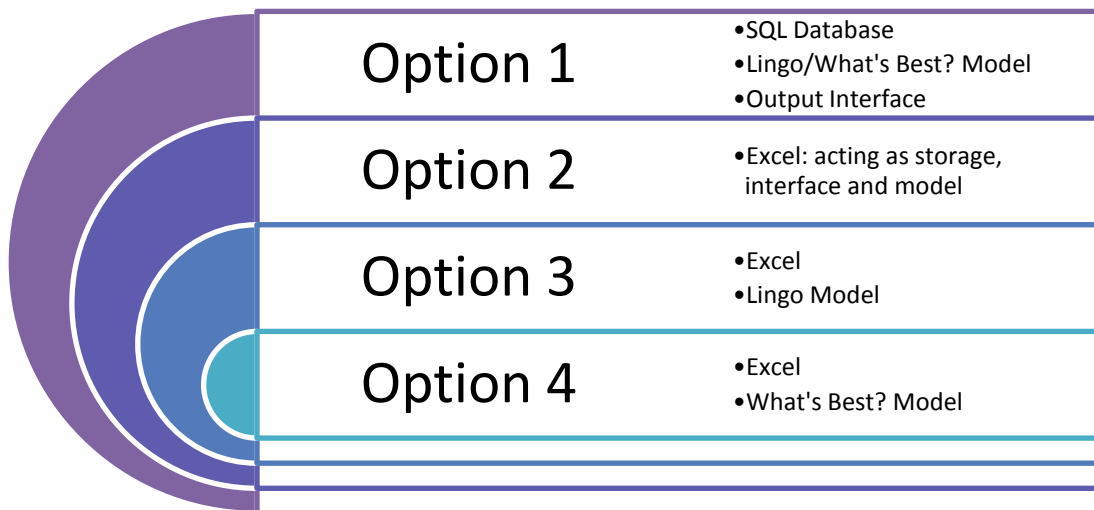


Figure 12: Software Options

## 2.3 Selection of Techniques

For the various phases of the framework, different academic techniques will be used. For the vehicle replacement strategy, one would need to employ a variation of the techniques described by Winston and Venkataramanan in 2003. This technique employs the used of DP to calculate the optimal replacement policy for the given vehicle fleet. To ensure that the ultimate financial benefit is obtained for IMPERIAL Distribution the replacement policy and decision-making will be based on financial indicators which is to include both variable and fixed cost factors, in combination with economic life computations.

To determine the most advantageous software package, or combination, we used what is called a decision matrix. According to Tague a decision matrix evaluates and prioritizes a list of predetermined options. This matrix chooses the most ideal solution by weighing each option against a set of criteria (Tague, 2004). One may use a decision matrix when a list of options is available, but only one option should be selected.

Firstly we need to define the parameters for each of the software packages so that when we compare the options, that the base facts are set. This is done in Table 3. The basis on which the software packages are compared includes cost, user-friendliness, capability and reliability.

**Table 3: Software Comparison**

Software	Cost	User-friendliness	Capability	Reliability
<b>Excel</b>	Free with Microsoft Office	High	All	High
<b>SQL</b>	\$4 000 - \$25 000	Training needed	Store Information; no calculations	As with all databases, bugs occur
<b>Lingo</b>	\$495 - \$6 000 per user	Programming knowledge needed	Calculations; need input and output interface	High
<b>What's Best?</b>	\$495 - \$6 000 per user	High	Need Excel & basic OR knowledge to function	High

Next, one can set up a decision matrix for the various software combinations as described in Section 2.2.1.4, Figure 12. Each decision criteria is given an importance weighting out of a total of ten, and a score out of five. The highest weighted score indicates the software choice which is the most advantageous to Imperial Distribution. This decision matrix is shown in Table 4 with follows on the following page.

Therefore, according to the outcome of the decision matrix in Table 4 (Tague, 2004) the software that should be used for this project is Microsoft Excel (Option 2). This software package holds great value to this project due to its capability to act as both a user interface as well as a calculating tool. Excel is also widely used and known and as a result, users will be more inclined to understand this software package above the rest. Microsoft Excel is already installed on all computers throughout Imperial Distribution and as such, no money will need to be spent in order to run a model which is created in Excel.

Table 4: Software Weighted Score

Criteria	Software	Option 1	Option 2	Option 3	Option 4
<b>User-Friendly</b>	Weight	3	3	3	3
	Score	1	5	4	5
	<b>Total</b>	<b>3</b>	<b>15</b>	<b>12</b>	<b>15</b>
<b>Low Cost</b>	Weight	2	2	2	2
	Score	1	5	2	2
	<b>Total</b>	<b>2</b>	<b>10</b>	<b>4</b>	<b>4</b>
<b>Adaptable</b>	Weight	2	2	2	2
	Score	5	3	3	5
	<b>Total</b>	<b>10</b>	<b>6</b>	<b>6</b>	<b>10</b>
<b>Reliable</b>	Weight	3	3	3	3
	Score	2	5	5	5
	<b>Total</b>	<b>6</b>	<b>15</b>	<b>15</b>	<b>15</b>
<b>Total Weighted Score</b>		<b>21</b>	<b>46</b>	<b>37</b>	<b>44</b>

## 2.4 Chapter Two Summary

Chapter Two's basis has been to find and investigate all the relevant academic literature, information and data pertaining to the problem set out in Chapter One. It is important to understand the background information on a problem so that the problem can be analysed and solved as best as possible.

The academic research section spanned four topics, all of which play a role in this project in some way or form. The most important topic covered was that of transportation and logistics seeing as this is the heart of IMPERIAL Distribution. We learnt that vehicles have many different cost factors, all of which vary with age, conditions and road standards. This will therefore require a lot of attention in the subsequent chapters.

The information study covered topics which are less scientifically based. This includes the issues of software and costs. Various options for software were considered and all information regarding the packages gathered. After the section's brief conclusion, appropriate techniques were selected following which we can now define the inputs to the model, knowing what the model itself will be designed in.

### 3. Model Input Gathering and Analysis

This chapter describes the inputs required for the successful modelling of the problem described in this dissertation. The following is a list of input that needed to be collected as input for this dissertation:

1.  $C_{pk}$  values for all truck sizes
2. Vehicle Master
3. CY Grid
4. Insurance
5. Miscellaneous Inputs

Each of these points will now be discussed in the sections that follow. As each input is different, these sections do not necessarily follow the same format.

#### 3.1 $C_{pk}$ Values

There are two factors which need to be encumbered when one looks at vehicle  $C_{pk}$  values. Firstly we look at maintenance  $C_{pk}$  and secondly at the tyre  $C_{pk}$  for a vehicle. These two  $C_{pk}$  values do not behave the same – maintenance  $C_{pk}$  increases with vehicle age, whereas tyre  $C_{pk}$  remains the same regardless. This can be easily explained in that tyre wear will not depend on the internal workings of the vehicle, but rather only on the travelling distances and conditions.

##### 3.1.1 Tyre $C_{pk}$

Let us first take a look at tyre  $C_{pk}$ . Tyre  $C_{pk}$  is calculated by the maintenance department using historical figures and present costs. The factors that come into play with tyre  $C_{pk}$  calculation are shown in the table below, which illustrates how the tyre  $C_{pk}$  is calculated for a Nissan UD 40L truck. All the  $C_{pk}$  calculations are performed whilst assuming that the truck is purchased new, and as a result has a current kilometre reading of zero.

Table 5: Calculating Tyre  $C_{pk}$

Tyres	UD 40L
Current kilometres	-
Monthly kilometres	5,000
Kilometres after next 5 years	300,000
Tyre expected life	35,000
Cost per recap tyre	600
Cost per new tyre	1,000
Number of recap tyres on truck	4
Number of new tyres on truck	2
Total cost per change	4,400
Total $c_{pk}$	13.00
Our $CPK$	17.00

Now that the method of calculation has been described, one can now investigate the behaviour of tyre  $C_{pk}$  for various vehicle types and sizes. As can be seen in Table 6, tyre  $C_{pk}$  increases with vehicle size, as well as varying between different manufacturers ( $C_{pk}$  is always shown in cents). It is thus imperative that this dissertation's model is linked directly to IMPERIAL Distribution's CY grid so that it can pull the correct tyre  $C_{pk}$  into the model.

Table 6: Tyre  $C_{pk}$ 

CY 1	CY code	Model	No. Tyres	cpk tyres
Dyna4-093	100	Dyna,4-093,Chassis Cab	6	17.6
Dyna5-103	102	Dyna,5-103,Freighter	6	21.8
Dyna5-104	104	Dyna,5-104,Freighter	6	21.8
Hino10-176	116	Hino,10-176,Freighter	6	23.5
Hino12-217	120	Hino,12-217,Freighter	6	23.5

As can be seen above, a Hino 12-217 freighter has six tyres (excluding spares) and has an associated cost of 23.5c per kilometre to maintain these tyres. This  $C_{pk}$  value will remain constant throughout the vehicles life, on the assumption that there is no varying relationship between a vehicle's age and the rate of wear on its tyres.

However, a tyre's wear does depend on the road standard travelled by the vehicle, and for this reason the tyre  $C_{pk}$  for this dissertation is multiplied out by factors which are illustrated in the following table. The application of these factors to the Excel model are to be explained in the cost calculation example in Appendix A, where the logic behind these factors are explained and expressed in equation form, so that the road standard travelled by the vehicle will have an effect on the total cost of operating that vehicle.

Table 7: Tyre  $C_{pk}$  Factors

If road is:	Tyre $C_{pk}$ should be multiplied by:
Normal	1
Hilly	1.1
Gravel	1.2

Hilly roads are assigned a higher value due to the extra strain which the tyres are placed under on inclines. Gravel roads are obviously more rough than tar roads and as such wear down the tyres faster over time in addition to causing bulges and imperfections in the rubber which cause the tyres to fail.

### 3.1.2 Maintenance $C_{pk}$

Maintenance  $C_{pk}$  is the cost of vehicle maintenance for every kilometre that a vehicle travels. This cost is dependant on vehicle type, size and road standard. Maintenance  $C_{pk}$  has a larger amount of factors in its calculation than tyre  $C_{pk}$ . The calculation of maintenance  $C_{pk}$  is illustrated in the following table, using a Nissan UD 40L as an example.

Table 8: Calculating Maintenance C<sub>pk</sub>

Vehicle	UD 40L
Year	new
Current kilometres	-
Monthly kilometres	5,000
Kilometres after next 5 years	300,000
Normal maintenance	
Service every 7,500 Km	R 4,500
<b>Other vehicle maintenance</b>	
Clutch every	40000 km
Brake reline every	67000 km
Propshaft every	250000 km
Injectors every	130000 km
Clutch cost per change	R 5,800
Brake cost per change	R 3,500
Propshaft cost per change	R 3,000
Injectors cost per change	R 4,000
<b>Total cost</b>	<b>R 252 000.00</b>
Total c <sub>pk</sub> maintenance	84c
Nissan CPK	85c
Our CPK normal no abuse or bad roads	44,4c

For this dissertation the *Total C<sub>pk</sub> Maintenance* figure will be used due to the model incorporating the effect of bad roads into the cost before deciding on the replacement strategy. The effect of the road standard on the maintenance C<sub>pk</sub> is calculated as with tyre C<sub>pk</sub>; by using a factor. The maintenance part of this factor is shown in the table below.

