MASTER THESIS

To achieve academic degree:

MASTER OF SCIENCE

Optimization of Automotive Spare Parts Distribution in Adam Opel GmbH

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Abstract

Policies on spare-parts delivery frequency is crucial for automotive companies. The same condition also valid for Adam Opel GmbH, a daughter company of General Motors Europe GmbH, which operates 2 warehouses, 17 regional distribution centers, and roughly 2000 authorized dealers throughout Germany. This study aims to provide thorough understanding on the impact of delivery frequency alternative on the total spare-parts distribution costs as well as the spare parts availability service level for the customers. To do so, this study apply historical data analysis and discrete event simulation analysis using DOSIMIS simulation platform.

Table of Contents

List of Tables

List of Figures

Chapter 1
Introduction

1.1 Problem Background

The spare parts distribution network of Adam Opel GmbH is surely one of the biggest automotive spare part distribution networks in Germany. A network consists of 2 source/central warehouses and 17 Local Distribution Centers (LDC) should serve the demand of roughly 2000 authorized retailers throughout Germany.

The demand of the retailers can be classified into two categories, stock orders and rush orders which are shipped separately. Stock orders are the demands which are addressed by a retailer to fulfill their desired stock level in order to be able to serve their daily operational needs. In other side, rush orders are the demands which are addressed by a retailer to fulfill their urgent demands of a specific part which is out of stock or in an urgent condition to be restocked.

In this company, stock order is usually being replenished in two types of frequency delivery setup, daily and weekly replenishment. Based on the annual sales of a retailer or based on a retailer’s agreement, a retailer can be determined whether it will get daily or weekly replenishment. However, the definition and standardization of distribution methods is so far not formalized. The decisions are made on a case by case basis, not taking the different cost elements into account.

Obviously there is a need to study the delivery frequency (stock orders) alternatives in terms of standardized delivery period and to analyze the effects of each alternative so further insight for a better operational policy could be gained.

1.2 Problem Definition and Limitation

Studying the impact of delivery frequency alternatives to the distribution costs is having great importance. By understanding the distribution costs behaviour corresponding to each delivery frequency alternative, management can decide the optimum operational level of delivery frequency which satisfy the desired service and overall cost level. Therefore a careful study is needed to investigate the impact of applying different delivery alternatives to distribution cost. For this purpose, historic data analysis and discrete event simulation analysis method will be applied.

1.3 Thesis Objectives

The three main objectives of this thesis project are defined by the points below:

- Studying and simulating of the impact of alternative delivery frequencies on the distribution cost to retailers.
- Development of a tool which allows Authorized Retailers to choose their preferred delivery method. The tool should allow the retailers to choose his preferred delivery methods and the corresponding surcharges.
- The implications of each policy alternative for the current LDC structure have to be assessed.

1.4 Thesis Outline

The following points explain the outlines and brief descriptions of each chapter of the thesis:

Chapter I Introduction

This chapter gives an explanation about the background of the thesis project, the problem definition and limitation, the objectives, and the outline of the thesis report.

Chapter II Theoretical Background

Theoretical background chapter explains all the corresponding theories, literature study, and preceding researches which have been taken as a theoretical basis for this thesis project.

Chapter III Research Method

This chapter gives an overview about the method which guides all research activities applied in this thesis project.

Chapter IV Real System Study

This chapter gives an overview of the existing real system operation. This step is important to build an understanding of the ongoing situation of the current operation and to analyse the potencies of making system improvement.

Chapter V Simulation Model Development

This chapter shows the translation process of the current distribution system and the translation process of the alternative distribution system set-ups to the simulation models.

Chapter VI Result Analysis

The analysis and the interpretation of the simulation results are explained thoroughly here.

Chapter VII Conclusions and Recommendations

In this chapter conclusions along with the recommendations and suggestions for current system improvement are being summarized.

Chapter 2
Theoretical Background

2.1 Introduction

Adam Opel GmbH applies multi echelon distribution system for its spare part and accessory distribution. Especially for a distribution network which is involving many logistics nodes, multi echelon distribution system offers a lot of benefits. As stated by Graves (2005), in general there are five reasons for applying multi echelon distribution system. Better service, transportation economies, mixing functions, risk pooling over the manufacturing and procurement lead time, and differentiated stocking and service policies are five reasons of applying multi echelon distribution system.

