THE LOGISTICAL ANALYSIS OF PHARMAPAC.

by

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PROJECT REPORT

THE LOGISICAL ANALYSIS OF PHARMAPAC

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Executive Summary

PharmaPac is a plastic manufacturing company producing plastic containers, for the pharmaceutical industry, in Durban South-Africa. PharmaPac's identification of an opportunity to improve their logistics strategy initiated this project. The project aim is established as the identification of the optimal logistics strategy for the company. The objectives include decreased logistical cost and increased system flexibility.

The current logistic system is dependent on the logistical network of PharmaPac's sister company PailPac. This results in a rigid network with high logistical costs.

Literature on logistics, warehousing and transportation is reviewed to establish a base of knowledge on methods, tools and techniques that could be implemented in a logistical analysis. In evaluation with the criteria set by management the cost centre method of logistical analysis is identified to be the appropriate method to implement. The method requires the construction of a model to simulate the cost centers and determine the total cost involved for a logistics strategy.

Prior to model construction, the data requirements is established and collected. As the demand data is deemed too sensitive to be made public the method is adapted to use random demand data. The model is built in Microsoft Excel and is used to compute the total cost of a logistics strategy. It is run for 10 iterations to ensure the result is accurate, as the demand is random. Six logistical strategies or scenarios, including the current strategy, are identified in collaboration with management. These scenarios are investigated through the model.

Scenario 3 proved to give the most cost effective logistical strategy with an average of 64% decline in the T.M.L.C. This scenario will also increase the flexibility and reliability of the current system significantly. The model is based on a wide range of demand levels which indicates that this scenario will remain feasible for an extended period.

Scenario 5 proved to be the second most feasible strategy with an average of 34% decline in the T.M.L.C. Through a break-even analysis it is established that a decrease of R120.34 per pallet in transportation cost is required from PailPac to make this scenario optimal on a purely cost based analyses. Further Analysis proved a much larger amount was required to make scenario 5 optimal.

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T.M.L.C: Total Monthly Logistics Cost.

Chapter 1: Introduction and Background

1.1 Company background

PharmaPac is a manufacturer of plastic medicine containers. Their clients include large pharmaceutical companies like Aspen and Adcock. The business started as a result of a business decision by Consol to abandon their plastics division. Most of Consol's plastic molding machinery were bought by PharmaPac and moved to a facility in Durban. This move resulted in PharmaPac being in close proximity of its larger sister company PailPac who manufactures plastic paint containers.

The open mouthed containers are produced through the process of injection molding with the dies being owned by the customers. As the containers are intended for pharmaceutical purposes the production facility has to operate in a clean room environment to ensure that contamination does not occur. PharmaPac's client base is mainly located in Gauteng (66%) with the rest spread along the coast to Cape Town.

1.2 Problem Statement

The logistical system under examination consists of a single production plant with multiple warehousing facilities. Customer dispatching also occurs from these facilities. The customers are largely found in Gauteng with a few found in Port-Elizabeth, East-London and Cape Town. PharmaPac wants to improve their logistic system as they believe it to be suboptimal. PailPac's transportation network is used to transport goods, as PharmaPac does not currently own a fleet of its own. Three of PailPac's warehouses are used, the first of which, the DC warehouse located near the plant is used to store finished products before delivery to the customer. The Krugersdorp warehouse is used to store finished product before dispatching to Gauteng customers, some safety stock is also stored at Krugersdorp. The G-store is used for raw material storage. At each store PailPac requires an off-loading -, loading- and a storage fee per pallet. This amounts to double handling costs. They are also concerned about the lack of dedicated trucks for PharmaPac, which results in their goods not always being delivered on demand. First priority is being given to PailPac's deliveries. PharmaPac prefers not to use the Krugersdorp warehouse because of possible contamination as PailPac does not have strict regulations. PharmaPac also believes that the current situation could be improved through eliminating the double handling costs as well as the high transportation and warehousing costs charged by PailPac. PharmaPac is looking at a number of different logistic system scenarios to implement but is unsure about the cost and service implications that each scenario would have. The problem involves establishing the appropriate transportation and warehousing method to be implemented through determining the most suited scenario for the company.

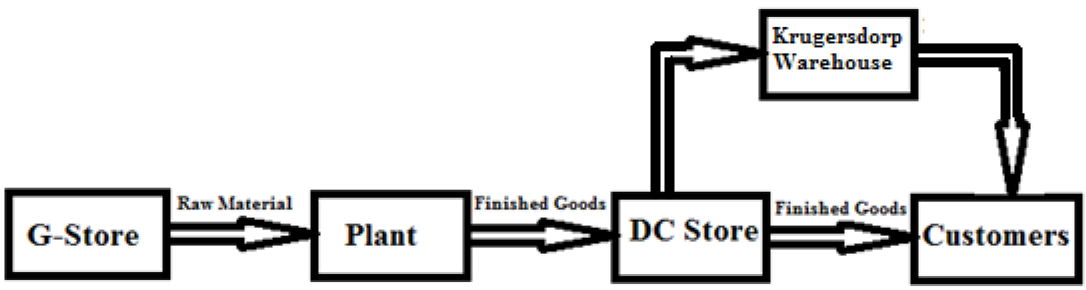

Figure1-1: Simplified Logistics Network of PharmaPac

1.3 Project Aim and Objective

The aim of the project is to establish the optimal logistical system to be implemented at PharmaPac. The logistical system should include the transportation and warehousing methods to be implemented in order to satisfy PharmaPac’s physical distribution needs.

These needs include:

- Finished product storage
- Finished product dispatching
- Transportation to customer

The following objectives must be achieved by this project:

- Decreased logistic costs of warehousing and transportation for the distribution of finished products to the customers.
- Increase system reliability through ensuring prompt product delivery.
- Improve system flexibility through ensuring system adaptability in product delivery.
- Maintaining the required customer service level.

1.4 Project Scope

PharmaPac's logistical needs include transportation and warehousing of products from the plant in Durban to the Customers located throughout South Africa. The logistical network capacity has to be able to meet the current and future demand levels. The project should address all PharmaPac's logistical needs and should exclude container dimension analysis as well as pallet warehousing.

1.4.1 Inclusions:

- Finished product warehousing: The identification of the size and location of the dispatching warehouse. Investigation of utilizing an additional warehouse in Krugersdorp.
- Raw Material Warehousing: Dispatching warehouse should include an area for raw material to be warehoused.
- Transportation to and from warehouses of finished goods and raw material.

1.4.2 Exclusions:

- Pallet warehousing
- Container dimension analysis
- Special shipping costs for less than truck loads
- Warehouse layout

1.4.3 The following assumption is made:

Usage of only single stacked pallets of finished products

1.4.4 Validation and Testing:

The project should be validated through conveying the results to management to ensure the results are realistic, applicable and in-line with management requirements.

1.5 Research Design and Deliverables

In the execution of the project the following deliverables should be completed:

- In depth analysis of the as-is condition.
- Identify possible areas for improvement.
- Generation of alternative logistic scenarios.
- Cost analysis to establish the best scenario based on cost.
- Identification of relevant factors for logistical decision making.
- Construction of an implementation plan.

1.6 Chapter Summary

This chapter was devoted as an introduction to the project. The project is based at PharmaPac a manufacturer of pharmaceutical packaging and aspires to establish the optimal logistical strategy for PharmaPac within given constraints and requirements.

Chapter 2: Literature Review

In order to achieve the aim of the project, which is to establish a logistical system for PharmaPac, it is imperative to select the appropriate method of investigation. This selection requires comprehension of the different methods available. The literature review attempts to create this understanding through analyzing literature relating to logistics, warehousing and transportation.

2.1 Logistics

According to Coyle et al (2003) logistics can be defined as the process of anticipating customer needs and gathering all the required resources and information necessary to satisfy these needs. It also includes the optimization of the manufacturing network and the implementation of such a network to realize the customer need promptly and effectively. According to Coyle et al (2003) the two largest cost categories associated with logistics is transportation and inventory cost and the management activities associated with logistics include:

- Traffic and transportation
- Materials handling
- Warehousing and storage
- Packaging
- Order fulfillment

All of these activities are crucial in the establishment of a stable, efficient and reliable logistical system within a company. According to Jacobs et al (2009) A logistical channel is part of the total distribution channel and includes both logistical flow as well as transactional flow. It is a network of intermediaries engaged in transfer, storage, handling, communication etc. that contribute to efficient flow of goods. Logistics is sometime referred to as an important element of marketing; the physical distribution component of logistics is responsible for finished goods movement and storage which in part is responsible for selling the product. According to Meade et al (1998) ,the logistics strategy to be implemented is mostly the strategy which would result in the greatest competitive advantage for the company.

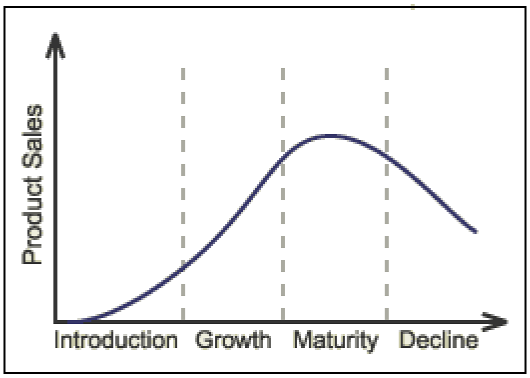

Figure 2-1: Product Life Cycle.