Table 9: Maintenance C<sub>pk</sub> Factors

If road is:	Maintenance C <sub>pk</sub> should be multiplied by:
Normal	1
Hilly	1.15
Gravel	1.2

Unlike tyre C<sub>pk</sub> however, maintenance C<sub>pk</sub> does change with vehicle age. This relationship needs to be understood so that its affects can be included in the model. The following set of graphs show the

behaviour of  $C_{pk}$  over time. What we are trying to find is a factor with which we can multiply the  $C_{pk}$  by to get the correct maintenance cost for a vehicle as it increases in age.

IMPERIAL Distribution’s historical data on  $C_{pk}$  values was used to draw up the following graph, from which it is quite clear that maintenance  $C_{pk}$ ’s behave in a similar way. As can be seen in the following set of figures, all the vehicle sizes’ trend lines follow nearly the same gradient, while merely starting at different points on the Y axis. We can thus conclude that the  $C_{pk}$  increases at the same rate across all vehicle sizes, where the extent thereof is merely determined by the initial purchase point’s  $C_{pk}$ .

The graph is not intended to show detail, but rather just the overall relationship between vehicle age and maintenance  $C_{pk}$ . To see the detail pertaining to vehicle types and maintenance  $C_{pk}$  please refer to Appendix B which contains all the relevant graphs.

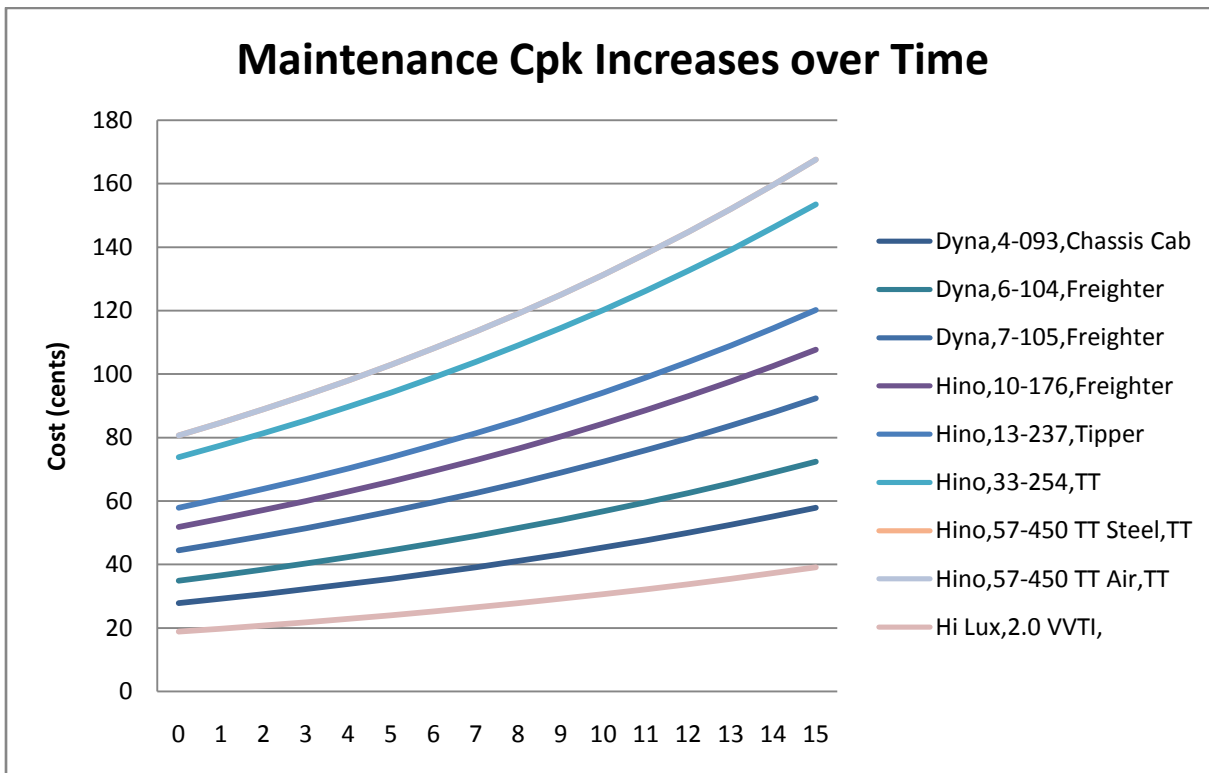


Figure 13:  $C_{pk}$  annual increases

The average yearly increase in maintenance  $C_{pk}$  across all vehicle types is shown in the graph on the following page. As can be seen, the annual increase does appear to follow a linear trend, and as such, what we found in the graphs above seem to be confirmed in this graph too; that maintenance  $C_{pk}$ ’s vary linearly with vehicle age.

Within the built model, the  $C_{pk}$ ’s will thus increase by the gradients found in the analysis in the subsequent graph. As a result, one can now apply these findings to the replacement model by creating a

table which links vehicle type to its age and relevant  $C_{pk}$ . A print screen of this table is shown in the Figure 16 below the following graph. This table is a user-defined variable which may be edited as time passes and IMPERIAL Distribution’s  $C_{pk}$  values change.

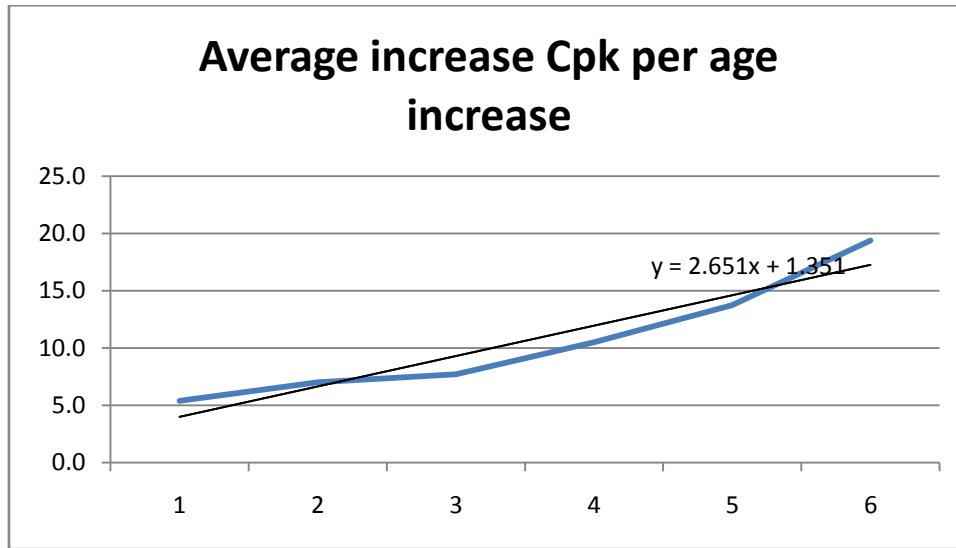


Figure 14: Average annual Cpk increase

Model	0	1	2	3	4	5
Dyna,4-093,Chassis Cab	27.8	29.2	30.6	32.2	33.8	35.5
Dyna,5-103,Freighter	27.8	29.2	30.6	32.2	33.8	35.5
Dyna,5-104,Freighter	27.8	29.2	30.6	32.2	33.8	35.5
Dyna,6-104,Freighter	34.8	36.5	38.4	40.3	42.3	44.4
Dyna,6-105,Freighter	34.8	36.5	38.4	40.3	42.3	44.4
Dyna,7-105,Freighter	44.4	46.6	49.0	51.4	54.0	56.7
Dyna,7-145,Freighter	44.4	46.6	49.0	51.4	54.0	56.7

Figure 15: Maintenance  $C_{pk}$ s per Vehicle Type

Due to the fact that IMPERIAL Distribution only records  $C_{pk}$  values up to a vehicle age of 6 years, the model had to be adjusted so that a maximum  $C_{pk}$  age of 6 years is used, even though a vehicle’s age can extend past 6 years. To do so, an assumption had to be made in terms of the  $C_{pk}$  values over time; that regardless of a vehicle’s age surpassing 6 years, the  $C_{pk}$  value is assumed to stay constant past 6 years. As a result, if a vehicle was 8 years old, the model would assume the  $C_{pk}$  to still be at a level of 6 years. This was accounted for under the following equation.

## Equation 6

$$C_{pk}(\text{year}) = IF(E27 > 0, IF(4.Fleet'!\$D\$12 - 4.Fleet'!E27) > 6, 6, 4.Fleet'!\$D\$12 - 4.Fleet'!E27), 0)$$

Which translates in Lehmanns terms into:

## Equation 7

$$C_{pk} = IF(\text{age} > 0, IF((\text{current year} - \text{purchase year}) > 6, C_{pk} = 6, \text{else}, C_{pk} = \text{current year} - \text{purchase year}), 0)$$

3.1.3 Effect of Road Standard on  $C_{pk}$  Values

Apart from increasing  $C_{pk}$  with vehicle age, one also needs to adjust the  $C_{pk}$  based on the road and travelling conditions. One of the requirements for this dissertation is to consider the effects of road standard or class on the viable lifetime of a vehicle. In able to do this one needs to include a relevant cost which reflects the road standard.

As a result, a section in the Excel model will be dedicated to asking the user how much of the delivery assignments for a particular vehicle cover either flat, hilly or gravel roads. Based on these percentages, the model will then increase the maintenance and tyre  $C_{pk}$ 's by the factors shown in Table 10, which is a summary of that which was presented in the preceding sections.

Table 10: Cpk factor multiplication

If road is:	Multiply Maintenance $C_{pk}$ by:	Multiply Tyre $C_{pk}$ by:
Normal	1	1
Hilly	1.15	1.1
Gravel	1.2	1.2

## 3.2 Vehicle Master

IMPERIAL Distribution's vehicle master is the document that contains all the information pertaining to their currently-owned vehicle fleet. This includes the purchase prices of these assets as well as their location and usage. Due to the fact that this information is absolutely vital to the calculations in the model, it is imperative that the information in the vehicle master stays updated. The vehicle master is a separate document kept on IMPERIAL Distribution's server which is regularly updated. Due to the sensitive nature of the vehicle master's content, the user will be responsible for updating the vehicle master within the excel workbook.

### 3: Model Input Gathering and Analysis

Once the user has updated the relevant information, the *Vehicle Master Update Complete* button should be pressed so that the new information is updated into all the relevant drop down lists and tabs. This button can be seen in Figure 16 below.



**Vehicle Master**

Vehicle Master Update Complete

To update the vehicle master list copy and paste the same format onto this page from the latest *Imperial Logistics - Asset Tech Imperial Distribution Final.xls* document.  
Do **NOT** copy or edit the column headings, just the vehicle entries.