In designing and planning a good network of multi echelon distribution system, there are some issues which have to be considered carefully. Number of echelons, number and location of distribution centers, stock locations, replenishment policies, and information systems issues are the common issues to be considered in designing and planning of multi echelon distribution system defined by Graves.

As one of the important issue to be considered in the assessment of multi echelon distribution system, current situation of stock order replenishment frequency policy of Opel distribution network of spare part and accessory will be reviewed. The effect of adjusting retailer’s replenishment frequency to the distribution cost will be analyzed. Different replenishment frequency alternatives (daily replenishment, twice a week replenishment, weekly replenishment) and their behavior to distribution cost will be analyzed. By the understanding gained, new fields of cost saving potencies are expected to be revealed.

In order to enrich the distribution cost savings possibility insight, not only the replenishment policy issues will be analyzed but also the issue considering the number and location of distribution centers will be analyzed. Extra scenarios which apply the reduction of current number of sourcing warehouse will be applied in this study to gain a better perspective of savings potencies existence.

2.2 Freight Consolidation

Adjusting the retailer's replenishment frequency and doing an adjustment of the warehouse sourcing policy to achieve distribution cost saving are strongly correlated to freight consolidation theory. Having an efficient transportation on minimum level of cost is the background of this freight consolidation theory.

As stated by Ballou (2004), consolidating small shipments into large ones is the primary way to achieve a lower transportation cost per unit of weight. The basic idea of freight consolidation is to arrange and to collect big number of low utilized vehicle shipments into smaller number of high utilized vehicle shipments. By the use of smaller number of shipments with higher filling degree utilization consequently lower unit cost of transportation can be achieved.

Ballou also has stated that shipment consolidation is usually achieved in four alternatives, *inventory* consolidation, *vehicle* consolidation, *warehouse* consolidation, and *temporal* consolidation. In *inventory* consolidation, the incoming demands are being accumulated and not being established until a specific threshold value of truck fill utilization achieved. In *vehicle* consolidation, grouping of several trips with low truck utilization into smaller number of trip with higher truck utilization value is being applied. By *warehouse* consolidation, the fundamental reason is to allow the transportation of large shipment sizes over long distances and the transportation of small shipment sizes over short distances. In *temporal* consolidation case, orders from costumers are held so that a few larger shipments may be made at one time, rather than making many small shipments at various times.

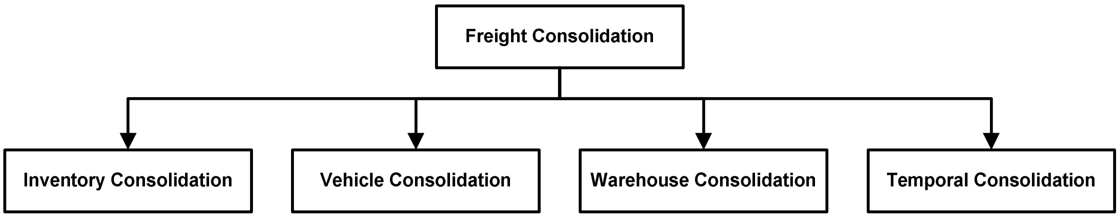

Figure 2-1 Freight Consolidation Classification (Ballou, 2004)

Since time variable (delivery frequency adjustment) and the number of sourcing warehouse variable are the only variable being tried out in this study, the consolidation methods which are applied in this thesis are clearly categorized as *temporal* consolidation and *warehouse* consolidation. The clear explanation about how these consolidation methods work are explained by the examples explained in the following sections.

2.2.1 Temporal Consolidation

In *temporal* consolidation case, orders from costumers are held so that a few larger shipments may be made at one time, rather than making many small shipments at various times. An example is being forwarded to make the concept of applying *temporal* consolidation and its benefit become clearer. Consider a single warehouse called WH1 is serving demands from four retailers named D1, D2, D3, and D4. Assume that those retailers are being served by the warehouse in one route of trucking trip. As additional information, the truck which is being used for transporting the goods for transporting the goods has a maximum capacity to carry the goods in total of six unit loads.