According to Meade et al (1998) a logistic analysis should be done in each stage of a products life cycle, to identify the appropriate logistic strategy to be implemented. As each stage will have its own contributing factors resulting in a unique strategy.

According to Coyle et al (2003) there are four approaches for analyzing a logistics system:

1. Materials management versus physical distribution

The system is divided into two parts: the inbound or material management and the outbound logistics (physical distribution). Each part is then analyzed separately.

2. Cost centers

This approach looks at transportation, warehousing, inventory, materials handling etc. as cost centers. Logistical activities are seen as interrelated. Possible trade-offs are then analyzed in accordance to a lower over-all cost and better customer service.

3. Nodes versus links

Nodes and links are defined for the system, with nodes being storage/processing areas and links being the transportation network between these nodes.

4. Logistic Channels

This method broadens the scope of the analyses, taking into consideration the suppliers and the customer's logistical system as well.

Logistic System Type	Description
Balanced system	When the number of shipments received and send out are approximately the same this is an indication that the system is balanced.
Heavy Inbound	The number of inbound shipments far outweighs the outbound shipments. For example a process that manufactures a single airplane out of millions of small parts.
Heavy Outbound	The number of outbound shipments far outweighs the inbound shipments. For example making thousands of different products like oil, wax etc out of coal.
Reverse System	When a customer may return products for trade-in or for a repair the system is a reverse system.

Table 2-1: Four Types of Logistic Systems According to Coyle et al (2003).

According to Meade et al (1998) there exist a number of models that can be used to analyze a logistics strategy. These include:

Added Value Strategy Modeling (AVSM): This cost versus service model, allocates weights to each of the primary factors that influence the achievement of the customer's objectives. The result is a logistics system that is customer specific and cost effective while increasing the companies competitive advantage. The Logistics strategy would have a unique solution for each of the organizations customers. Depending on each customers objectives and preferences.

Analytical Models: The two types of Analytical models described by Meade et al (1998) are the (1) Analytical hierarchy process and the (2) Analytical Network Process:

Analytical hierarchy process (AHP) is a Quantitative model that can be used to model strategic decisions. The draw-backs of this process is that the environment cannot be modeled and system elements are assumed to be uncorrelated.

Analytical Network Process (ANP) could be implemented to analyse decision attribute relationships which are dynamic and multi-directional. This includes multi-attribute, multi-year decisions. The ANP approach allows the modeling of complex and dynamic environments. Meade et al (1998) stated that: "The ANP approach has been defined as a non-linear, network relationship among various factors." The following framework could be used to analyze a logistics strategy:

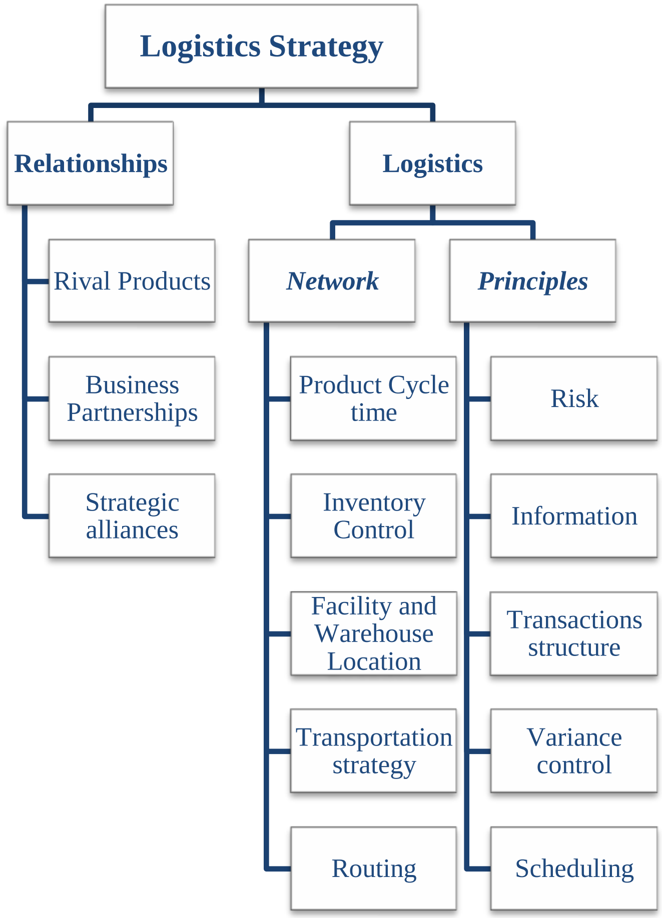

Figure 2-2-Framework for the analyses of a logistics strategy according to Meade et al (1998)

To evaluate the alignment of a company's logistics strategy with the company's business strategy the following factors are evaluated according to Meade et al (1998):

- Company markets
- Company products
- Customer service
- Logistics
- Transportation
- Product Operations

2.2 Transportation

In transportation there are two key decisions to be made. Firstly the mode of transportation to be used needs to be identified. Each mode has its own advantages and disadvantages. Implementing intermodal transportation could result in obtaining only the benefits of the modes involved while reducing their disadvantages.

Transportation Mode	Advantage	Disadvantage
Ocean	Low Rates	Long transit times
	Wide variety of products	Low accessibility
		Higher Damage potential
Air	Low transit times	High freight rates
	Decreased Packaging requirements	Difficult intermodal shipments
Motor	Low transit times	
	Safety	
	Reliability	
	Accessibility	
Rail	Low Rates	Long transit times
	Wide variety of products	Low accessibility
Pipeline	Low Rates	Low accessibility
		Long transit times

Table 2-2: Advantages and Disadvantages of the five types of Transportation Modes as adapted from Coyle et al (2003).

Secondly the type of arrangement/contract to be used should be identified. The transportation could be either for-hire or not for-hire. The for-hire carriers are further classified as either common, regulated, contract or exempt.

2.3 Warehousing

Warehouses can, according to Coyle et al (2003), be divided into two ownership groups: private ownership and public warehouses. Furthermore the warehouse could be either centralized or decentralized with a centralized warehouse usually having a larger holding capacity and centered between the customers. The advantages of decentralized warehouses are increased customer service as a result of shorter lead times, increased responsiveness and increased flexibility. The disadvantages include higher inventory levels, increased inventory holding cost and increased warehouse operating costs. Decentralized warehousing usually requires a larger number of warehouses then centralized warehousing.

According to Coyle et al (2003) warehousing functions include:

Product mixing
Service
Protection against contingencies
Smooth operations

The key decisions in warehousing, according to Coyle et al (2003), include the ownership ,size, location and the number of warehouses. The type of warehouse is dependent on three factors: the throughput volume, the stability of demand and the security and control requirements of the warehouse. All of these factors needs to be addressed when choosing a suitable warehouse. There are several techniques of Warehouse Location Selection the choice of which to use is dependent on the company's individual needs and requirements.

According to Jacobs et al (2009) warehouse location is dependent on the following factors:

Proximity to customers	Free trade zones
Business climate	Political risk
Total cost	Government barriers
Infrastructure	Trading blocs
Quality of labor	Environmental regulation
Suppliers	Host community
Other facilities	Competitive advantage

Method	Description
Factor-rating system	Identification of location factors important to the company. Each factor is allocated a weight of importance. Each possible site is then assigned a value for each criterion multiplied by that criteria's weight a final total for each location is determined.
Transportation method	Main objective is to minimize the total cost of shipping n units to m suppliers or to maximize the profit of shipping n units to m destinations. Through total cost determination the optimized solution is found.
Centroid Method	Location Identified through finding the centre most point between all customers in an area. Uses the summation of all the customers x/y-coordinates divided by the number of customers to get the warehouse location's x/y-coordinate.
Statistical techniques	Identify variables that impact the operating profit and how they impact the profit. Estimate the profit that could be made at each site.

Table 2-3: Techniques of Warehouse Location Selection According to Jacobs et al (2009).

This chapter defined logistics and gave insight into different techniques of analysing and implementing logistical strategies. The broad spectrum analysed in the review should be narrowed through focusing on the given situation at PharmaPac. A thorough understanding of the current logistical environment is required to correspond the correct method from the above mentioned literature with the specific environmental- and management requirements of PharmaPac. The following chapter is dedicated to establishing the current logistical environment at PharmaPac.

Chapter 3: Project environment of PharmaPac

The previous chapter discussed the methods and techniques available in the literature to investigate a logistical system. In order to achieve clarity when selecting the accurate method to develop, in the following chapter, the current logistical system and its environment is investigated in this chapter.

3.1 Inventory

PharmaPac currently holds a month worth of raw material inventory at a time. The finished goods inventory fluctuates with the routing schedule and the demand.

Raw Materials are delivered to the G store which keeps a month worth of Raw Materials in stock. As the Stock levels of Raw Materials depletes at the plant it gets replenished by stock from the G store once a week.