	Nr of Assets	Nr of Active Assets	Missing Reg No		
Summary Line	613	578	3		

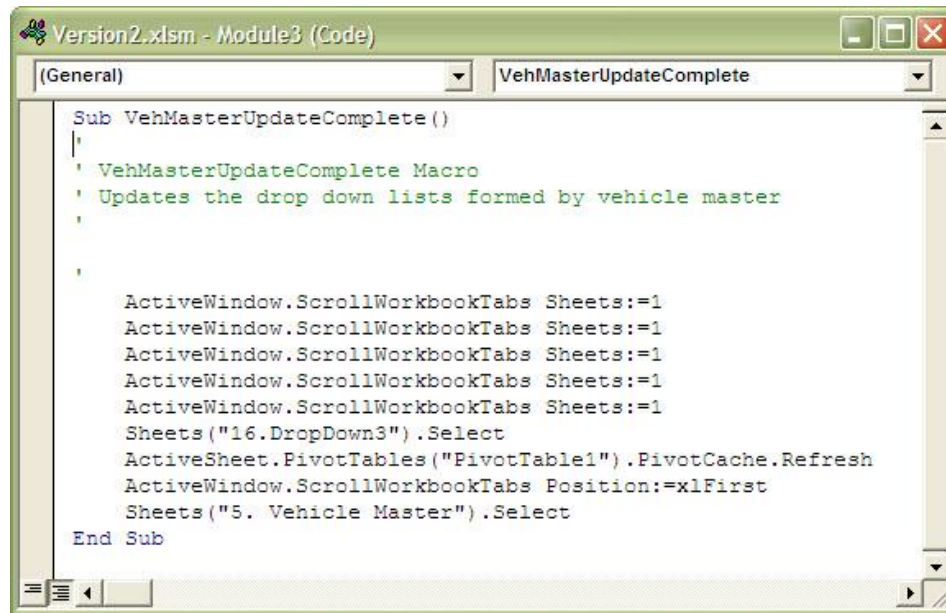
Verification	Asset No	Fleet No	Status	Registration No	Vehicle_Make	Model (Introduction Year)
Invalid MM Inf	1018	54743	Active	HKC618GP	HINO	10-146 F/C C/C - (1994)

Figure 16: Vehicle Master

This button functions on a macro which is activated when the button is pressed. The macro runs in the background and fetches all the new information, placing it in the relevant positions elsewhere in the spreadsheet whilst refreshing all the linked tables. This macro was written in VBA and is shown in the figure on the following page.

It is important to point out that due to the size of the information being imported, that the macro might take up to half a minute to run to completion, for which time the user should just be patient. Even more important is the fact that the location of the vehicle master must not change with respect to the document. This is because the macro fetches the document from a specific location and will thus fail if the location or tab name is changed. This becomes null and void if the user has enough VBA knowledge to change the destination of the macro.

Due to the nature of the information contained in the Vehicle Master, a copy of it cannot be attached to this document. This is because this information is confidential due to it containing fine details about the assets, locations and value of these assets.



```

Sub VehMasterUpdateComplete ()
'
' VehMasterUpdateComplete Macro
' Updates the drop down lists formed by vehicle master
'
'
'
ActiveWindow.ScrollWorkbookTabs Sheets:=1
ActiveWindow.ScrollWorkbookTabs Sheets:=1
ActiveWindow.ScrollWorkbookTabs Sheets:=1
ActiveWindow.ScrollWorkbookTabs Sheets:=1
ActiveWindow.ScrollWorkbookTabs Sheets:=1
ActiveWindow.ScrollWorkbookTabs Sheets:=1
Sheets("16.DropDown3").Select
ActiveSheet.PivotTables("PivotTable1").PivotCache.Refresh
ActiveWindow.ScrollWorkbookTabs Position:=xlFirst
Sheets("5. Vehicle Master").Select
End Sub

```

Table 11: Macro for Updating Vehicle Master List via Asset Register

### 3.3 CY Grid


The CY grid is an input into the model in the sense that it holds some vital information pertaining to the vehicle fleets owned by IMPERIAL Distribution. It is an Excel spreadsheet which contains all the costs associated with all the vehicles on the asset register. This worksheet is extremely large and contains a lot of information, most of which this project does not require.

To draw the appropriate information from the CY grid we make use of a *vlookup* function, which finds the information that corresponds with the selected vehicle. It then makes a reference to this information and uses it whenever an equation is specified. The *vlookup* function for one of the calculations is shown in Equation 6.

#### Equation 8

$$= VLOOKUP("Cell\_Reference\_Vehicle\_Name", SheetCY\_Grid! A1: B650, 2, FALSE)$$

Just for interests sake a section of the CY grid is included here so that the reader can visualise the format of the data which is provided as input for the model. This part of the CY grid is showing the relevant license fees linked to every vehicle type. These license fees are representative of the size of the vehicle, as well as the province of registration. For example, CY code 106 is a Dyna 6-104 freighter. This vehicle, however many IMPERIAL Distribution may own, costs IMPERIAL Distribution R957 in licensing fees.



## CY Grid

CY Grid Update Complete

**NB:** When updating this sheet, please copy **ONLY THE VALUES** from the CY grid, NOT the column headings. In addition, paste the **VALUES ONLY** (to do this access the drop down below 'Paste' in the 'Home' tab.

CY 1	CY code	Model	Licence fee	Gauteng	KZN	W Cape	E Cape - Apr 08
Dyna4-093	100	Dyna,4-093,Chassis Cab	516	642	891	1032	786
Dyna4-093	101	Dyna,4-093,Chassis Cab	516	642	891	1032	786
Dyna5-103	102	Dyna,5-103,Freighter	597	774	1131	1032	999
Dyna5-103	103	Dyna,5-103,Freighter	597	774	1131	1032	999
Dyna5-104	104	Dyna,5-104,Freighter	873	1071	1446	1737	1280
Dyna6-104	106	Dyna,6-104,Freighter	957	1182	1599	1881	1416

Figure 17: CY grid

### 3.4 Insurance

Insurance is an important cost to consider in the replacement-point problem. This is due to the fact that vehicle insurance is calculated 5.5% of the market value of the vehicle and is paid out monthly. If a truck has a higher market value, the insurance would increase.

So for example, if a truck is valued at R450 000, then the monthly insurance on the vehicle is calculated as follows:

**Equation 9**

$$\text{Monthly Insurance} = \frac{0.055 * \text{Vehicle Value}}{12} = \frac{0.055 * 450\ 000}{12} = R\ 2062.50 \text{ per month per vehicle}$$

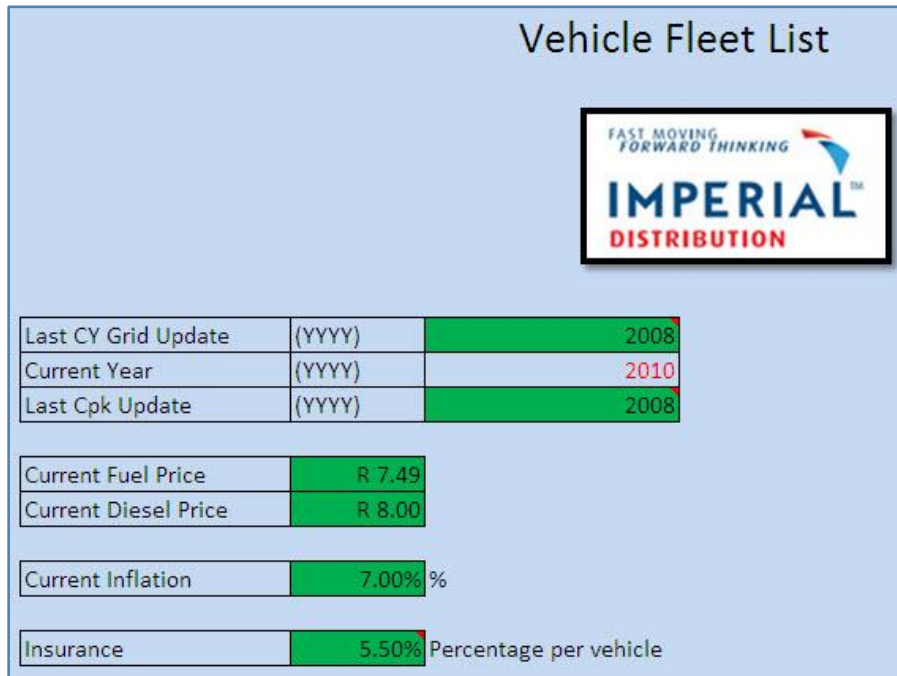
This will need to be compared to the insurance cost of a new vehicle, whether the purchase cost increases or decreases.

The insurance cost is calculated on a separate tab in the Excel Spreadsheet so that if company policy changes and the percentage required for insurance was to increase or decrease the user could edit just one cell pertaining to this value, in lieu of changing all the insurance cost calculating cells in the workbook.

### 3.5 Miscellaneous Inputs

There are a couple of inputs required by the model which cannot be classed into the categories of this chapter. A print screen of these inputs from the Excel document is given in Figure 18.

The CY grid update – date is included so that the user knows when last the CY grid was updated. This will help ensure that the data is recent. It also provides the baseline year so that all costs can be increased by inflation from that year.




Vehicle Fleet List		
		
Last CY Grid Update	(YYYY)	2008
Current Year	(YYYY)	2010
Last Cpk Update	(YYYY)	2008
Current Fuel Price	R 7.49	
Current Diesel Price	R 8.00	
Current Inflation	7.00%	
Insurance	5.50%	Percentage per vehicle

Figure 18: Miscellaneous Inputs

The fuel and diesel prices are to be inserted here manually so that the vehicles variable cost can be calculated accordingly. The inflation rate needs to be inserted too so that the model can compute future costs based on this figure.

The insurance percentage is not a value that is likely to change often at all. However, it is added here so that if IMPERIAL Distribution was to change their insurer or insurance policy that the user can just change this one cell, instead of changing relevant formula which are spread across the entire Excel workbook.

### 3.7 Comprehensive Example of Cost Calculation

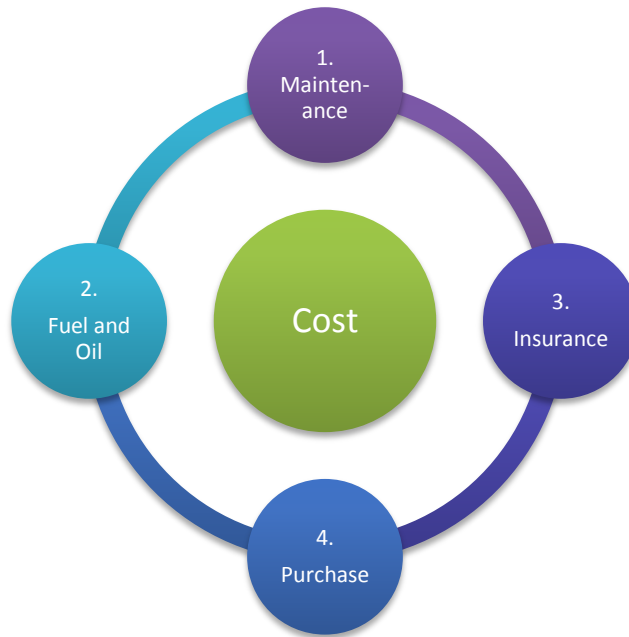


Figure 19: Cost factors

The costs considered for every individual vehicle span purchase, maintenance, obsolescence, insurance, fuel and lubrication. A comprehensive cost example is provided in Appendix A.