Table 2-1 hows the comparison of daily replenishment policy and weekly replenishment policy application. In daily replenishment policy each retailer can address their needs at any day they like within a week, on the other side in weekly replenishment the orders which are triggered within a week will be accumulated and delivered in one shipment.

Table 2-1 Temporal Consolidation Case Study

Daily Replenishment							
Sourcing Warehouse	Dealer	Monday	Tuesday	Wednesday	Thursday	Friday	
W1	D1	2	3	3		2	
	D2		3		3	3	
	D3	1	2	1	2	1	
	D4	1		2		1	
Daily Total Good Needs		4	8	6	5	7	30
Daily Total Truck Needs		1	2	1	1	2	7
Truck Utilization		66,7%	66,7%	100,0%	83,3%	58,3%	71,4%

Weekly Replenishment			
Sourcing Warehouse	Dealer	Week	
W1	D1	10	
	D2	9	
	D3	7	
	D4	4	
Weekly Total Good Needs		30	30
Weekly Total Truck Needs		5	5
Truck Utilization		100%	100%

As shown in table 2-1, it is clear that by adjusting the delivery frequency into a less frequent period, a reduction of total truck needs and the average truck utilization performance increase can be achieved. The example showed by table 2-1 indicates two out of seven trucks use reduction which accounts for 28% truck use savings by the weekly replenishment policy implementation. In the average truck utilization number side, the number of truck utilization increase reaches the number of 28.6%.

2.2.2 Warehouse Consolidation

Reducing the number of transportation effort by consolidating smaller size of shipment into bigger sized of shipment can also be done by doing *warehouse* consolidation. Warehouse is a vital component of a distribution network. Installation of warehouses leads to a trade off between considerable infestation and costumer service level. A network with many warehouses distributed at several regions can offer better service to costumer. In other side a network with fewer warehouses could endanger its service level to costumer but account to less infestation and operating cost. Considering the consolidation theory, transportation cost is one of the costs which also will be decreased by the application of fewer warehouses policy.

An example is being forwarded again to understand the transportation cost saving potency that exists due to the application of *warehouse* consolidation method. Consider two systems which are described by the figure 2-2 below. In the first system, four different retailers, D1, D2, D3, and D4, are being served by two warehouses, W1 and W2. In the second system all of the retailers are being served by one warehouse, W3. Let the second system be the warehouse consolidated system in which the demands of the retailers which are addressed to W1 and W2 will be accumulated and served by only one warehouse W3. Assume at each system, the retailers are being served by each warehouse in one route of trucking trip, so at the end the first system will have two routes and the second system will have only one route. As additional information, the truck which is being used for transporting the goods for transporting the goods has a maximum capacity to carry the goods in total of six unit loads.

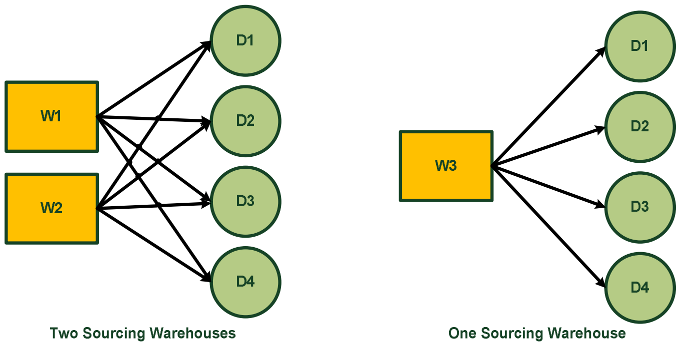

Figure 2-2 Sourcing Warehouse Consolidation

The demand distribution sample of each retailer to each warehouse in each system is described by the table 2-2 below. The left side of the table shows the unconsolidated replenishment condition of first system. The shipment between W1 and W2 are treated separately due to the different sourcing location. At the right side, the orders of each retailer referred to W1 and W2 are fulfilled by one warehouse only. So the chance of consolidating the orders which build less than full truck at W1 and W2 exists. By the simple example showed, the consolidated warehouse replenishment has gained one out of nine trucks or 11% saving. As an additional remark, the average truck utilization which has increased 11% from 85% up to 96%. As the example already showed, the opportunity to increase the utilization the transportation means in order to reduce the transportation effort is existing.