3.2 Warehousing

PharmaPac is currently using the warehouses of PailPac, at a cost R30 off-loading per pallet, R30 per pallet per month for storage and R30 for vehicle-loading. This is very similarly to using a public warehouse where a fee is charged per square meter of warehouse space used. The feasibility of purchasing own warehouses will be investigated later in the document. PharmaPac prefers not to use the Krugersdorp warehouse because of possible contamination as PailPac does not have strict warehousing regulations. Secondly double handling costs are high. Customers also prefer that Pharmaceutical product do not mix with PailPac's Industrial products.

Name	**Location**	**Items Stored**	**Costs**
G store	At plant	Raw Materials	
		Completed products	
Distribution Centre (DC)	500m from plant	Finished goods	R30 p/Pallet Off-Loading
			R30 p/Pallet Loading
			R30 p/Pallet storage cost per month
Dispatch Area	Part of plant	Finished goods	-
Storage Area 1	Part of plant	Pallets	-
Warehouse 2	Krugersdorp, Johannesburg	Finished Goods	R30 p/Pallet Off-Loading
			R30 p/Pallet Loading
			R30 p/Pallet storage cost per month

Table 3-1: Warehouse and Storage Area List.

PailPac's DC warehouse has a maximum storage space of 6000 pallets. The warehouse has limited space for double stacked pallets. A vacant warehouse is situated next door to the plant. Hiring this warehouse will cost R32 500 per month.

3.3 Customers

PharmaPac currently have ten regular customers. A table containing customer locations and distances from the plant can be found in Table 9-1: Distances of Customers. The demand data for each customer has been deemed to be too sensitive for this paper and as the company is in the introduction phase of its life cycle, the demand is not currently stable and there is not enough past data to accurately predict forecasted values accordingly. It is however known that approximately 66% of the demand will come from the Gauteng area as most of the customers are located in this province.

3.4 Transportation

PharmaPac does not currently own a fleet of its own and uses PailPac's fleet and other transportation companies organized by Pailpac.

Route	**Transport Type**	**Nr. Of High Pallets per truck**	**Cost**
Durban to Krugersdorp	Public service provider	30	R 240.00 to R 290.00 per pallet
Durban to PE	Public service provider	30	R 240.00 to R 290.00 per pallet
Krugersdorp to Customer	Public service provider PailPac private fleer	10	R 21.00 per pallet
Durban to Capetown	Public service provider	30	R 240.00 to R 290.00 per pallet
Plant to Durban Warehouse	PailPac private fleer	24	R12.5 per Pallet

Table 3-2: As-Is Transportation Strategy and Costs.

After a Full pallet has been wrapped it is moved to the dispatch area where a truck load of product is loaded onto a 24 pallet truck (hired from PailPac at R600 per day) and shipped to the DC

Warehouse. In the case of no space availability at the DC the product is taken to the G store, no dispatching to a customer can occur from this store. To fill customer orders the product is then loaded onto PailPac's fleet (Interlink logistics) to distribute their product. These are 60 pallet trucks.

PailPac has its own fleet of trucks at the Krugersdorp warehouse which in conjunction with a public logistics company handles all the deliveries to the Gauteng customers.

3.5 Ordering

PharmaPac uses a manufacture-on-order process but is currently not running completely as they are still trying to deplete the backlog of orders since they opened. The lead time for product delivery is 2days for un-printed products and 2 weeks for printed products. An order for printed products has a minimum of 10 000 units per order.

3.6 Equipment and assets related to logistics

The project environment includes the equipment and assets that are related to logistics. PharmaPac currently owns the following equipment:

Equipment/ Asset type	Number on hand	Description	
Forklifts	2	1 owned 1 rented	1.5ton 2phase with 3 meter reach
Trucks	0		
Pallets	1000	1.2mx1.2m 1 entry dimension	Charges R400 per pallet if customer
Mules	2	Electric pallet jacks	
Bakkie	1		

Table 3-3: Logistics Related Assets.

3.7 Chapter Summary

This chapter examined the project environment in those aspects which influences the logistics strategy. Logistical data was presented and analyzed accordingly to ensure a complete picture is created of the current logistical strategy and to highlight the options available to this project. The following chapter will focus on method selection and method development phase.

Chapter 4: Conceptual Design

The conceptual design phase of the project is concerned with the development of the optimum method to evaluate the system. The method should be able to assist in the attainment of the project aim as well as fall within the project constraints. The project is directed at developing a logistical system for PharmaPac which takes into consideration, reducing total logistics cost and increasing system flexibility and falls within constraints such as time and scenario restrictions set by management. Knowledge obtained through the literature study and the project environment investigation will be used to establish the correct method to be implemented. There after the optimal method will be developed and described in the chapter. The method implementation and results gained will be discussed in chapter 5.

4.1 Method selection

The selection of the appropriate method is dependent on the following factors or constraints:

Deficiency of demand data

Usage of random data

Time constraint: Two months were allocated for project completion.

Iterations of scenarios should be possible.

Only outbound logistics should be considered.

Method should be based on minimizing the over-all logistics cost.

The method selected should be able to investigate the different scenarios set by management from a financial perspective. The total logistical cost should be considered including warehousing, transportation, truck maintenance, acquisition costs etc.

The literature study identified four different approaches for analyzing a logistics system. The logistic channel approach is used to analyse a system in order to give a better overview of the system as a whole rather than to analyse different scenarios. Thus this method is determined as unsuitable for the project. The materials management versus physical distribution method will be partly implemented as the project requires the system to be divided into these two separate parts. The materials management part of this method is recommended as future work to lead out of this project. The node versus links method is seen to be to narrow in its examination of a system.The cost center method is directed to decreasing cost and increasing service level while maintaining a broad spectrum of analyses. The method allows scenario evaluation and trade-offs to be made.

In consideration of these factors the cost center analyses method is chosen to be the most suitable method to use. This method satisfies all the factors and it is easily understandable and thus promotable to management. This method requires building a model to simulate and run the scenarios against one another.

4.2 Method Development

The logistical strategy of the company will change over time as a result of numerous factors such as:

- Company growth
- Change in transportation costs
- Change in warehousing cost
- Regulations change etc.

The company would like the model to be simple and adaptable to change. The model should also be economically feasible. To ensure simplicity and limit the expenditure on costly programs, Microsoft Excel software was chosen to model the project. The program is developed to evaluate the cost of each scenario and determine the optimal strategy to follow. The six logistical strategies or scenarios, including the current strategy, identified by management to be investigated are given in Table 4-1: Scenario Description. A “Yes” in the table indicates that the particular scenario would use the particular cost factor. The scenarios only allows either Own transportation or PailPac’s transportation and does not provide for a combination of the two. The optimal strategy will be determined through taking into consideration the total cost as well as the flexibility of each scenario.

The optimal logistics system for PharmaPac will be developed through determining the scenario with the lowest total logistics cost per month within the customer limitations. As management will only allow transportation by truck this is the only mode that is analyzed. The partnership that PharmaPac has with PailPac makes the usage of other public warehouses in Durban and Krugersdorp infeasible.

Scenario	1 (as is)	2	3	4	5	6
DC warehouse	Yes	Yes	No	No	No	No
KDP warehouse	Yes	Yes	No	Yes	No	Yes
Own Durban warehouse	No	No	Yes	Yes	Yes	Yes
Pailpac's transportation	Yes	No	No	Yes	Yes	No
Own transportation	No	Yes	Yes	No	No	Yes

Table 4-1: Scenario Description.

Identified Cost Centers:

- Transportation
  - From plant to PailPac's Durban warehouse
  - To Customer
- Warehousing
  - Krugersdorp warehouse cost
  - PailPac's Durban Warehousing cost
  - Krugersdorp Warehousing cost
- Capital Investment

The analysis is done 5 times with the demand being taken to be random values as indicated in Table 4-2: Demand Value for Each Analysis. The values were distributed as such for simplicity reasons. Each analysis consists of 10 runs of each scenario. The model is run over such a broad spectrum of demand values with numerous iterations at each to analyse the consistency and future viability of the results.

Analysis	Demand
1	Random between 0 and 100
2	Random between 0 and 200
3	Random between 0 and 300
4	Random between 0 and 400
5	Random between 0 and 500

Table 4-2: Demand Value for Each Analysis.

The price of owning and operating trucks was computed over a 10 year planning horizon at a 10% inflation rate with price inputs from Volkswagen and MAN trucks. The monthly cost for acquisition is computed for all three types of trucks and added to the total transportation cost. It is assumed that a truck can only travel a maximum of 12 000km per month (allowing for loading and unloading times). This maximum was considered when determining the amount of trucks to be acquired. The fixed and running cost is computed as per the AA suggestions to obtain the cost per kilometer for each truck. This cost was then multiplied by the distance the truck would have to travel in a given month, including the back haul kilometers. For each scenario the transportation cost was computed using all three sizes of trucks and subsequently using the lowest cost for the total logistic cost calculation.

Truck	Size (pallets)	Price	Price Per Month	Description
A	16	R 446,764.56	R 6,168.33	Based on a Isuzu NQR 500 with curtainsider and a 5ton loading capacity.
B	20	R 568,518.00	R 7,513.01	Based on a VW constellation 13-180 LWB with curtainsider and a 5ton loading capacity.
C	24	R 709,878.00	R 9,381.09	Based on a VW constellation 17-250 LWB with curtainsider and a 7.5ton loading capacity.