### 3.8 Chapter Three Summary

Within this chapter we have defined the inputs that are necessary for this model to work. We investigated the change of  $C_{pk}$ 's with age, as well as the effect which road standard has on these figures. We then took a brief look at how the inputs are inserted into the Excel model, and what form they would take. We concluded with an example of how the cost calculations are being performed on the inside of the model, where the user cannot see it, neither access it.

## 4. Solution Design and Evaluation

This chapter is a very vital one to the success of this dissertation, seeing as it is the practical application of the chosen solution to the problem which has been thoroughly described from Chapter One. This chapter has three parts to it, which is illustrated in the following Chevron process diagram.



Figure 20: Chapter Map

**Note:** It is important to note, that for this chapter the word ‘solution’ refers to the chosen solution for this problem. It is by no means the only solution to this dissertation’s problem, an assumption which would be unfounded. Please proceed through the rest of this chapter with this in mind.

### 4.1 Part 1: Solution design

This dissertation has been based on the problem concerning when a vehicle should be replaced so as to minimize the total operational cost of the vehicle. One of the possible solutions of this problem is to develop a model which merges all the relevant data into a decision tool which helps the user to determine whether or not the vehicle is economically viable.

At first, the Excel model was meant to determine a single vehicle’s entire life cycle and inform the user at which point in the next 6 years the vehicle would need to be replaced. Despite the numerous advantages associated with this type of model, the Managing Director of IMPERIAL Distribution asked for a more simplified, practical solution to this problem. Upon encouragement from the Business Analysis manager, the model is now designed to calculate the costs associated with the delivery weighting over the period of six months, and encompasses the entire fleet assigned to a specific client. This meets the needs of IMPERIAL Distribution more directly, seeing as the user just needs to insert a list of vehicles and run the model once. Even though it appears to be a less glamorous solution given the removal of the life cycle predictions, this solution is in fact more complex and more practically applicable to IMPERIAL Distribution at the same time.

#### 4.1.1 Excel Workbook

The model for this dissertation was designed in Microsoft Excel. A comprehensive breakdown of this document is given in the subsequent sections so that the reader can grasp how the problem was solved, and why the workbook appears as it does.

Firstly, when designing the model in Excel, the flow was determined and the structure then designed to fit the flow. The inputs and outputs were separated from each other so that the user would not per accident edit calculation fields, and so that the answer and the summary thereof can be easily interpreted. Every separate calculation area (for example depreciation or new vehicle purchase) was assigned its own tab so as to not clutter the workbook, as well as allowing for traceability throughout the workbook. In this way, if an error or calculation needed to be traced it would be reasonably easy to locate the point in question.

The workbook is extensively linked within itself. This means that the calculations were spread out as far as possible, instead of calculating everything in a single cell. This also allows for great traceability, while assisting the writer to not make errors during the solution design. In addition to these two advantages, designing the model in traceable fragments also means that future additions and alterations would be much easier.

### *4.1.1.1 Tabs*

The order of the tabs was selected as follows to ensure that the user will not have to navigate to and fro across the document. The tabs are arranged so that the user can move sequentially from Tab 1 to 4 and then exit the model. In this way the user will not become disorientated or confused and will not be given the opportunity to alter important equations and formulae which will be contained in the latter tabs. These calculation tabs could very easily be hidden in Excel, but for the sake of future alterations and additions these tabs were not hidden from IMPERIAL Distribution.

1. Index
2. Instructions
3. Input
4. Output
5. Vehicle Master
6. CY Grid
7.  $C_{pk}$
8. Book Values
9. Overhaul Cost
10. Contracts Vehicles Accounting
11. Drop Down 2
12. Inflation
13. Overhaul Distance
14. Drop Down 3
15. Drop Down List
16. Vehicle List
17. Current Vehicles
18. Replace New

- 19. Cpk Maintenance
- 20. Cpk Tyres
- 21. Purchase Prices

The tabs were coloured as shown in Figure 21 so that the user will know whether or not to utilize a tab. The red tabs are obviously a no-go area for the user of the model seeing as these tabs contain formulae and calculations which should not be altered.

After reading all the information on the blue tabs the user will proceed to filling in all the manual inputs on the yellow tabs. The inputs for the model will be presented on the first green tab (*'Input'*) whereas the result of the model will immediately be available on the second green tab, *'Output'*.

Vital Information		
The TABS are coloured as follows:		
i	BLUE Tabs	Read BEFORE using model; information and help
ii	GREEN Tabs	User input required.
iii	YELLOW Tabs	Contains information which needs to be updated as often as possible
iv	RED Tabs	Not to be edited or accessed by user
**	On the active tabs, cells which require user input are highlighted in GREEN	

Figure 21: Vital Information for Excel Model

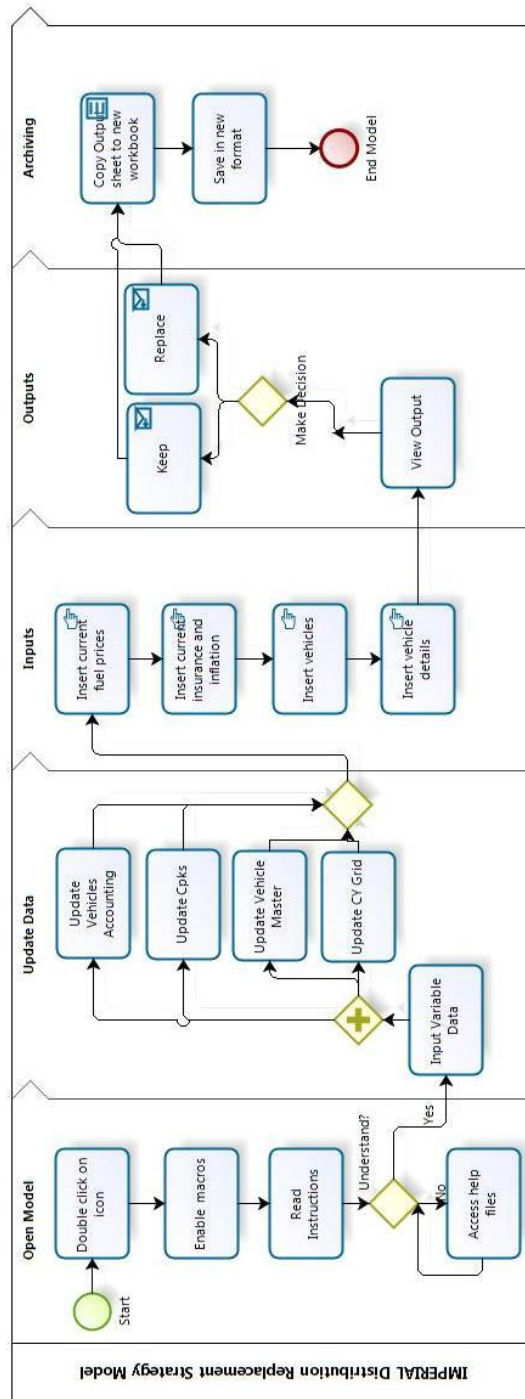
#### 4.1.1.2 Functioning

The basic model flow is described in the BizAgi process model diagram below. The flow was made as logical as possible so as to make it user friendly. Unless all the steps are followed the model will not run to completion. However, provision had to be made for the omission or addition of certain information so there are steps which have multiple options. The information and inputs required for the model are all concurrent events and as such can be completed in any order, as long as they are all completed before running the model.

Most of the process steps in the diagram below can be expanded into further sub-processes. The lowest level of sub-process is designed to handle any possible combination of events and decisions made by the user.

One can see the logical flow of the Excel document. Firstly, the user will make use of the instructions and help tabs, until they feel comfortable enough to use the model. Next they will insert and update data sources. This will ensure the validity of the model. After all the relevant data is available, the model

will be able to run and process an output. This output will then be available to the user and he/she will be able to interpret it and use it.



powered by  
BizAgi  
Process Modeler

Figure 22: Excel Workbook Flow in BizAgi

#### 4.1.2 Designing to Meet Project Requirements

This section is intended to illustrate how the model requirements were met throughout the design of the model. The said requirements are those that were set by IMPERIAL Distribution in the investigation phase of this dissertation (Chapter 1), as well as extra requirements that the author added so as to increase the ability and usability of the model.

The subsections that follow include:

- i. Differentiating between vehicle types
- ii. Overhaul
- iii. Road type and its effect on maintenance cost
- iv. User friendliness

##### 4.1.2.1 Differentiating Between Vehicle Types

The Excel model is designed in such a way that all the relevant information pertaining to a specific vehicle and the choice thereof is included in the decision calculation. Each vehicle has its own fuel consumption, insurance costs, depreciation costs and so forth which all carry different advantages and disadvantages. In this model, we wish to weigh the advantages and disadvantages of different vehicles against one another so that the most economically advantageous option can be chosen for IMPERIAL Distribution.

For each vehicle inserted into the model (by its registration number) it needs to be compared to purchasing a new vehicle of the same type. The factors that are weighed against one another are shown in the table below, as well as the general behaviour of the factors according to vehicle age.

Table 12: Cost Factors

	Current Vehicle (Old)	Replacement Vehicle (New)
<b>Insurance</b>	↓	↑
<b>Depreciation</b>	↓	↑
<b>Purchase Cost</b>	N/A	↑
<b>Maintenance Cpk</b>	↑	↓
<b>Tyres Cpk: Initial</b>	↑	↓

Ultimately, we need to ascertain whether or not the advantage of lower Cpk values and overhaul services outweigh the higher insurance, depreciation and purchase price.

#### 4.1.2.2 Overhaul

Depending on the vehicle's size, there comes a time in the vehicle's economic life when an overhaul is necessary. The mileage at which a specific vehicle size requires an overhaul is shown in the table below.

Table 13: Overhaul Distances

Size Category	Distance to Overhaul
1t	350,000km
1t	350,000km
1.5-4t	350,000km
1.5-4t	350,000km
1.5-4t	350,000km
6-8t	425,000km
6-8t	425,000km
> 8 t	900,000km

The costs associated with an overhaul are fourfold. Firstly, there is the cost of the parts; engine, gearbox and differentials (see Table 14). The fourth cost component is that of the downtime cost of the vehicle. As can be seen in the table below, different vehicle sizes have different overhaul lengths, and while the vehicle is down, the client's deliveries still have to take place. As a result, for every day that a vehicle is out of service, a similar vehicle needs to be hired in its place in order to complete all the deliveries on time (see Table 15). Therefore, the cost of a vehicle overhaul can be quite extensive. This is shown in the table on the following page.