Table 2-2 Warehouse Consolidation Case Study

Unconsolidated Replenishment						
Sourcing Warehouse	Dealer	Needs	Sourcing Warehouse	Dealer	Needs	
W1	D1	10	W2	D1	8	
	D2	9		D2	2	
	D3	7		D3	3	
	D4	5		D4	2	
						Total
Total Needs		31	Total Needs		15	46
Total Truck Needs		6	Total Truck Needs		3	9
Truck Utilization		86%	Truck Utilization		83%	85%

Warehouse Consolidated Replenishment			
Sourcing Warehouse	Dealer	Needs	
W3 = W1 + W2	D1	18	
	D2	11	
	D3	10	
	D4	7	
			Total
Total Needs		46	46
Total Truck Needs		8	8
Truck Utilization		96%	96%

2.3 Transportation Cost

As a common knowledge in the business science, subcontracting the part of the business which is not considered as a core part of a business can lead to many benefits. A company can concentrates to the main core on the business and sort out the auxiliary part of the business which is not considered as the business core. Big saving of cost can also be achieved by the partnership. For instance, in the transportation field, by doing a partnership with a transportation company, a company can avoid the complexity of organizing the vehicle, manpower, organizational issues, etc. By concentrating the resources in hand only to the core field of the business, and letting other companies take cake the tasks which are being their core field of the business, an effective business progress can be achieved.

There are so many cases at which a company subcontracted some of their supply chain parts to third party logistics companies. These conditions are also valid in the field of transportation. In term of benefit, by subcontracting the transportation assignment the subcontracted company will take care all of the transportation assignment as the performance points agreed in the contract.

However, the contract of partnership between a company and third party logistics should be reviewed thoroughly. Beside the benefits that can be achieved by the partnership establishment, a suitable tariff agreement should be considered carefully. A careful tariff setup leads to a reasonable way of payment. Therefore the background and the reasoning of a rate agreement should be well understood by every company which will cooperate with a third party logistic transportation company.

2.3.1 Parcel, LTL, and FTL Transportation Cost

Lapierre, Ruiz, and Soriano (2004) have already described the types of transportation function cost which exist nowadays. Parcel rate cost function, less than truck load (LTL) rate cost function, and full truck load (FTL) cost function are three common transportation cost function exist nowadays. The costing characteristic of each cost function is clearly described by the figure 2-3 below. By the parcel cost function, the goods transported are charged in a linear manner. The transportation cost grows linearly with a constant gradient as the transported goods accumulate. By the LTL rate, the cost grows linearly with a decreasing gradient at a specific fraction of filling degree, as the goods accumulate. This LTL cost function satisfies the theory of consolidation, while in the LTL cost function the cost gradient is decreasing as the utilization increased, in which the theory of higher the truck utilization leads to the fewer total trucks number is being satisfied. In the FTL cost function, the charge applied is calculated by the number of vehicle use. A small fraction of good transportation request and big fraction of good transportation request will be charged equally, one full truck charge. This cost of function works well if the truck utilization of each trip is always high or nearly full.