Table 4-3: Truck Cost Data

The following assumptions are made:

- Demand per customer is randomly distributed.
- Transporting goods via PailPac's logistic company from Durban to East-London, Port Elizabeth and Cape Town costs R265.
- 10 year planning horizon
- A maximum of 12 000 kilometers can be driven by a truck in a month.
- Variation of Different truck sizes in a fleet is not possible

4.3 Data analysis

In each analysis the model will be run 10 times. Gauteng has 7 customers with PE, East-London and Cape Town each having only one. This also ensures that Gauteng approximately has 66% of the demand. The transportation costs from Durban to Krugersdorp, Cape Town and Port-Elizabeth will be taken to be the average of R265.

Costs			
Transportation from plant to Pailpac's Durban warehouse			**R 7,717.33**
	Cost per pallet		12.5
	Nr of pallets		617.3862417
Pailpac's Durban warehousing cost			**R 55,564.76**
	Cost per pallet		90
	Nr of pallets		617.3862417
Transportation to customer cost			**R 70,907.19**
	Gauteng		**R 7,978.29**
		Cost per pallet	21
		Nr of pallets	379.9186906
	East-London		**R 19,281.64**
		Cost per pallet	265
		Nr of pallets	72.760895
	PE		**R 20,863.19**
		Cost per pallet	265
		Nr of pallets	78.72901898
	Capetown		**R 22,784.07**
		Cost per pallet	265
		Nr of pallets	85.97763712
Transportation to krugersdorp warehouse cost			**R 100,678.45**
	Cost per pallet		265.000
	Nr of pallets		379.9186906
Krugersdorp warehousing cost			**R 34,192.68**
	Cost per pallet		90
	Nr of pallets		379.9186906
Capital Investment			**R 0.00**
	Warehouse cost		0
	Truck cost		0
Total Scenario Cost			R 269,060.42

Table 4-4: Depiction of Program Main Screen.

This chapter focused on the method selection and development which included the construction of the scenario assessment program. The following chapter will analyse the scenarios according to the constraints of the system in order to establish the total monthly logistical cost of each scenario over a broad range of demand values.

Chapter 5: Method Implementation and Results

The previous chapter presented the selection of the cost centre method of evaluation as the appropriate method to be implemented. This selection was done through combining knowledge obtained from the literature review and project environment investigation with the constraints and requirements set forth in chapter 1. The method was also developed in the previous chapter. This chapter will focus on Scenario Evaluation and results which forms a critical component of the project. Scenario Evaluation is done through running each scenario through the program. The total logistical cost of each scenario is established for each of the ten iterations per demand value. The data tables collected from the experiments are shown in Appendix A. The average of the iterations is taken as the result for the scenario at the particular demand value as shown in Table 5-1: Total Logistical Cost per Month for Each Scenario per Demand Level. The results gained from the experiments are discussed in this chapter including the observations that are made.

Demand	Scenario Total Logistics Cost (R)					
	1	2	3	4	5	6
0-100	R 241,503.69	R 222,380.57	R 111,609.37	R 218,278.28	R 176,570.56	R 205,552.94
0-200	R 417,202.89	R 377,396.41	R 169,207.55	R 352,217.55	R 284,535.25	R 323,605.62
0-300	R 889,217.17	R 760,621.66	R 287,080.09	R 718,224.55	R 558,602.86	R 613,003.75
0-400	R 780,078.76	R 692,678.33	R 278,080.41	R 630,694.46	R 502,737.46	R 564,187.58
0-500	R 1,217,863.77	R 1,024,493.57	R 365,594.49	R 973,131.93	R 749,245.72	R 811,611.61

Table 5-1: Total Logistical Cost per Month for Each Scenario per Demand Level.

Demand	Truck		
	A	B	C
0-100	3.50	2.60	2.50
0-200	5.30	4.50	3.70
0-300	9.80	8.00	6.60
0-400	9.50	7.70	6.50
0-500	12.70	10.40	8.80

Table 5-2: Number of Trucks required per demand level and type of truck

The chapter so far discussed the data gathered through the experiments. The following section will convert the data into information and discuss the observations that are made from this activity. This conversion is crucial in establishing the behavior of the system and the feasibility of each scenario. Each scenario is discussed in line with the observations that were made during the experiments.

5.1 Results:

5.1.1 Demand between 0 and 100:

As PharmaPac is a new-found company this demand level is seen as the most applicable for the current business environment. Through analyzing the data gathered in the experiments the following results as seen in Figure 5-1: Results of Scenario Comparison with Random Demand between 0 and 100. were obtained.

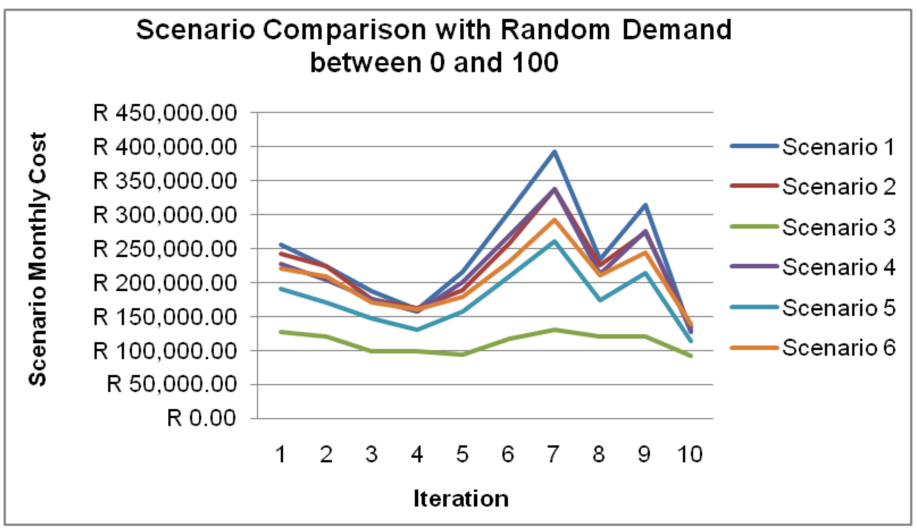

Figure 5-1: Results of Scenario Comparison with Random Demand between 0 and 100.

The graph above indicated that scenario 3 out performs all other scenarios within the set of iterations with an average monthly cost of R115 365.87. Scenario 5 has the second lowest T.M.L.C. at R176 570.56. Implementation of scenario3 within the particular demand level will decrease the monthly logistical cost by 52.24%. Scenario3 requires a private Durban warehouse as well as a private transportation network. Both aspects will greatly improve the system flexibility and level of customer service that could be accomplished. Figure 5-2: Truck Size Comparison at a 0 to 100 Demand, depicts the results of the truck price comparison. Truck B was found to be the best performer.

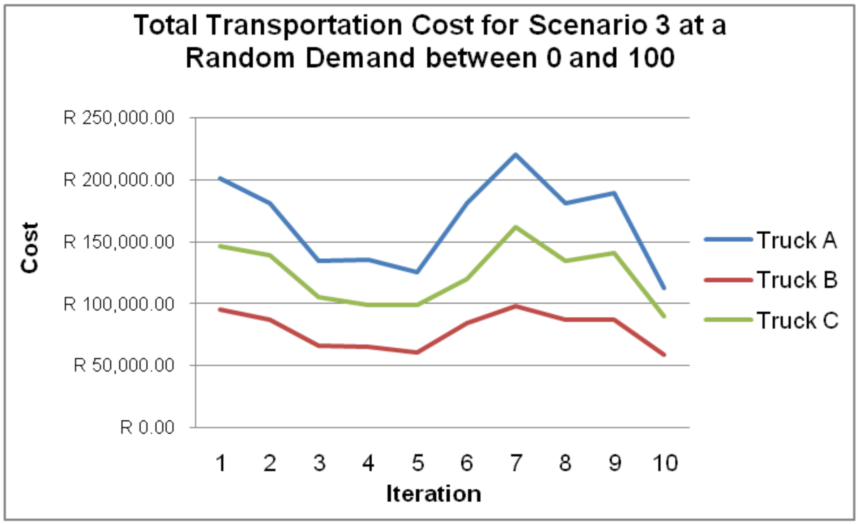

Figure 5-2: Truck Size Comparison at a 0 to 100 Demand

5.1.2 Demand between 0 and 200:

The second scenario required the program to be run for 10 iterations with the demand level adjusted to random values between 0 and 200. The graph bellow depicts the results of these iterations.