Table 14: Partial Excerpt: Overhaul Costs

	Costs:			Total Cost:
	Engine:	Gearbox:	Differential:	
<b>4x2 1 Ton Vehicle</b>	25,000.00	40,000.00	6,000.00	<b>73,125.00</b>
<b>4x2 2.5/3.0 Ton Vehicle</b>	29,000.00	44,000.00	7,000.00	<b>84,200.00</b>
<b>4x2 4 Ton Vehicle</b>	30,000.00	45,000.00	8,000.00	<b>87,340.00</b>
<b>4x2 5/6 Ton Vehicle</b>	35,000.00	50,000.00	9,000.00	<b>100,800.00</b>
<b>D/Axle Truck Tractor</b>	60,000.00	95,000.00	30,000.00	<b>208,800.00</b>
<b>Poni Semi-Trailer</b>	55,000.00	80,000.00	9,000.00	<b>167,800.00</b>

Table 15: Partial Excerpt: Downtime Costs

	<b>Downtime (Working Days):</b>	<b>Hiring Cost (Pool Fleet Rate) per Day:</b>	<b>Total:</b>
<b>4x2 1 Ton Vehicle</b>	5.00	425.00	<b>2,125.00</b>
<b>4x2 4 Ton Vehicle</b>	7.00	620.00	<b>4,340.00</b>
<b>4x2 5/6 Ton Vehicle</b>	8.00	850.00	<b>6,800.00</b>
<b>4x2 7/8 Ton Vehicle</b>	10.00	1,200.00	<b>12,000.00</b>
<b>6x2 12 Ton Vehicle</b>	13.00	1,500.00	<b>19,500.00</b>
<b>S/Axle Truck Tractor</b>	14.00	1,700.00	<b>23,800.00</b>
<b>D/Axle Truck Tractor</b>	13.00	1,700.00	<b>22,100.00</b>
<b>Poni Semi-Trailer</b>	12.00	1,700.00	<b>20,400.00</b>
<b>S/Axle Semi-Trailer</b>	10.00	1,700.00	<b>17,000.00</b>
<b>D/Axle Semi-Trailer</b>	12.00	1,700.00	<b>20,400.00</b>

To include overhaul in the Excel model, an *if* statement was set up to flag a value if the cumulative mileage reaches a multiple of the overhaul distances shown in Table 15 above. If flagged, the model then assigns the relevant cost (according to vehicle size) to the vehicle concerned. This will be added to the total vehicle cost and will thus be a disadvantage to the choice of that particular vehicle.

#### 4.1.2.3 Road Type and its Effect on Maintenance Cost

Accounting for the effect of road type on the maintenance cost of the vehicles was done by employing a factor by which the cost needs to be increased by for a given type of road. For this, a set of values was required which represent the fraction of the contract distance which takes place on each of the three road types: normal, hilly and gravel. This was done by creating a user input which is to be completed for every vehicle on the contract (see Figure 23).

Road Standard			Data Check
Normal	Hilly	Gravel	
80%	10%	10%	OK
60%	10%	30%	OK
60%	30%	0%	ERROR

Figure 23: Road Standard

The default value is set on 100% normal. If the sum of assigned percentages does not add up to 100% then an error message is given in bright red, as can be seen in Figure 23, which will prompt the user to check the relevant cells.

These user inputs then become the weighting for a calculation which increases the  $C_{pk}$ 's as relevant. This cell equation for maintenance  $C_{pk}$  looks as follows: (the computation of tyre  $C_{pk}$  is identical)

#### Equation 10

$$\text{Adjusted } C_{pk} = (C_{pk} * \text{Normal}\% * 1) + (C_{pk} * \text{Hilly}\% * \text{Hilly Factor}) + (C_{pk} * \text{Gravel}\% * \text{Gravel Factor})$$

This equation considers the weighting (percentage) of travel distance on a given road standard, and then increases the  $C_{pk}$  proportionally by the factors defined in table 10 (Section 3.1.3). As a result, a road which is predominantly gravel will have a much higher  $C_{pk}$  than one which is normal. This equation will take the higher maintenance costs associated with road standards into account when choosing a replacement strategy.

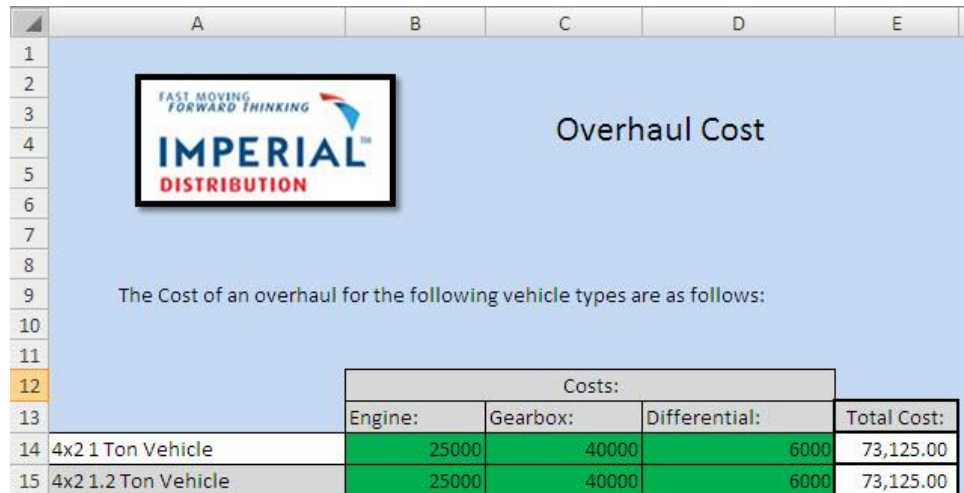
For an example of a practical cost calculation which shows how this road standard is factored into the cost calculation please see Appendix A, Section 1.

#### 4.2.1.4 User Friendliness

Being user friendly was a very important requirement for this model, seeing as it is not a once-off model like many other projects which gives a definitive answer and it ends there. Rather, this model is a tool to be used by IMPERIAL Distribution's business analysts at least biannually. Due to this, it was important to design the model to be as user-friendly as possible, so that glitches wouldn't arise.

Firstly, colours were utilized to assist the user in progressing through the model. Green cells indicated values that must (on input) or could (on data sheets) be edited by the user. This is illustrated in the figure below. As can be seen, the costs associated with the various aspects of overhaul are highlighted in green. This means that these values can be edited, and the new values would automatically update the

calculations elsewhere in the workbook. This is practical because service costs will change over time and IMPERIAL Distribution need to be able to edit these costs.



		Costs:			
		Engine:	Gearbox:	Differential:	Total Cost:
14	4x2 1 Ton Vehicle	25000	40000	6000	73,125.00
15	4x2 1.2 Ton Vehicle	25000	40000	6000	73,125.00

Figure 24: Coloured Cells

Colouring the cells makes a model more user friendly because the user will be able to tell from a glance where his/her input is required.

Instructions also help to make a model more user friendly. Obviously if a user knows what he/she will have to do they will be able to utilize this tool more effectively and efficiently. Instructions are added to the model in three forms. Firstly, there is an *Instructions* tab which contains all the relevant instructions for running the model. This can be seen in Figure 25 below.

Each subheading can be expanded (as *Getting Started* is in the figure) by clicking on the addition symbols to read the finer details. The instructions were concatenated in such a way so that the page would not be cluttered.

The second way in which instructions were implemented in the model is by means of comments throughout the model. If the user's mouse wandered over the relevant cell, a comment would pop up, as shown in Figure 26, which provides the user with more information on how to complete a certain cell.

	A	B	C	D	E	F
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
19						
21						
23						
24						
27						
30						
35						
39						
44						
50						

<ol style="list-style-type: none"> <li>1 Getting Started             <ol style="list-style-type: none"> <li>i Opening the document</li> <li>ii Important Points</li> <li>iii Input Forms</li> <li>iv Data Masking</li> </ol> </li> <li>2 Entering Data</li> <li>3 Running the Model</li> <li>4 Intepretation of Output</li> <li>5 Editing the vehicle master</li> <li>6 Editing the CY grid</li> <li>7 Editing the Cpk values</li> <li>8 Archiving Results</li> </ol>
-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

Figure 25: Instructions

Last CY Grid Update	(YYYY)	2009	Enter date of last CY grid update (Ref: CY grid Tab 6)
Current Year	(YYYY)	2010	
Last Cpk Update	(YYYY)	2010	

Figure 26: Comments

In the event that the user still has a problem, he/she can click on the help buttons throughout the document which would divert them to the *Help* tab where the relevant help section would be opened for them.

Another feature that was added to the model was done to allow for future additions into the model. Here, the additions can refer to new vehicles, vehicle types, sizes and models. If additions are made, the model will pick them up and add them to the relevant formulae and calculations by means of a dynamic name range. This is done by using the *offset* function, which is shown below in the example of how the drop down lists automatically update following an addition to the CY Grid.

## Equation 11

$$= \text{OFFSET}('5. CY Grid'! \$A\$1,9,0, \text{COUNTA}('5. CY Grid'! \$A: \$A) + 1, \text{COUNTA}('5. CY Grid'! \$10: \$10))$$

Ultimately, this tool has been designed for a user, and as a result, as much allowance was made for the user as possible, to ensure that the user has a positive experience of the model, while still maintaining the accuracy and dependability of the model's output.

### 4.1.3 Model Input

This section describes the trucks which are to be inserted for investigation by the model. These trucks, or 'fleet' if you will, are those assigned to a specific contract owned by IMPERIAL Distribution. As a result, the future usage (in next six months) can be estimated.

The crux of this model would not work without the most basic input: the vehicles to be investigated. As a result, this data input needs to be in a very specific format. In order to achieve continuity and uniformity an input sheet was designed for this very purpose. This input sheet is shown in Figure 27 on the next page and contains columns like vehicle type (drop-down list as defined by Asset Register), engine type (needed for fuel calculations), size (needed for  $C_{pk}$ ), current and estimated future mileage (needed for maintenance costs) and replacement cost (necessary for comparison).

The green cells on the sheet are those cells which require user input. By colouring the cells strategically, the user will be able to identify inputs at a glance. The entry at the bottom of the figure shows what an empty entry looks like.

It will be very important that the inputs are entered correctly into this input sheet. Incorrect data will return a wrong answer, no matter how good the model is. As a result, this input sheet will have extensive and clear instructions which will guide the user through its use, in addition to limiting the majority of the inputs to drop down selections.

Given that the inputs are entered correctly, the rest of the model will fetch all the relevant details pertaining to the inserted fleet and calculate the replacement strategy directly. What makes this interesting is that because the calculations are instant, the effect of changing the loading on a vehicle can be investigated. Say for example, a vehicle with 45 000km worth of deliveries is currently displaying a *replace* message. If that loading is reduced to 10 000km the message would change to *Keep*. This is a handy side-tool which IMPERIAL Distribution can use if the need for it arises, or just for interest's sake.

4: Solution Design and Evaluation

### Vehicle Fleet List

Last CY Grid Update (YYYY)		2009	
Current Year (YYYY)		2010	
Last Cpk Update (YYYY)		2010	
Current Fuel Price		R 7.94	
Current Diesel Price		R 8.14	
Current Inflation		7.00%	
Insurance		5.50%	

No.	Vehicle Type	Reg No.	Size	Purchase Year	Engine	Km in next 6 months	Cost of new vehicle	Road Standard	Data Check	Keep/Replace	% cost as Maintenance
1	Hino,33-254,TT	CA103478	4x2 4 Ton Vehicle	2006	Diesel	310,000	R 572,693.00	Normal 80%	Hilly 10%	Gravel 10%	33%
2	Hino,12-217, Freighter	RNG468GP	4x2 2.5/3.0 Ton Vehicle	2004	Diesel	249,000	R 464,883.00	Normal 60%	Hilly 10%	Gravel 30%	33%
3	Hino,12-217, Freighter	MLC353GP	6x2 12 Ton Vehicle	2001	Diesel	400,000	R 484,883.00	Normal 70%	Hilly 30%	Gravel 0%	31%
4	Hino,10-176, Freighter	CA120092	4x2 4 Ton Vehicle	2006	Diesel	300,000	R 438,027.00	Normal 100%	Hilly 0%	Gravel 0%	30%
5				None			None	100%			None

Summary	
Replace	3
Keep	3
Total No of Vehicles in Fleet	
	5

Figure 27: Model Input Sheet  
Seline van der Wat

#### 4.1.4 Model Outputs

This section describes the outputs of the Excel model. Within the workbook, the output can be found on Tab 4, *Outputs*. Rather than presenting the output on the same sheet as the inputs, the results were separated to allow for better understanding. The *Outputs* tab is a more compact and visual which gives the user a very vivid summary. The tab is divided into four subsections which summarize the contract details, fleet, cost and cost division.