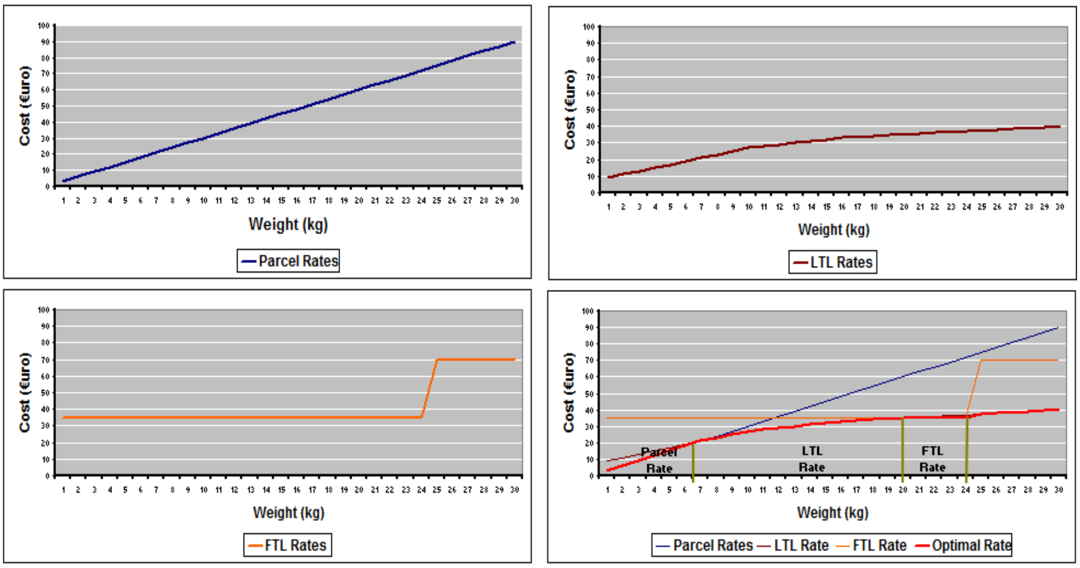

Figure 2-3 Function Cost for Parcel, LTL, and FTL Carriers (Lapierre, 2004)

After discussing three types of transportation cost function described by Lapierre, Ruiz, and Soriano, the next issue to be discussed is the optimal transportation cost function. From the indication described by figure 2-3, Lapierre and his colleagues have tried to combine all of the three cost function into one chart. As seen on the chart, the parcel rate work well as a minimum rate method in the beginning start of small fraction rate of shipment zone. As the size of the shipment grows the LTL rate overtakes the parcel rate as the lowest costing rate. At the near to full until full truck transportation fraction, the FTL rate is the cost function which give minimum transportation rate. By the combination of all of three cost functions, an idea of how the optimal tariff agreement should be built is achieved. The knowledge of this condition should lead a company to a better perspective of defining its freight contract with the third party logistic transportation company.

2.3.2 Long Haul and Short Haul Transportation

As Ballou (2004) has stated, there are three criteria which are commonly used in developing transportation rates. The criteria are volume, distance, and demand. The discussion of transportation cost function as a function of truck filling degree, which strongly correlated to the volume and demand criteria, is already done at the preceding section. The distance importance factor in determining the transportation cost function will be discussed in this section.

Distance in one essential factor in determining the total transportation charge. The longer the route that should be travelled, the more cost should be expensed, consequently because the higher kilometres travelled governs higher operating cost. In terms of transportation the trip can be considered in two categories, long haul trip and short haul trip. As shown in figure 2-4, long haul trip usually defined as the trip between the sourcing warehouse and a transhipment point. This trip is called long haul due to the long distance trip. On the other side short haul trip is usually defined as the distribution trip from the transhipment point to its subordinate members. A transhipment point is normally located near to the retailers due to the reactivity and the serviceability reason. Due to the short travelling distance, transportation from a transhipment point to its retailers is called short haul trip.