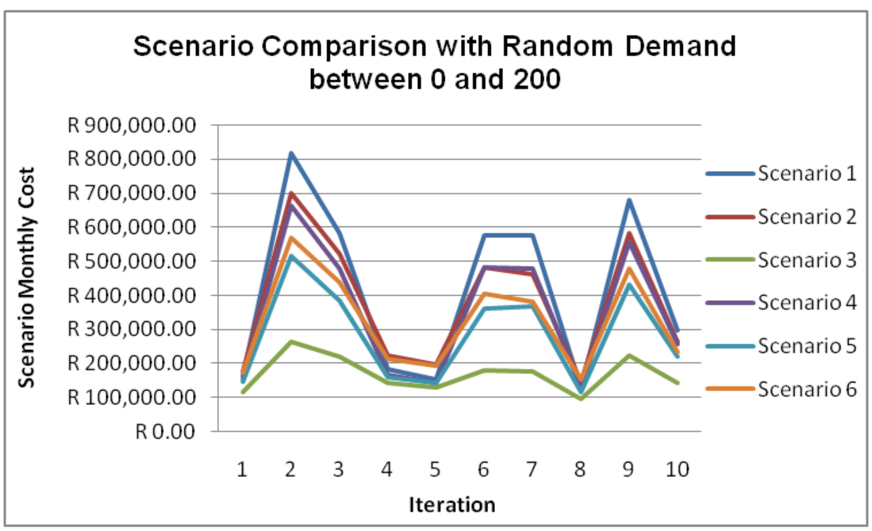

Figure 5-3: Results of Scenario Comparison with Random Demand between 0 and 200.

Scenario 3 yields the best result with an average monthly cost of R142 420,04. This scenario will bring about a 57.48% decline in the total monthly logistical cost. Scenario 5 produced the second lowest monthly cost at R 233 964,29. Truck B was established to have the lowest total cost as seen in Figure 5-4: Truck Size Comparison at a 0 to 200 Demand.

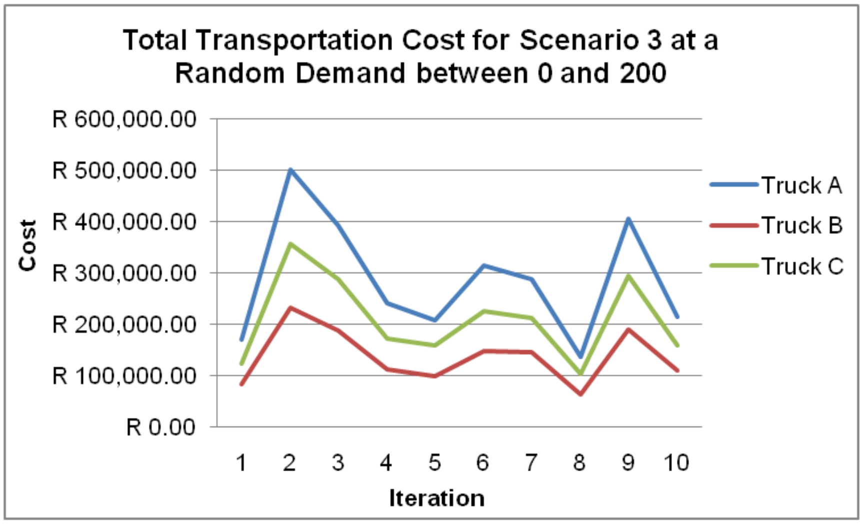

Figure 5-4: Truck Size Comparison at a 0 to 200 Demand.

5.1.3 Demand between 0 and 300:

The third scenario required the program to be run for 10 iterations with the demand level adjusted to random values between 0 and 300. The graph bellow depicts the results of these iterations.

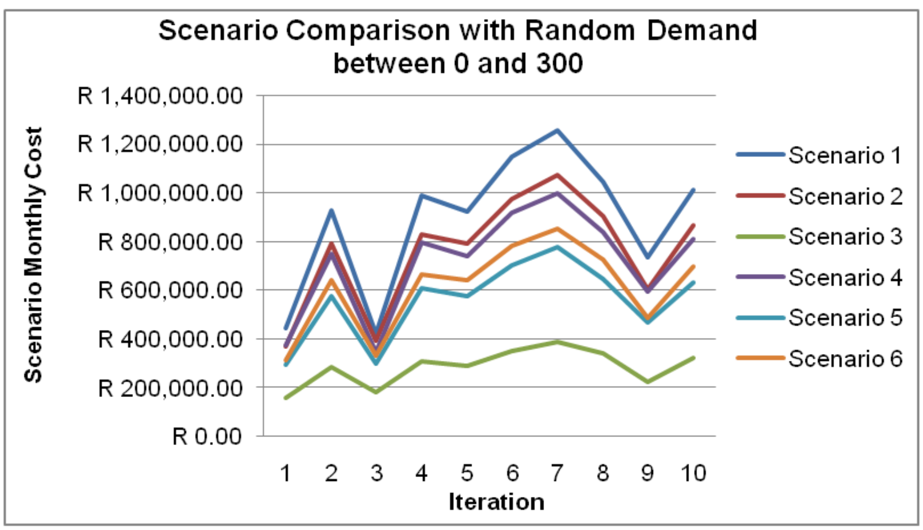

Figure 5-5: Results of Scenario Comparison with Random Demand between 0 and 300.

The results indicate that scenario 3 achieved the lowest total monthly cost at R264 541.07. Implementing this scenario will decrease the total logistical costs by 70.25% from the As-Is scenario. Scenario 5 and 6 was roughly level in succeeding scenario 3. Truck B was established to be the most cost effective.

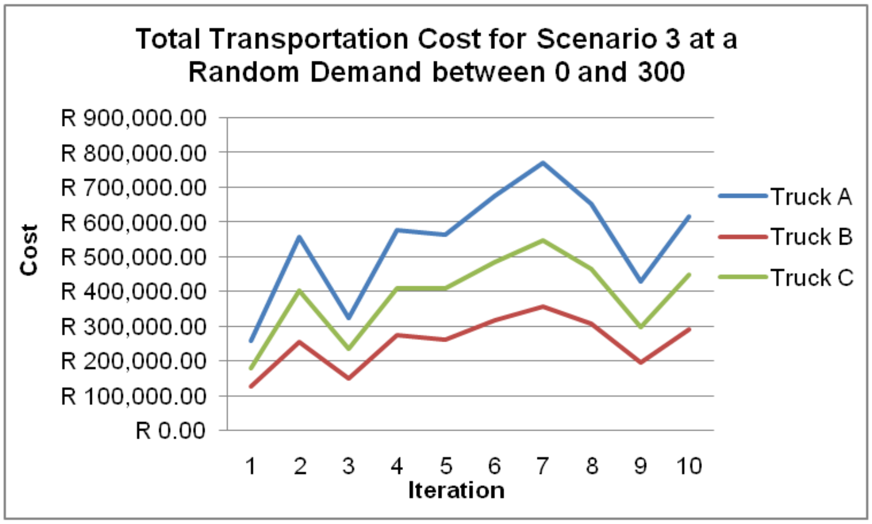

Figure 5-6: Truck Size Comparison at a 0 to 300 Demand.

5.1.4 Demand between 0 and 400:

The program was again run for 10 iterations, with the demand level adjusted to random values between 0 and 400. The graph bellow depicts the results of these iterations.

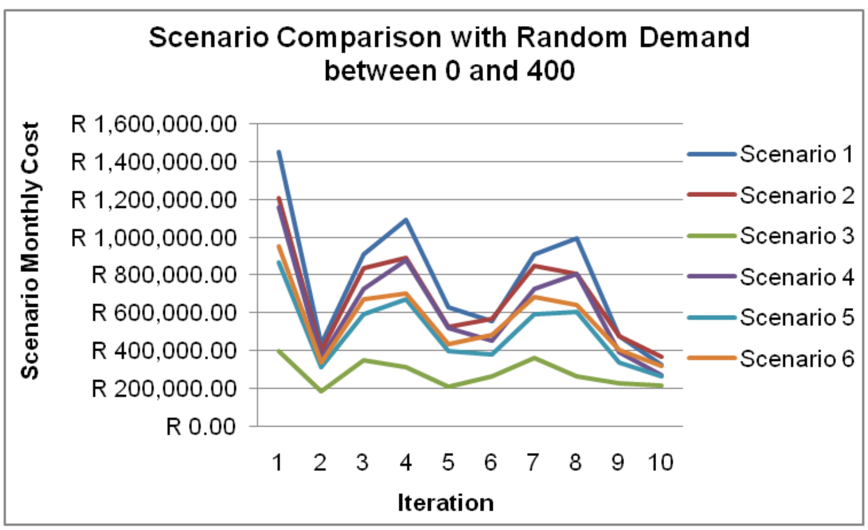

Figure 5-7: Results of Scenario Comparison with Random Demand between 0 and 400.

From Figure 5-7: Results of Scenario Comparison with Random Demand between 0 and 400. it is observed that scenario 3 has the lowest T.M.L.C. over all the iterations of the specific demand level. The average monthly cost for this scenario, at R257 795.29, is 66.95% lower than the current scenario. Scenario 5 performed the best of the remaining scenarios. Truck B resulted in the lowest total transportation cost for scenario 3.