An example of the output sheet is shown in Figure 32 on page 51. Some important points will now be highlighted in all the various sub sections.

Firstly, the fleet summary shows the vehicle list and the decision prescribed by the model. This can be seen on the right of Figure 28 below. Adjacent to the fleet summary is the cost summary which shows the average and total cost in the next six months for all vehicles in the fleet as it exists currently (i.e. without replacing any vehicles). This is provided so that IMPERIAL Distribution is given the opportunity to assess the situation better.

Fleet Summary			Cost Summary		
No.	Reg No.	Decision	Cost:	Average:	Total:
1	CA103478	Keep	Maintenance	R 26,119.22	R 156,715.31
2	RNG468GP	Keep	Tyres	R 9,481.67	R 56,890.05
3	MLC353GP	Replace	Fuel	R 70,401.33	R 422,408.00
4	CA120092	Keep	Lubrication	R 1,608.50	R 32,250.63
5	HFW756GP	Replace	Insurance	R 32,250.63	R 32,250.63
6	XSV119GP	Keep	Obsolescence	R 100,800.00	R 100,800.00
7	0	None	Depreciation	R 45,834.75	R 45,834.75
			<b>TOTAL:</b>	<b>R 137,424.96</b>	<b>R 824,549.74</b>

Figure 28: Fleet and Cost Summaries

Included on the output sheet is a pie-chart depicting how much of the total cost is made up of which cost factors. For example, on the pie-chart in Figure 32 preventative maintenance makes up 23% of the total cost over the next six months.

The blue ribbon below the cost summary shows the percentage of the total cost made up of maintenance in a totally old versus totally new fleet.

Average Cost % as Maintenance: CURRENT	35.6%
Average Cost % as Maintenance: NEW	23.7%

Figure 29: Percentage of cost from maintenance

The grey ribbon shows the cost saving that would be experienced if the vehicles which indicate a *Replace* message are indeed replaced.

Total savings over 6 months IF "Replace" vehicles are in fact replaced:	R 87,846.10
-------------------------------------------------------------------------	-------------

Figure 30: Total savings on contract

A very important output to the model is that of economic life. As described in Section 2.1.2.2, the economic life of a vehicle can be a great indication of when a vehicle should be replaced, as it shows one where a vehicle stops being economically viable. The economic life of the vehicle is shown on the output tab as a percentage. It is explained to the user that if a vehicle is currently at over 95% of its economic life, that IMPERIAL Distribution should look into replacing that vehicle in the coming months.

It is interesting to note that the economic life did not factor into the decision calculation, but was added as an indicator into the model. The results of the decision calculations and the economic life calculations supported one another which verifies the decision calculations and indicates to one that the model is rather close to emulating reality. An example of the outputs supported by the economic life calculation is shown in Figure 31 below.

No.	Reg No.	Decision	Economic Life
1	CA103478	Keep	12%
2	RNG468GP	Keep	44%
3	MLC353GP	Replace	98%
4	CA120092	Keep	67%
5	HFW756GP	Replace	120%
6	XSV119GP	Keep	39%

Figure 31: Economic Life

As can be seen in the figure, both the vehicles which are flagged by a *replace* message have both nearly, or completely reached the end of their economic lives, while the *keep* vehicles are still within their economic lives.

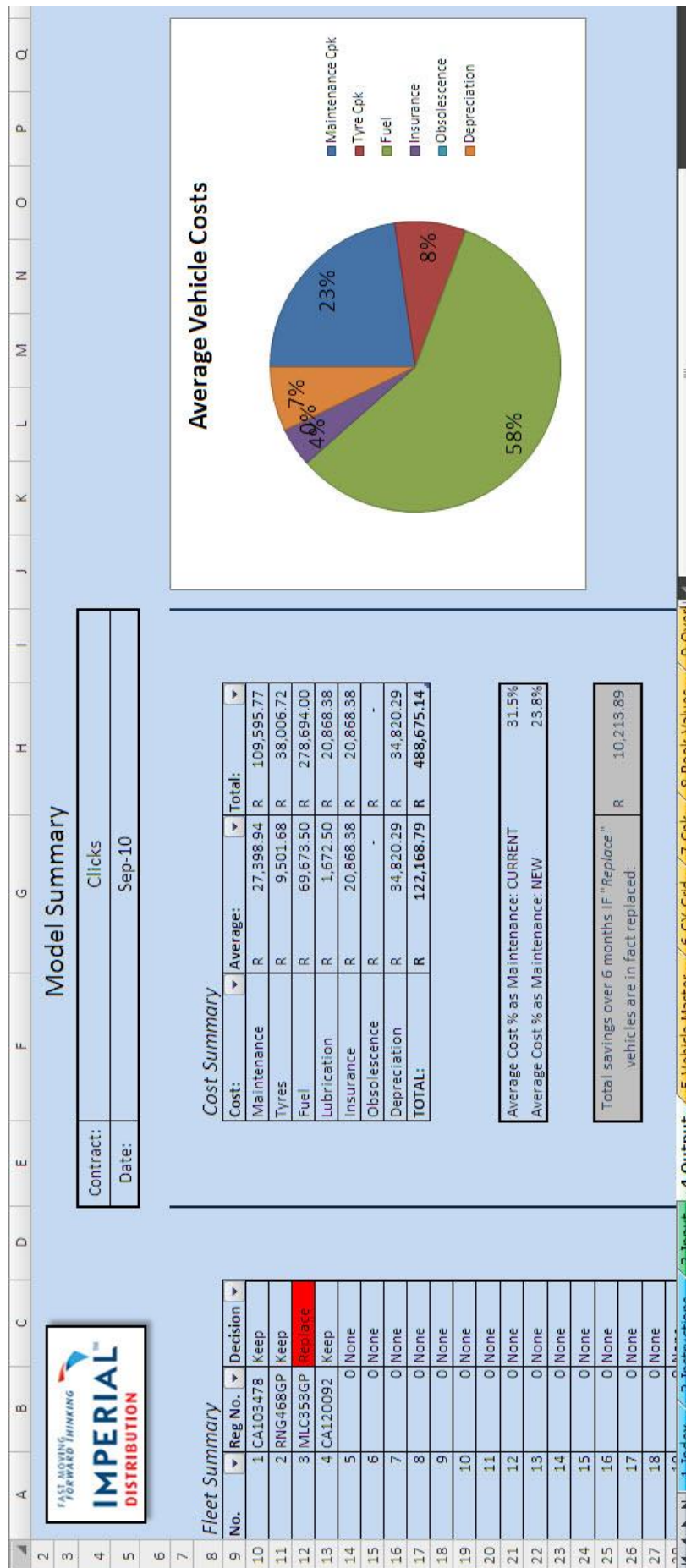


Figure 32: Model Outputs

Seline van der Wat

#### 4.1.5 Archiving Model Results

Archiving of model result is important for traceability reasons, as well as for tracking contract progress. Consequently a method of archiving model results, for every contract for which the model is run, was created so that IMPERIAL Distribution can track and trace their decision making with regards to vehicle replacement strategies.

To archive fleet strategies, the user will navigate to *Output* tab and right click on the select tab button in the top left corner of the window (Figure 33). This will select the entire sheet and show the pop up in Figure 34.

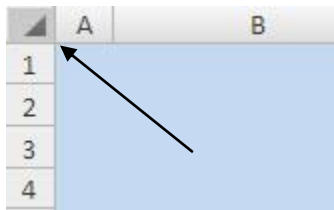


Figure 33



Figure 34

The user will click on the 'copy' option, following which a new Excel workbook should be opened. Once the new workbook is opened, the user should select the *Paste* button under the *Home* tab. This will paste the entire results tab into the workbook. If the user so wishes, he/she can copy the *Inputs* tab as well, although this is not necessary.

The workbook must now be saved in a new standard format. This format appears as follows: *ContractName\_Replacement\_Date.xlsx*. For example: *ClicksCapeTown\_Replacement\_Sep2010.xlsx*

By using this format the user will be able to easily identify the period for which the model was run without having to open a series of documents. By copying and pasting only the results, the file size is decreased which will save hard drive space.

#### 4.1.6 Assumptions

The following list of assumptions was made for the Excel model:

- Following an overhaul, the maintenance and tyre  $C_{pk}$ 's drop to that of a vehicle of 4 years old. This is based on the fact that an overhaul includes a new engine, gearbox and differentials and as such these vital parts will require less maintenance than an older vehicle.
- To calculate the percentage of the total cost that maintenance is responsible for we consider maintenance and tyre  $C_{pk}$ 's, lubrication and overhaul as *maintenance* because these cost elements are responsible for the upkeep of the vehicles and will differ depending on vehicle age, type and size.
- We assume that in the first two years of operation, that the actual tyre  $C_{pk}$  is only 5% of the predicted tyre  $C_{pk}$  over the rest of the vehicles life.

- The actual maintenance  $C_{pk}$  increases by 5% year-on-year from the predicted value.
- IMPERIAL Distribution will purchase the new vehicles from their trusted suppliers at the discounted prices quoted to them, not at market prices.
- If a vehicle is older than 15 years, it assumes the  $C_{pk}$  of a 15 year old vehicle.

### 4.1.7 Future Adaptations

This Excel model was designed in such a way that future additions and changes are allowed. For example, at present, IMPERIAL Distribution does not keep a list of the carbon outputs per vehicle type on their records. However, it is assumed that in the future companies are going to be taxed on their carbon emissions, or rewarded for reducing their carbon emissions. The South African government just implemented new legislation which taxes a citizen when he/she purchases a vehicle, depending on the carbon monoxide output of that vehicle per kilometre. Once the relevant data is recorded by IMPERIAL Distribution, two cost factors can very easily be added to the cost calculation. Firstly, the appropriate carbon tax would increase the cost of a new vehicle, which is a disadvantage to the choice of a new vehicle seeing as the older vehicles are not taxed. And secondly, a cost can be worked out for every vehicle based on the kilometre forecast multiplied by the carbon emissions and cost per milligram of carbon monoxide. This second cost would differ between vehicle makes, sizes and age and would thus prove an advantage to a younger vehicle seeing as the truck manufacturers are producing vehicles which are more efficient and green than their predecessors.

Secondly, allowance was made for future additions to the list of vehicles, vehicle types and registration numbers. This was done by making use of dynamic name ranges, which will count and list all the entities in a given table. In this way, IMPERIAL Distribution will not have to edit the calculations or drag formulae around to destination cells. The model will automatically update itself and make all the options available to the user.