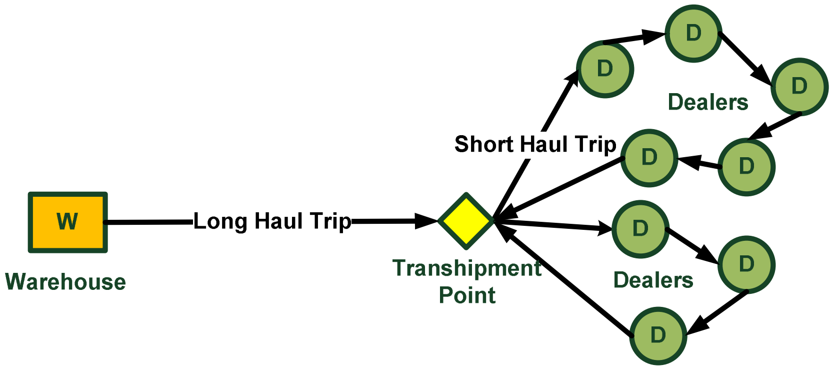

Figure 2-4 Long Haul and Short Haul Trip

2.3.2.1 Long Haul Transportation Cost

Aldarrat (Aldarrat& Noche, 2007) in his dissertation has modelled long haul transportation cost function in his simulation model. The cost function modelled is taken from a real life transportation tariff practice examples from his experiences. As can be seen at the figure 2-5, instead of picturing the total accumulated transportation cost as done before, he chose the unit cost per palette chart as the representation of the cost function behaviour. The cost function behaves exactly as the LTL transportation cost function, but in a different cost format, unit cost per palette format. The LTL rule is also valid in his chart indication whereby higher the truck utilization leads to cheaper unit cost. The lines representing different distance class is also represented. Without loosing the general cost behaviour to the truck utilization, logically the longer the distance the more expensive the unit cost is.

A useful remark can be concluded from Aldarrat's chart. Starting from a fraction of truck utilization (in his example 76.3%) the unit cost decrease rate for an increasing number of truck utilization is negligible. Though the number is different for each cost agreement, the opportunity to have a threshold point with the cost rate of full truck load exists. By assuring the truck filling degree reaches a threshold fraction of truck utilization number, without necessarily load the truck full, the cheapest costing rate could be gained. This phenomenon is also already spotted by Lapierre, Ruiz, and Soriano (2004) which already realized the potency of "cheating" up the transportation cost by doing addition of the shipment volume to reach cheaper transportation rate zone.

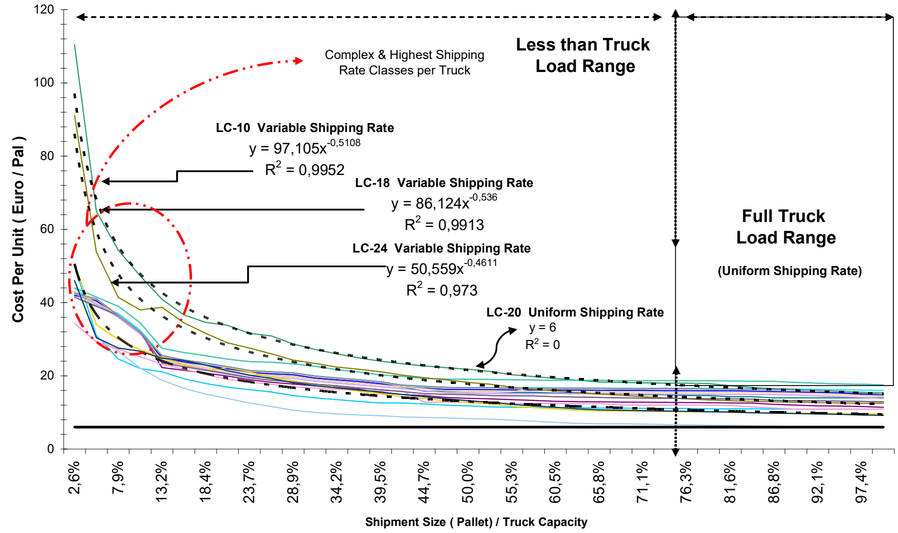

Figure 2-5 Example of Long Haul Freight Rate (Aldarrat& Noche, 2007)

2.3.2.2 Short Haul Transportation Cost

In his dissertation, Aldarrat shows also the short haul transportation cost function chart. By his example chart, short haul transportation cost rate for various route distance alternatives varies from travelling distance of zero km until the maximum travelling distance of 325 km are described clearly at the figure 2-6. The cost behaviour of short haul transportation is pretty much similar with the one already showed at the long haul cost function.

As showed by the chart, a clear unit cost gap between a long travelling distance group and the lowest travelling distance group exists. This gap is decreasing considerably as the truck utilization increase. As shown in the chart, the cost gap between the zero km travelling distance unit cost and the 325 km travelling distance unit cost gap at the truck utilization level of 20% reach 14 Euro. At the 100% truck utilization level, the cost gap between zero km travelling distance unit cost and the one at the travelling distance 325 km is decreasing to the level of 10 Euro. This phenomenon at the example is somehow interesting to give an idea of how the costing method could look like.