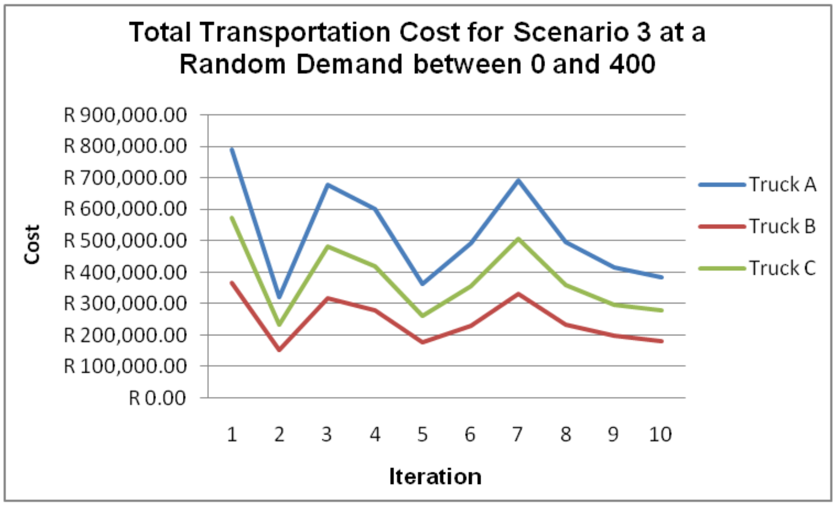

Figure 5-8: Truck Size Comparison at a 0 to 400 Demand.

5.1.5 Demand between 0 and 500:

For the last experiment the program was run for 10 iterations at a demand level between 0 and 500. The graph bellow depicts the results of these iterations.

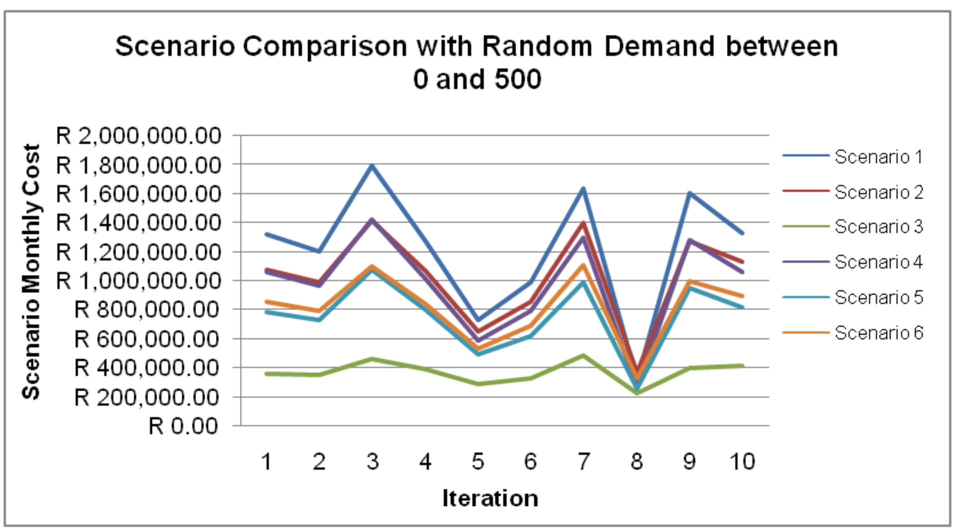

Figure 5-9: Results of Scenario Comparison with Random Demand between 0 and 500.

Analyses of the data gathered in the experiment performed shows that scenario 3 outperformed the remainder of the scenarios. Having an average monthly cost of R325 024.25. 73.31% lower than the current scenario. Scenario 5 indicated the best results subsequent to scenario 3. Scenario 3 truck analyses conclude truck B to have the lowest total cost involved.

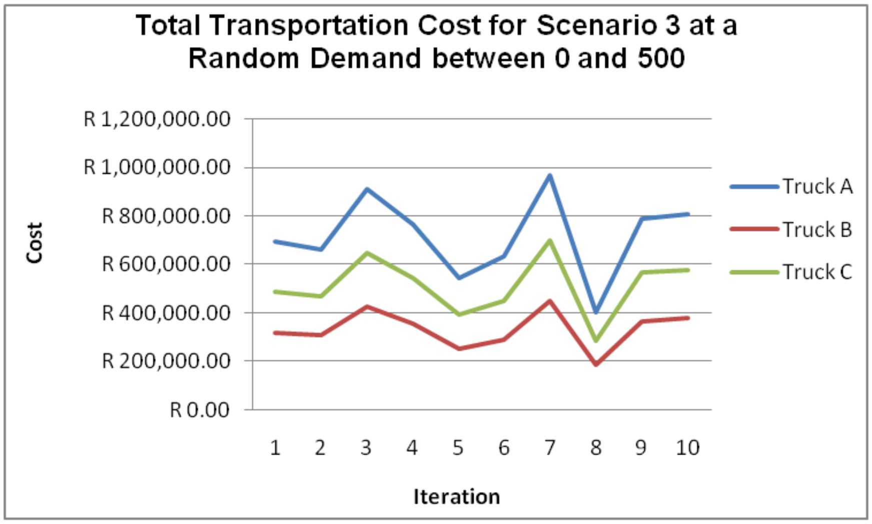

Figure 5-10: Truck Size Comparison at a 0 to 500 Demand.

5.1.6 Break-Even Analysis

In the analysis of the data it is observed that scenario 3 gave the best result in each of the demand levels with scenario 5 performing second to best. The data was analysed according to a break-even analyses in order to determine the point at which it would be indifferent which scenario is implemented. Both scenarious implement a private Durban warehouse. Thus this cost centre could be seen as a constant. The difference between the scenarios is the mode of transport used. The only variable that could affect this cost centre is the price required per pallet by PailPac for transportation to the customers. The analysis was done over all 5 demand levels with the results shown in Figure 5-11: Break-Even Analysis Results.

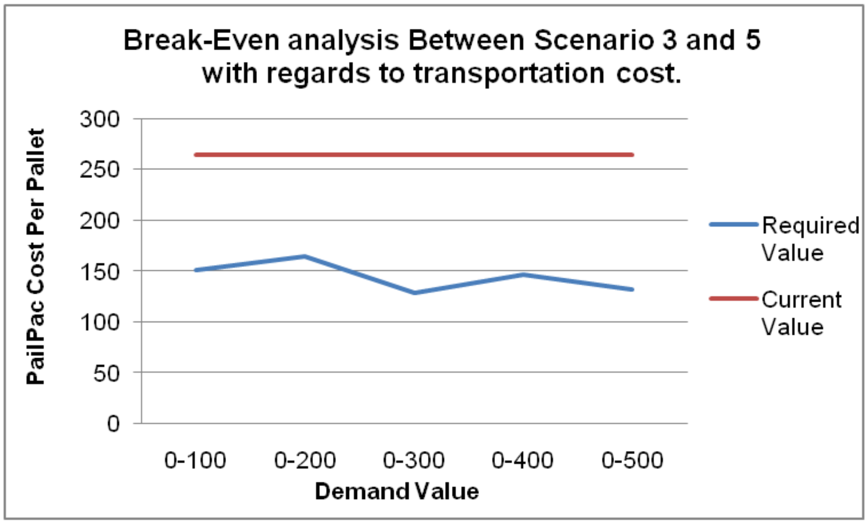

Figure 5-11: Break-Even Analysis Results.

As seen from the figure above the Price asked by PailPac must drop on average R120.34 per pallet to justify the usage of this scenario on a merely cost based outlook.

5.2 Chapter Summary

Scenario3 achieved the lowest total monthly logistic cost of all the scenarios at every demand level. It achieved on average a 64.05% decrease in the T.M.L.C. Through establishing the appropriate analysing method and its implementation, the above mentioned results were obtained. The following chapter will conclude on the logistical system identified, to be implemented at PharmaPac, and the motivation behind the choice of system.

Chapter 6: Conclusion and Future Work

Through studying the logistical system of PharmaPac clear benefits about the execution of the project can be observed. This chapter will discuss this conclusion and how the project objectives were resolved. The chapter also aims to elucidate the benefits that could be achieved through implementing the findings of the report.

The aim of the project was to establish the optimal logistical system to be implemented for PharmaPac. To facilitate the aim a number of project objectives had to be met within the project constraints. As a result a program was built and applied to different scenarios at various demand levels. The optimal logistical strategy identified is scenario 3. This scenario requires a private Durban warehouse as well as a private Transportation network to be implemented. PailPac's transportation and warehousing networks will not be utilized further.

Truck B, a 20 pallet truck based on a VW constellation 13-180 LWB with curtainsider and a 5 ton loading capacity, was established to be the most suitable truck to acquire as it gave the lowest average transportation cost over all of the demand levels. As the company is in the start-up phase it is suggested to acquire 3 trucks to begin with. This should be sufficient until the demand level increase to over 160 pallets per customer. As the product demand increases the prospect of acquiring additional trucks should be investigated. This analysis should include the prospect of acquiring a different size truck.

Through implementing scenario 3 a decrease of approximately 63.05% in the T.M.L.C. is expected. The dedicated trucks, suggested through this scenario, would increase system flexibility and improve system reliability eventually increasing the customer service level that could be acquired by the company .The broad spectrum of demand that was used facilitates longevity in the applicability and accurateness of the project results. This also makes long-period planning with reference to the project results possible.

The breakeven analysis determined that a decrease of R120.34 in PailPac's transportation cost per pallet will make scenario 3 and 5 equally cost effective. Scenario 3 provides better system flexibility and customer service while scenario 5 reduces the risk involved in owning and operating a private transportation fleet. The advantages of scenario 3 far outweigh those of scenario 5. Thus in conclusion scenario 5 should only be implemented in case of a substantial decrease in the transportation cost required by PailPac.