## 4.2 Part 2: Solution Evaluation and Testing

Testing a model such as the one inspired by this dissertation is important because significant business decisions concerning asset procurement and management will be affected by its output. We thus have to ensure that the model is as accurate as possible. We do this by testing whether or not the correct output is received from controlled situations.

To evaluate and test the model two tests were run:

1. Firstly, an old vehicle with many kilometres and scheduled services was run, one which should give the result of: 'replace vehicle.' Knowing that the result of this test should be to replace vehicle, one can evaluate whether the model returns the same answer.

- Secondly, a new vehicle was run which has hardly been used yet. Running the model should result in a decision to keep the vehicle. Obviously, a new vehicle with low maintenance costs and  $C_{pk}$  should not prompt a 'replace' message from the model.

#### 4.2.1 Test One

**Vehicle Type:** Hino, 13-234 Freighter

**Vehicle Description:** This vehicle (registration: HFW 756 GP) was purchased by IMPERIAL Distribution in 1991. To date it has clocked 450 000km.

**Test Result:** Model shows a "Replace" message (Red cell in Figure 35), while indicating that the vehicle's maintenance cost makes up greater than 60% of the vehicle's total cost. The inputs to this test are shown in the first two images below, followed by the model output in the third image. In the model the images lie in a continuous line, but are staggered in this report to save space.

**Analysis:** Using historical service results of this vehicle, it was found that it has been in for numerous unscheduled services, with a total cost exceeding that forecasted for the vehicle and the replacement cost of a new vehicle. As a result, this vehicle is no longer economically viable. It has reached the end of its economic life and should thus be replaced. The Excel model provided this conclusion as well, so this test can be considered a success.

No.	Vehicle Type	Reg No	Size	Purchase Year	Engine
1	Hino,13-234,Freighter	HFW756GP	4x2 7/8 Ton Vehicle	1991	Diesel

Current Km	Km in next 6 months	Cost of new vehicle	Road Standard			Data Check
			Normal	Hilly	Gravel	
450000	90000	R 398,727.00	80%	10%	10%	OK

Keep/Replace	% cost as Maintenance
1	69%

Figure 35: Test One

The Keep/Replace decision for any model result is interpreted by using the key shown in Figure 36 on the subsequent page.

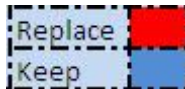


Figure 36: Decision Key

4.2.2 Test Two

**Vehicle Type:** Hino, 12-217, Freighter

**Vehicle Description:** This vehicle (RNG468GP) was purchased by IMPERIAL Distribution in 2004 and has a total mileage of 249 000km.

**Test Result:** Model shows a “Keep” message (blue cell in Figure 37), while indicating that the vehicle’s maintenance cost makes up only 40% of the total vehicle cost. As with test one, the inputs to this test are shown in the first two images below, followed by the model output in the second image. In the model the images lie in a continuous line, but are staggered in this report to save space.

**Analysis:** This vehicle clearly still holds great advantage in keeping it, based on the fact that its maintenance costs have not increased beyond that which is to be expected for a vehicle of its type and size. Its higher  $C_{pk}$  values and fuel consumption are still low enough so that the purchase of a new vehicle is not warranted.

No.	Vehicle Type	Reg No	Size	Purchase Year	Engine (Petrol/Diesel)
2	Hino,12-217,Freighter	RNG468GP	4x2 2.5/3.0 Ton Vehicle	2004	Diesel

Current Km	Km in next 6 months	Cost of new vehicle	Road Standard			Data Check
			Normal	Hilly	Gravel	
249,000	38,000	R 384,883.00	60%	10%	30%	OK

Keep/Replace	% cost as Maintenance
Keep	40%

Figure 37: Test Two

4.2.3 Miscellaneous Model Tests

In addition to the major tests done in the preceding sections, the model was also tested for the following. The results are given in paragraph form following the test description.

#### 4.2.3.1 Multiple Vehicles

This Excel model has the capacity to calculate the replacement strategies of 80 vehicles at a time. All 80 of the available spots are unlikely to be filled, seeing as contract fleets are usually much smaller than this. An exaggerated number of spots are included for future expansion purposes. Seeing as not all the spots are likely to be filled in one go, the model displays 'None' in the cells whose rows are not linked to a vehicle. In addition, if no vehicle exists for a spot, it will not be counted into the tally which is shown in the contract summary. An example of this summary section is shown in Figure 38.

Summary	
Replace	1
Keep	4
Total No of Vehicles in Fleet	5

Figure 38: Fleet Summary

#### 4.2.3.2 All Vehicle Types

The model was tested over all types of vehicles and all possible combinations of sizes and registration numbers. After adjusting the *vlookup* functions slightly (see Section 4.2.4) the model ran all vehicle types without error.

#### 4.2.3.3 Macro Testing

To test the macros embedded in the model, the model was run on two separate computers, one set on the Microsoft Vista operating system and the other on the Microsoft XP operating system. After deactivating the security warnings on both computers the model ran correctly, and the macros ran without any bugs.

#### 4.2.4. Recommended Model Alterations

Following the tests in this Section 4.2 the model will be adapted and tweaked so that the model output is as close to the real value as possible, while being continually consistent.

The changes that were made include:

- A user output tab was created, to make it easier for the user to interpret the solution. This was done upon the request of IMPERIAL Distribution.
- Upon troubleshooting it was found that some of the macros had bugs in them, and did not work if pressed repeatedly or if opened on a new computer. This required a change in the programming of the macros.
- The model's *vlookup* functions report errors if the lookup cell has any spaces in it. As a result, all the input data's names were edited to omit these spaces; which fixed the error. It is important to note however, that when IMPERIAL Distribution updates the input data that this data must not contain spaces either, else the model will report errors again.

### 4.3 Part 3: Implementation of Solution

The implementation and degree of usage of this project model will be left up to the Business Analysis team at IMPERIAL Distribution after a presentation on the system is given to them. A copy of the user manual and all accompanying files will be provided to IMPERIAL Distribution. Copies of these documents can be found attached in the form of a CD on the back inside cover of this final document. For the author of this dissertation, implementation infers the explanation and handing over of the project to IMPERIAL Distribution following a comprehensive workshop explaining the way in which the model and its supporting models function, and how the model can be edited and utilized in the future.

### 4.4 Chapter Four Conclusion

There are always many solutions to a given problem. The solution designed for this dissertation is therefore neither the only solution to the problem, nor is it the best way to solve such a problem. It is however the solution which is most suited to IMPERIAL Distribution's set up and requirements.

The solution is in the form of an Excel document which has been specially designed so as to maximise computation speed and usability. The model has been checked by both the Business Analysis team at IMPERIAL Distribution and a consultant at Volition Consulting Services, following which tests were run on the model to ensure that it returns values which strongly resemble the correct solution. The tests revealed small errors in the models, including incorrect assumptions, which were ironed out and improved upon before implementation.

## 5. Conclusion

The management of vehicles has become a vital cost saving operation in the logistics industry. Being able to determine when an asset has come to the end of its financially viable useful life will allow a company to stay ahead in the logistics game. IMPERIAL Distribution has championed this project in the hope that they will attain the benefit gained from vehicle management.

The crux of this project is ensuring that the optimal fleet replacement strategy is determined based on financial benefit of IMPERIAL Distribution. The cost of replacement options will be weighed against one another and the most advantageous answer returned to the list of input vehicles. We will then be provided with a summary of how many vehicles must be kept or replaced. The entire model has been built in Microsoft Excel, which was chosen based on its extensive operating capabilities as well as user-friendliness and familiarity.

If this project is completed and applied correctly, it will save IMPERIAL Distribution a lot of effort and time in determining optimal fleet solutions for current and prospective clients. It is believed that this will give IMPERIAL Distribution even more of a competitive edge and will assist them greatly in saving time, and thus money now and in the future when they wish to expand. Another potential benefit that this model holds for IMPERIAL Distribution is the potential savings by means of a decrease in variable cost per kilometre. This will remove volatility in addition to receiving better recovery on the vehicles within the IMPERIAL Distribution fleet.

To analyse the proposed savings that would result from implementing this model, the model was run for Clicks in the Western Cape alone. The fleet consists of ten vehicles. After running the model it was concluded that 3 of the ten vehicles needed to be replaced. The savings that would be achieved if these three vehicles were replaced totalled an astounding **R 507 109.81**. And this is just for *one* of IMPERIAL Distribution's *eighty* contract fleets.

Therefore, according to the proposed savings that were recorded during the testing phase of this dissertation, it can be concluded that if applied correctly, that this model holds great value for IMPERIAL Distribution and has the ability to greatly increase their margin at the end of the financial year.

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## 7. Addendum

### 7.1 Appendix A: Comprehensive Cost Example.

These calculations are examples of how the Excel model calculates the costs effecting the keep/replace decision.

#### 1. Maintenance

For the purpose of this calculation, let's use a 4x2 4 Ton truck on a road that is 80% normal, 10% hilly and 10% gravel. The maintenance Cpk for a 4 year old 4x2 4 Ton is 47c, while its tyre Cpk is 23c regardless of its age. This vehicle is assumed to have 20 000km forecast for it in the coming time period.

##### Equation 12

*Maintenance Cost = Tyre Cpk + Maintenance Cpk*

*= (TCpk \* Factors \* Rating + MCpk \* Factors \* Rating) Kilometres*

*= ((0.8 \* 1 + 0.1 \* 1.2 + 0.1 \* 1.3) \* 23 + (0.8 \* 1 + 0.1 \* 1.1 + 0.1 \* 1.2) \* 47) \* 20 000*

*= (0.24 + 0.49) \* 20 000*

*= 0.73 \* 20 000*

*= R 14 600*

Where the factors are as shown in the Figure below and the ratings are a percentage totalling 100%.

IF:	Multiply M. Cpk by:	Multiply Tyre Cpk by:
Hilly	1.1	1.2
Normal	1	1
Gravel	1.2	1.3

Figure 39

#### 2. Fuel and Oil

Fuel cost is simply calculated as the product of the current fuel price (inserted by user), fuel consumption (from vehicle master) and planned mileage (inserted by user). Oil is based on an average oil consumption over each vehicle size. Therefore this cost will depend on the planned mileage (inserted by user) corresponding with oil replacement schedule. The cost of oil will be inserted by user (although this value will not change drastically in a short period of time).

Say, for example we use a Dyna,5-103,Freighter. This vehicle has a fuel consumption of 14 liters per 100 kilometers. If its planned mileage in the next time period is 20 000 km and the current diesel price is R 7.89, then the price of fuel can be calculated as follows:

**Equation 13**

$$\begin{aligned} \text{Fuel} &= \text{Fuel Price} * \text{Consumption} * \left( \frac{\text{Kilometers}}{100} \right) \\ &= 7.89 * 14 * \left( \frac{20000}{100} \right) \\ &= R 22\ 092.00 \end{aligned}$$

### 3. Insurance

Insurance is an important cost to consider in the replacement-point problem. This is due to the fact that vehicle insurance is calculated 5.5% of the present market value of the vehicle and is calculated and paid out monthly. If a truck has a higher market value, the insurance would increase.