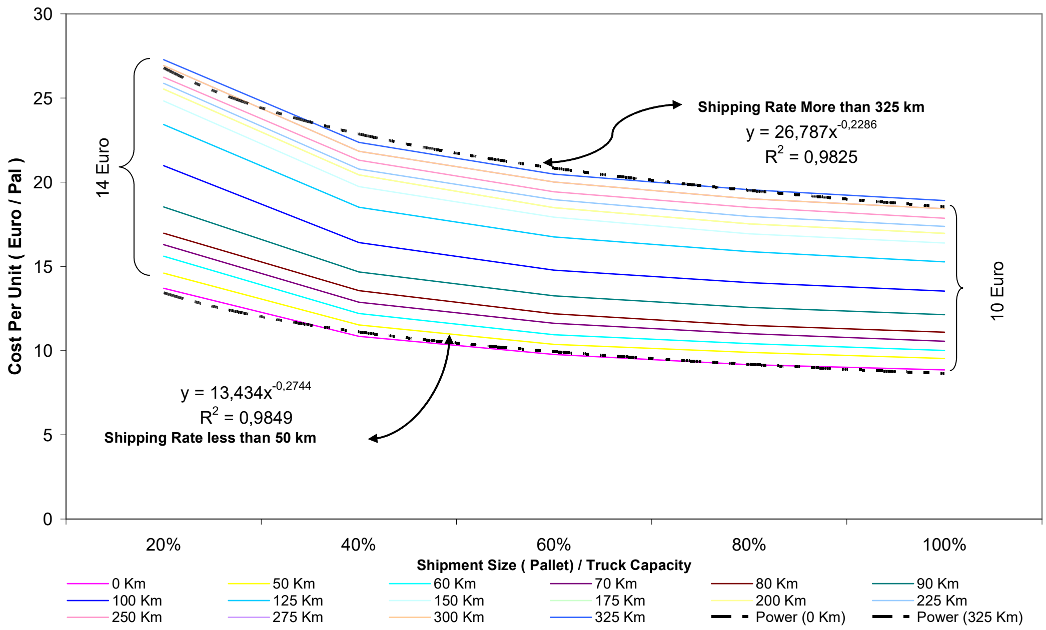

Figure 2-6 Example of Short Haul Freight Rate (Aldarrat& Noche, 2007)

2.4 Multilevel Utilization Issue

As discussed many times before, a better utilized truck leads to a cheaper transportation unit cost. A better utilized truck means that the empty space existence level within the truck's trailer is low. In many cases utilizing the full truck utilization of the space available in the trailer is impossible. The nature of solid parts which cannot not flow and fill every empty space available is one unavoidable fact. Other than that, the packaging issue exists as one workable problem which could lead to poor utilization. The effect of multi-layered packaging to a poor total utilization will be discussed deeper in this section.

In a shipment, parts usually are being packed in a multi layered package. The example of multi layered packaging is shown in the figure 2-7. In this example, the first layer of packaging mean taken is a packaging carton. A packaging carton usually contains one or several parts. The parts packed in the carton could be homogenous or not. Depending on how the parts being arranged in the carton, good carton utilization can be achieved. In fact, achieving 100% carton space utilization is somehow nearly impossible; especially when the parts packed is not homogeneous. The fact that 100% utilization is generally impossible considered as a boundary. The carton which is the first level of packaging is considered as the first level of utilization boundary.