6.1 Validation and testing

To ensure the validity of the project findings the results were presented to management. The findings were found to reflect the actual circumstances and were established as a good estimator of the total logistical cost.

6.2 Future work

The project was restricted to the physical distribution side of logistics. Future work, to lead from this project, should include the examination of the materials management side of logistics as well a continual examination of the physical distribution side through implementing current and forecasted demand values into the model.

Bibliography

Coyle, J. J., Bardi, E. J., & Langley, C. J. (2003). *The Management of Business Logistics: a supply chain perspective 7th edition.* Mason Ohio: South-Western Thomson Learning.

Deshpande, V., Iyer, A. V., & Cho, R. (2006). Efficient Supply Chain Management at the U.S. Coast Guard Using Part-Age Dependent Supply Replenishment Policies. *OPERATIONS RESEARCH* , 1028–1040.

Galvez-Fernandez, C., Khadaoui, D., Ayed, H., Habbas, Z., & Alba, E. (2009). Distributed Approach for solving time-dependant problems in multimodal transport networks. *Advances in Operations Research* , 1-15.

Gitlow, H. S., Oppenheim, A. J., Oppenheim, R., & Levine, D. M. (2005). *Quality Management.* New York: McGraw-Hill.

Jacobs, F. R., Chase, R. B., & Aquilano, J. N. (2009). *Operations & Supply Management twelfth edition.* New York: McGraw-Hill Irwin.

Kutanoglu, E., & Lohiya, D. (2008). Integrated inventory and transportation mode selection: A service parts logistics system. *Transportation Research Part E* , 665-683.

Meade, L., & Sarkis, J. (1998). Strategic analysis of lofistics and supply chain management systems using the analytical network process. *Transport Res_E (logistics and Transport Rev.), Volume 34, No. 3* , 201-215.

Mentzer, J. T., & Konrad, B. P. (1991). an Efficiency/effectiveness approach to logistics performance analysis. *Journal of business logistics* , 33-61.

Tan, K. C. (2001). A framework of supply chain management literature. *European Journal of Purchasing & Supply Management 7* , 39-48.

Appendix A

Experiment 1: Summary		1	2	3	4	5	6	7	8	9	10
Variables:											
Demand	Gauteng	331.52	289.41	253.57	229.26	381.55	542.52	698.85	348.58	557.64	124.54
	PE	91.27	77.57	86.33	7.98	55.07	83.31	18.65	67.90	81.11	58.49
	East-London	92.52	61.25	63.31	47.11	28.13	20.57	86.37	28.59	9.19	82.42
	Capetown	81.78	95.40	27.49	84.63	6.79	16.05	54.37	85.13	37.84	42.57
Results:											
Total Scenario Cost (R)	Scenario 1	R 256,228.71	R 224,562.69	R 186,428.85	R 161,045.43	R 215,642.39	R 303,669.38	R 392,974.43	R 233,538.28	R 313,924.76	R 127,021.94
	Scenario 2	R 242,142.96	R 223,817.72	R 176,335.48	R 161,868.98	R 189,513.19	R 257,514.94	R 337,860.20	R 226,591.71	R 274,214.82	R 133,945.72
	Scenario 3	R 128,034.32	R 120,156.38	R 98,483.85	R 97,376.36	R 92,851.19	R 117,262.18	R 130,785.76	R 119,940.07	R 119,935.75	R 91,267.82
	Scenario 4	R 227,527.08	R 203,389.60	R 174,782.05	R 155,725.62	R 199,809.82	R 268,268.32	R 337,505.29	R 211,693.56	R 276,131.71	R 127,949.75
	Scenario 5	R 190,728.60	R 171,264.58	R 146,635.64	R 130,278.04	R 157,457.39	R 208,049.10	R 259,932.40	R 173,000.98	R 214,233.23	R 114,125.65
	Scenario 6	R 220,472.33	R 208,809.42	R 169,760.95	R 160,884.47	R 179,228.74	R 229,909.96	R 292,496.04	R 210,976.39	R 244,492.27	R 138,498.84
Total Transportation Cost (R)	Truck A	R 201,492.12	R 181,444.70	R 134,601.81	R 135,994.84	R 126,053.32	R 181,089.95	R 220,579.14	R 181,012.08	R 189,153.92	R 112,859.31
	Truck B	R 95,534.32	R 87,656.38	R 65,983.85	R 64,876.36	R 60,351.19	R 84,762.18	R 98,285.76	R 87,440.07	R 87,435.75	R 58,767.82
	Truck C	R 146,022.48	R 139,014.10	R 104,921.98	R 99,098.97	R 98,545.22	R 119,302.14	R 161,761.05	R 134,125.54	R 141,038.74	R 89,598.72
Nr of Trucks Required	Truck A	4	4	3	3	3	4	4	4	4	2
	Truck B	3	3	2	2	2	3	3	3	3	2
	Truck C	3	3	2	2	2	2	3	3	3	2

Table 8-1: Experimental data for a random demand level between 0 and 100.

Experiment 2: Summary		1	2	3	4	5	6	7	8	9	10
Variables:											
Demand	Gauteng	70.32	1349.11	860.44	73.74	6.98	1091.94	1022.73	139.00	1133.21	350.03
	PE	142.50	152.78	173.73	92.81	44.85	22.31	31.24	73.25	67.29	188.33
	East-London	158.38	131.04	141.54	114.93	198.75	28.01	185.22	11.50	155.43	167.10
	Capetown	59.23	186.21	152.88	199.35	169.11	96.85	23.31	91.65	152.32	1.36
Results:											
Total Scenario Cost (R)	Scenario 1	R 165,989.06	R 818,286.51	R 583,767.30	R 184,889.30	R 155,011.12	R 576,578.21	R 577,489.24	R 131,336.36	R 680,069.99	R 298,611.80
	Scenario 2	R 179,409.62	R 701,376.54	R 524,688.59	R 225,074.53	R 198,231.84	R 485,181.63	R 463,553.71	R 148,360.96	R 582,651.32	R 265,435.38
	Scenario 3	R 116,219.58	R 264,799.74	R 220,207.21	R 144,130.43	R 130,275.27	R 179,196.75	R 177,829.68	R 95,338.73	R 222,789.93	R 141,288.14
	Scenario 4	R 154,369.91	R 664,324.29	R 480,086.51	R 168,104.44	R 144,492.77	R 482,069.39	R 480,583.70	R 131,508.32	R 557,973.96	R 258,662.24
	Scenario 5	R 146,564.13	R 514,573.04	R 384,577.17	R 159,919.38	R 143,718.17	R 360,864.26	R 367,060.65	R 116,079.81	R 432,187.31	R 219,808.62
	Scenario 6	R 172,859.38	R 568,838.47	R 436,646.16	R 213,936.63	R 192,648.15	R 405,261.85	R 381,512.19	R 152,233.10	R 478,318.26	R 233,801.99
Total Transportation Cost (R)	Truck A	R 167,835.38	R 501,040.21	R 391,235.17	R 240,245.09	R 207,297.83	R 312,586.36	R 287,555.97	R 135,233.43	R 405,528.81	R 213,657.29
	Truck B	R 83,719.58	R 232,299.74	R 187,707.21	R 111,630.43	R 97,775.27	R 146,696.75	R 145,329.68	R 62,838.73	R 190,289.93	R 108,788.14
	Truck C	R 122,053.58	R 356,219.21	R 286,176.71	R 171,339.17	R 158,654.87	R 225,305.66	R 210,380.41	R 102,032.11	R 292,916.86	R 156,820.57
Nr of Trucks Required	Truck A	3	9	7	5	4	6	5	3	7	4
	Truck B	3	7	6	4	3	5	5	2	6	4
	Truck C	2	6	5	3	3	4	4	2	5	3

Table 8-2: Experimental data for a random demand level between 0 and 200.