So for example, if a Dyna,5-103,Freighter is valued at R 200 000, then the monthly insurance on the vehicle is calculated as follows:

**Equation 14**

$$\text{Monthly Insurance} = \frac{0.055 * \text{Vehicle Value}}{12} = \frac{0.055 * 200\ 000}{12} = R\ 917 \text{ per month}$$

This will need to be compared to the insurance cost of a new vehicle, whether the purchase cost increases or decreases.

The insurance cost is calculated on a separate tab in the Excel Spreadsheet so that if company policy changes and the percentage required for insurance was to increase or decrease the user could edit just one cell pertaining to this value, in lieu of changing all the insurance cost calculating cells in the workbook.

### 4. Purchase

The original cost of vehicle in question is stored on the asset register. This is a direct input into the cost model.

The cost of a new similar vehicle will be inserted by the user and will be used to compare costs.

IMPERIAL Distribution gets special rates from suppliers so the total vehicle purchase price is calculated using equation 14 below.

**Equation 15**

$$\text{Purchase Price} = \text{Manufacturers Cost} - \text{Discount}$$

For example, a Dyna 5-103, Freighter:

$$= 216\,190.02 - 4\,239.02$$

$$= R\,211\,951.00$$

A record of all the discounted purchase prices is kept by IMPERIAL Distribution and is an integral input into the Excel model.

**Total Cost**

The total cost for the vehicle in question is:

**Equation 16**

$$TC = \text{Maintenance} + \text{Fuel} + \text{Oil} + \text{Purchase} + \text{Insurance}$$

$$= 14\,500 + 22\,092 + 211\,951 + 917$$

$$= R\,249\,460$$

In conclusion it is important to note that the user will not see these equations. They all occur in the background and return the replacement status to the user after comparing the old costs to new costs.

## 7.2 Appendix B: Cpk Analysis

The graph that was too cluttered to include in the report’s body is shown in the figure below.

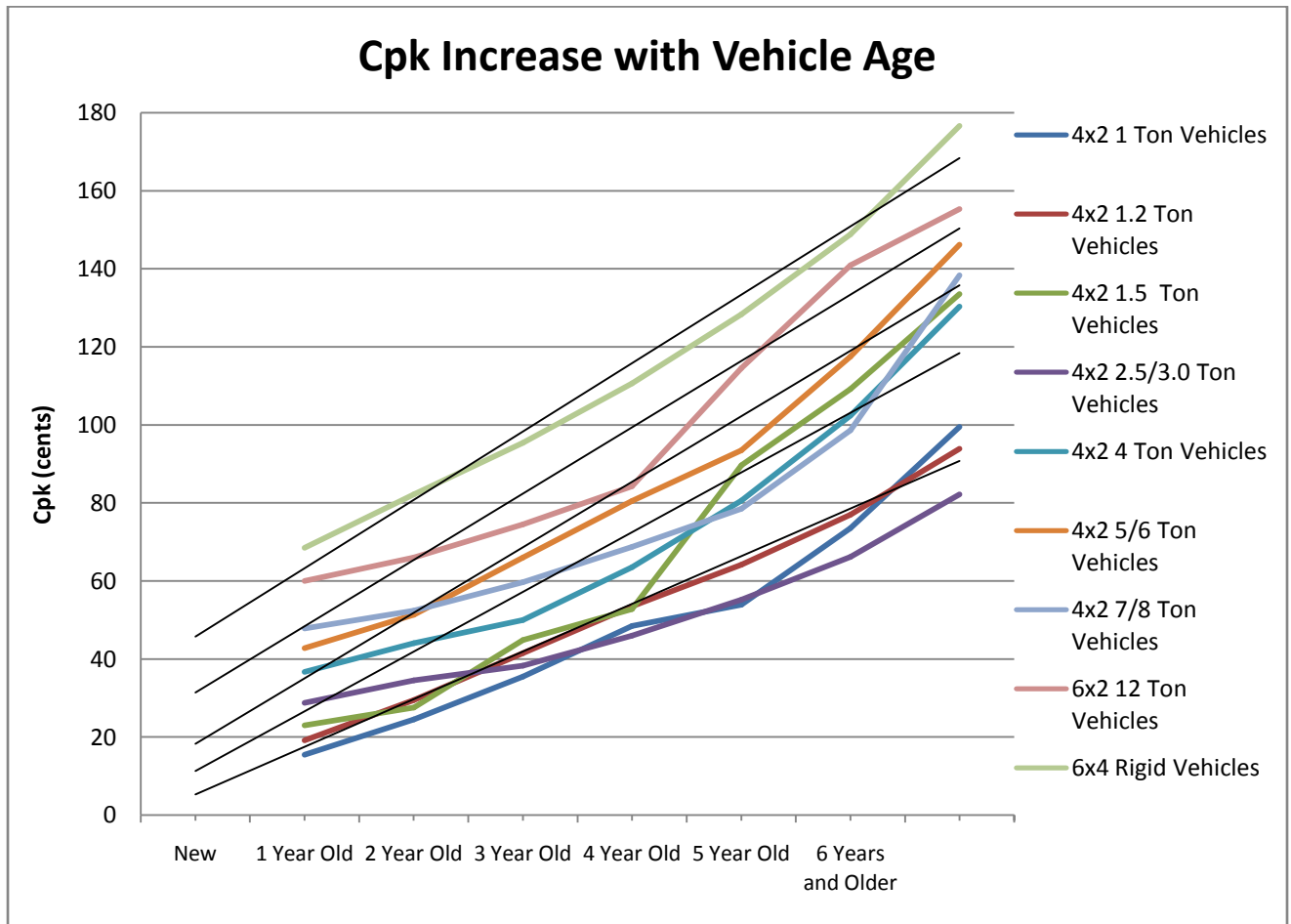


Figure 40: Cpk Increase

As can be seen by analysing the black trend lines in the figure above, the Cpk increases all seem to follow the same pattern and gradient. This can be reduced to the next graph.

The graph is followed by the relationship between tyre Cpk and time. The explanation for this graph will be provided after the figure is presented on the next page.

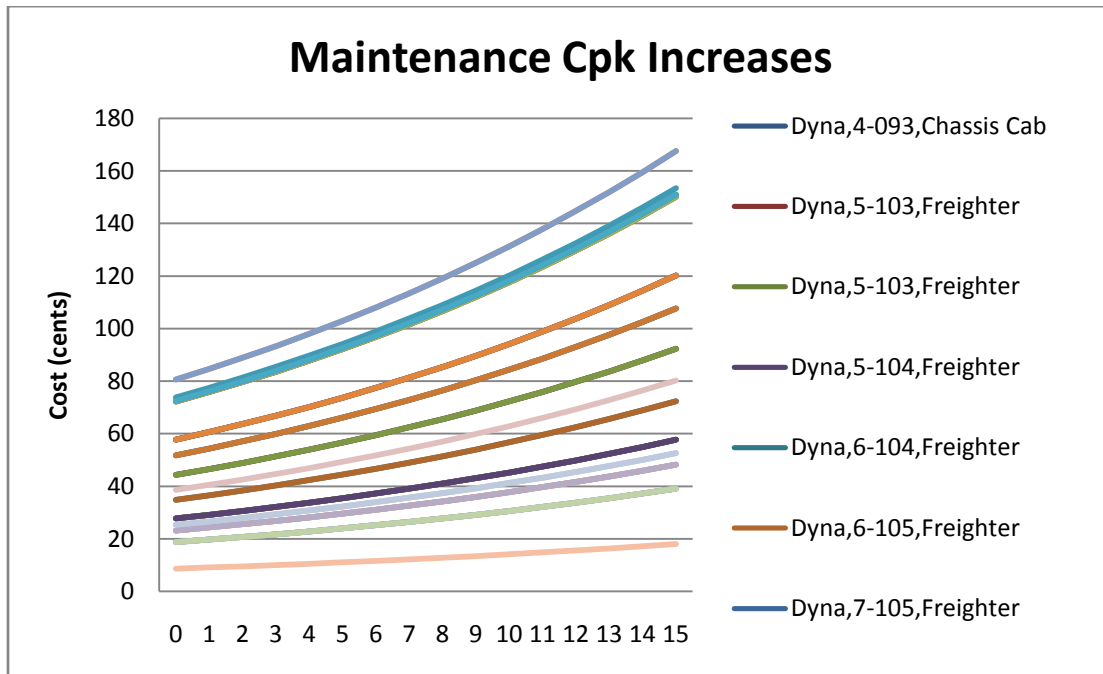


Figure 41: Maintenance Cpk Increases

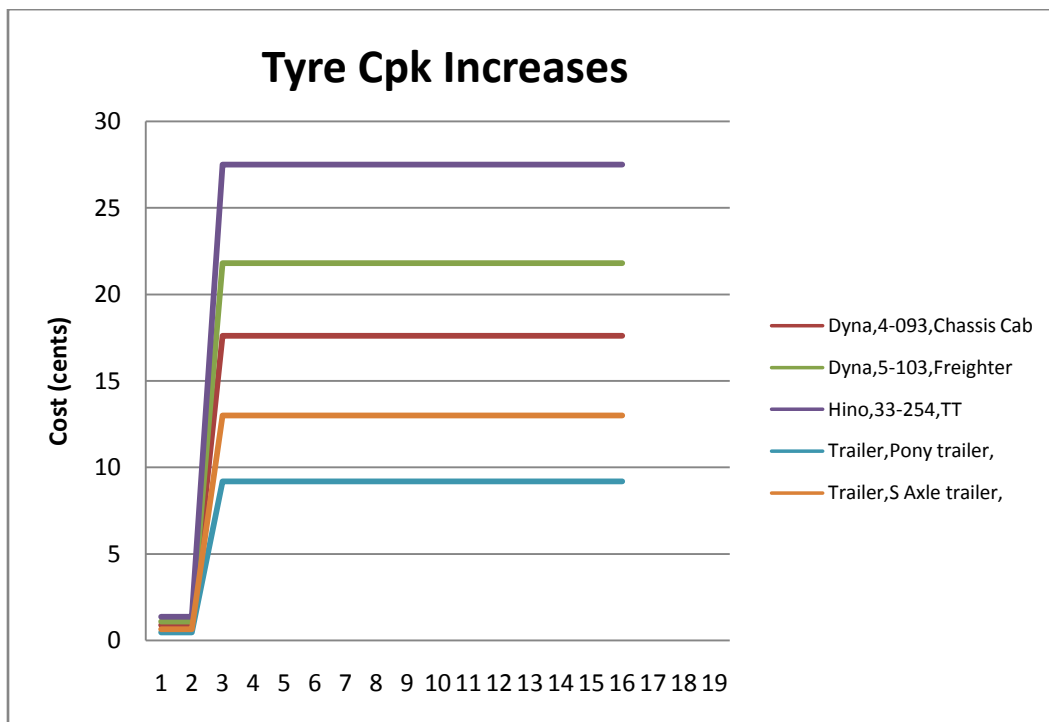


Figure 42: Tyre Cpk increases over time

For the first two years, tyre Cpk's are only 5% of the usual value, following which the Tyre Cpk is considered constant over the rest of the vehicle's life. The graph above shows that all the vehicle sizes behave in the same manner (they are parallel to one another). Different makes and sizes were chosen to illustrate this point, as can be seen in the graph there are Dyna's, a Hino and truck trailers.

### 7.3 Appendix C: Model User Manual