Experiment 3: Summary		1	2	3	4	5	6	7	8	9	10
Variables:											
Demand	Gauteng	735.28	1556.78	438.33	1697.85	1492.49	1931.17	1996.45	1742.43	1163.69	1625.85
	PE	186.79	150.10	234.38	5.33	294.30	122.40	282.62	193.05	295.87	185.34
	East-London	44.85	149.04	257.27	207.81	95.67	240.56	293.92	101.37	162.30	233.33
	Capetown	21.47	197.66	78.95	261.30	174.08	240.07	240.72	281.37	19.96	220.74
Results:											
Total Scenario Cost (R)	Scenario 1	R 444,847.58	R 927,497.09	R 419,434.07	R 986,777.57	R 921,446.47	R 1,145,682.54	R 1,255,643.44	R 1,045,352.61	R 732,539.19	R 1,012,951.13
	Scenario 2	R 370,892.00	R 793,308.19	R 392,029.89	R 829,942.55	R 794,294.49	R 977,093.31	R 1,073,224.99	R 904,454.42	R 603,575.88	R 867,400.92
	Scenario 3	R 159,042.70	R 288,042.66	R 183,306.60	R 309,671.93	R 293,818.09	R 351,050.12	R 391,052.59	R 342,488.65	R 227,085.81	R 325,241.78
	Scenario 4	R 376,038.11	R 749,504.22	R 348,519.34	R 796,618.02	R 743,150.82	R 918,426.03	R 999,738.48	R 840,235.84	R 596,752.46	R 813,262.22
	Scenario 5	R 294,422.04	R 576,701.09	R 299,864.90	R 608,156.40	R 577,483.88	R 704,065.62	R 778,132.34	R 646,826.28	R 467,582.76	R 632,793.26
	Scenario 6	R 313,710.55	R 639,496.98	R 332,982.61	R 665,361.88	R 640,217.42	R 779,680.13	R 850,449.41	R 726,636.76	R 487,117.90	R 694,383.80
Total Transportation Cost (R)	Truck A	R 260,335.78	R 556,457.55	R 324,690.96	R 578,062.39	R 563,422.67	R 673,885.28	R 770,270.58	R 652,090.09	R 428,742.20	R 616,650.96
	Truck B	R 126,542.70	R 255,542.66	R 150,806.60	R 277,171.93	R 261,318.09	R 318,550.12	R 358,552.59	R 309,988.65	R 194,585.81	R 292,741.78
	Truck C	R 178,832.08	R 401,265.17	R 235,212.57	R 409,242.61	R 409,502.18	R 484,528.42	R 546,827.10	R 464,775.17	R 298,108.26	R 447,340.75
Nr of Trucks Required	Truck A	5	10	6	10	10	12	14	12	8	11
	Truck B	4	8	5	9	8	10	11	10	6	9
	Truck C	3	7	4	7	7	8	9	8	5	8

Table 8-3: Experimental data for a random demand level between 0 and 300.

Experiment 4: Summary		1	2	3	4	5	6	7	8	9	10
Variables:											
Demand	Gauteng	2634.99	467.44	1200.74	1857.82	1111.28	687.38	1164.00	1836.37	508.77	58.86
	PE	8.04	257.99	290.14	257.58	35.78	237.54	302.43	269.71	61.28	193.76
	East-London	200.28	298.82	289.12	261.14	90.67	18.74	302.13	50.12	288.87	394.67
	Capetown	317.83	26.18	335.01	48.08	143.09	363.62	362.56	0.38	285.70	225.90
Results:											
Total Scenario Cost (R)	Scenario 1	R 1,454,204.58	R 437,915.55	R 910,544.28	R 1,097,266.78	R 630,802.67	R 556,728.51	R 912,392.94	R 996,379.81	R 477,117.73	R 327,434.72
	Scenario 2	R 1,210,132.57	R 397,320.24	R 836,201.76	R 893,475.84	R 527,614.54	R 568,836.87	R 846,460.16	R 806,671.39	R 474,273.13	R 365,796.82
	Scenario 3	R 398,182.10	R 183,691.63	R 349,838.79	R 310,147.81	R 208,963.52	R 262,532.83	R 361,921.76	R 263,536.50	R 229,434.91	R 212,554.24
	Scenario 4	R 1,162,687.39	R 362,747.31	R 726,256.80	R 881,242.96	R 521,768.89	R 455,231.31	R 726,452.54	R 807,830.40	R 392,295.20	R 270,431.77
	Scenario 5	R 870,202.97	R 310,861.79	R 592,974.97	R 675,024.99	R 398,416.59	R 378,931.79	R 597,248.35	R 603,993.59	R 335,821.66	R 263,897.88
	Scenario 6	R 955,845.46	R 334,520.86	R 676,811.66	R 705,994.74	R 434,837.32	R 482,729.03	R 685,618.72	R 643,521.81	R 402,927.60	R 319,068.59
Total Transportation Cost (R)	Truck A	R 789,227.81	R 321,853.00	R 679,033.41	R 599,752.98	R 363,945.76	R 493,071.43	R 690,160.30	R 497,276.46	R 415,443.59	R 384,313.32
	Truck B	R 365,682.10	R 151,191.63	R 317,338.79	R 277,647.81	R 176,463.52	R 230,032.83	R 329,421.76	R 231,036.50	R 196,934.91	R 180,054.24
	Truck C	R 572,258.24	R 233,265.80	R 482,737.39	R 420,040.70	R 261,656.03	R 353,891.74	R 505,962.19	R 360,363.67	R 296,222.05	R 278,675.15
Nr of Trucks Required	Truck A	14	6	12	11	7	9	12	9	8	7
	Truck B	11	5	10	9	6	7	10	7	6	6
	Truck C	10	4	8	7	5	6	9	6	5	5

Table 8-4: Experimental data for a random demand level between 0 and 400.

Experiment 5: Summary		1	2	3	4	5	6	7	8	9	10
Variables:											
Demand	Gauteng	2512.11	2124.93	3141.57	1942.66	844.12	1553.23	2813.34	48.15	2994.59	2195.22
	PE	27.91	350.01	470.25	398.21	388.04	254.03	149.18	136.33	72.32	55.77
	East-London	38.10	8.60	306.07	411.59	364.07	142.96	198.42	328.73	232.42	320.16
	Capetown	257.30	134.71	11.97	128.38	131.13	257.91	438.30	331.49	152.80	379.93
Results:											
Total Scenario Cost (R)	Scenario 1	R 1,320,862.39	R 1,198,078.05	R 1,792,934.97	R 1,274,344.32	R 728,499.07	R 983,900.11	R 1,634,998.41	R 315,769.93	R 1,601,055.96	R 1,328,194.46
	Scenario 2	R 1,079,934.50	R 993,988.86	R 1,416,512.07	R 1,067,149.47	R 656,318.36	R 855,508.87	R 1,397,719.13	R 369,837.92	R 1,277,535.72	R 1,130,430.77
	Scenario 3	R 351,763.93	R 343,137.57	R 456,318.30	R 387,371.02	R 285,827.67	R 325,090.36	R 480,824.46	R 221,167.62	R 395,270.59	R 409,173.34
	Scenario 4	R 1,062,731.47	R 962,206.44	R 1,422,625.03	R 1,011,558.25	R 583,945.48	R 790,065.87	R 1,298,577.13	R 261,688.73	R 1,279,712.88	R 1,058,208.04
	Scenario 5	R 783,887.25	R 726,338.79	R 1,073,911.06	R 795,922.52	R 490,248.32	R 617,656.83	R 986,296.48	R 256,344.07	R 947,313.81	R 814,538.06
	Scenario 6	R 855,187.13	R 788,941.99	R 1,092,487.33	R 838,280.03	R 532,110.73	R 687,667.03	R 1,103,692.55	R 325,692.44	R 996,852.37	R 895,204.47
Total Transportation Cost (R)	Truck A	R 692,072.46	R 659,072.51	R 910,298.17	R 766,904.82	R 541,895.69	R 633,073.07	R 969,003.39	R 400,856.55	R 788,033.79	R 806,852.58
	Truck B	R 319,263.93	R 310,637.57	R 423,818.30	R 354,871.02	R 253,327.67	R 292,590.36	R 448,324.46	R 188,667.62	R 362,770.59	R 376,673.34
	Truck C	R 486,985.68	R 469,430.12	R 645,138.71	R 542,094.28	R 392,491.71	R 449,754.74	R 697,132.47	R 286,263.23	R 567,923.43	R 576,151.78
Nr of Trucks Required	Truck A	12	12	16	14	10	11	17	7	14	14
	Truck B	10	10	13	11	8	9	14	6	11	12
	Truck C	8	8	11	9	7	8	12	5	10	10

Table 8-5: Experimental data for a random demand level between 0 and 500.

Appendix B

	Wadeville			Clayville			Isando			Pretoria			Roodepoort			Randburg		
	Path 1	Path 2	Path 3	Path 1	Path 2	Path 3	Path 1	Path 2	Path 3	Path 1	Path 2	Path 3	Path 1	Path 2	Path 3	Path 1	Path 2	Path 3
Wadeville	0	0	0	52.6	47.8	54.4	25.7	18.3	23.4	69.3	77.6	87.6	44	59.8	38.3	50.9	55	35.9
Clayville	52.6	47.8	54.4	0	0	0	28.7	26.5		33	40.4		50.5	76.9	63.9	41.6	68	
Isando	25.7	18.3	23.4	28.7	26.5		0	0	0	53.9	60		50.6	51.7	37.1	41.7	33	30.5
Pretoria	69.3	77.6	87.6	33	40.4		53.9	60		0	0	0	64.2	63		55.3	61.1	
Roodepoort	44	59.8	38.3	50.5	76.9	63.9	50.6	51.7	37.1	64.2	63		0	0	0	12.1	14.4	18.8
Randburg	50.9	55	35.9	41.6	68		41.7	33	30.5	55.3	61.1		12.1	14.4	18.8	0	0	0
Longmeadow	24.7	22.4		31.4	42.6		15.4	8.8	11.7	46.1	58.7		36.7	49.4		27.8	25.3	18.3
PE	1077			1111			1085			1123			1066			1077		
East London	969			1003			977			1015			958			969		
Cape Town	1413			1448			1421			1460			1403			1413		
Durban	554			598			572			615			591			597		

Table 9-1: Distances of Customers.