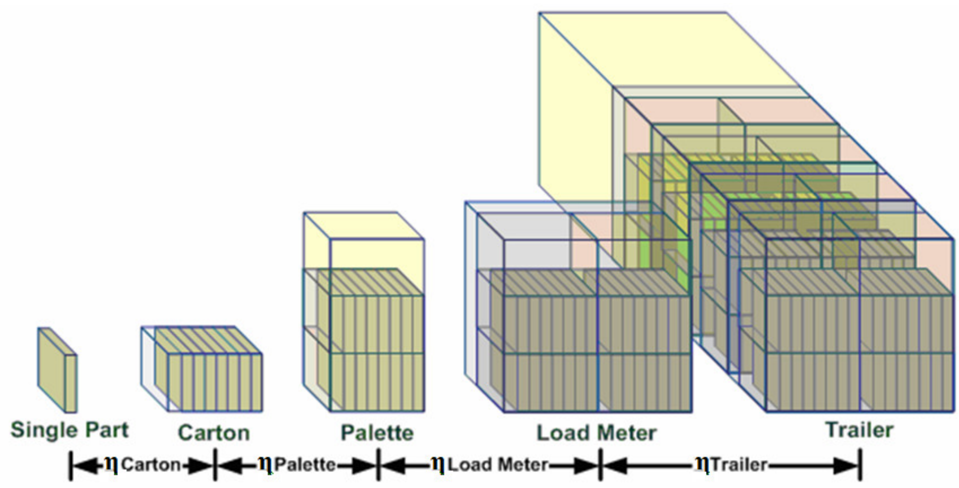

Figure 2-7 Multilevel Utilization Issue

Collection of cartons will be stacked up in a pallet or other packaging means. A good dimensioned carton will open the possibility of piling up the cartons on the palette with 100% utilization of palette space. Poor designed cartons make themselves incapable in reaching the full degree of palette space utilization. So again, the palette utilization problem is considered as another level of utilization boundary.

After cartons being piled up onto the palette, the palette will be stored in the trailer and then will be processed for the Load Meter measurement. Again Load Meter space utilization is a parameter which embracing as the third level of utilization boundary. At the end stage, how many load meters utilization in a term of full truck load is again a utilization boundary that exist.

As the discussion implies, the more packaging layer number leads to the multi utilization problem which at the end make total product of poor net utilization. The reason behind that is in every packaging layer, the parts receive a utilization boundary layer which limited the parts to reach full utilization. The more layer/level of packaging exist, the effect of utilization boundary layer is multiplied. Therefore well considered boundary layer level and good packaging mean which lead to reduction of multiplied effect of utilization boundary layer is important.

2.5 Simulation Study

Simulation is the limitation of the operation of real world process or system over time. Simulation involves the generation of an artificial history of the system, and the observation of that artificial history to draw inferences concerning the operating characteristics of the real system that is represented, Banks, Carson, Nelson, and Nicol (1999). Considering another definition of simulation, Shannon (1998) has defined simulation as a process of designing a model of a real system and conducting experiments with a model of a real system and conducting experiments with this model for the purpose of understanding the behavior of the system and/or evaluating various strategies for the operation of the system.

Simulation study produces a set of advantages and disadvantages. Some set of advantages and disadvantages are defined by Banks (1999). Some of the advantages are stated by these points:

- New policies, operating procedures, decision rules, information flows, organizational procedures, and so on can be explored without disrupting ongoing operations of the real system.
- New hardware design, physical layouts, transportation systems, and so on can be tested without committing resources for their acquisition.
- Insight can be obtained about the interaction of variables.
- Insight can be obtained about the importance of variables to the performance of the system.
- Bottleneck analysis can be performed indicating where work in process, information materials, and so on, are being excessively delayed.
- A simulation study can help in understanding how the system operates rather than how individuals think the system operates.

- “What-if” questions can be answered.

After discussing the good things which can be brought by simulation, naturally simulation study also has some limitation. Some of the disadvantages of simulation study which could appear also defined by Banks (1999) by the following points:

- Model building requires special training
- Simulation results may be difficult to Interpret.
- Simulation modeling and analysis can be time consuming and expensive.
- Simulation may be used inappropriately

Even thou simulation has some disadvantages; Banks also has explained some counter opinion in facing the reality. Nowadays the simulation application programs are created in even more user friendly package. A person can simulate their system with less even no programming or technical skill. Other than that the simulation software developers try their best to make the simulation representation of simulation results easier to comprehend even to a beginner. The rapid progress of the development of computer hardware makes the simulation study even faster and cheaper. At the present time doing a simulation study is gaining less and less constraints.

2.5.1 Steps in Simulation Studies

In doing a complete simulation study, several steps should be accomplished. Banks, Carson, Nelson, and Nicol (1999) has settled up the methodology of doing the simulation study in a clear step by step explanation. The flowchart shows at the figure 2-8 shows the step by step explanation for conducting simulation study in a systematic way.

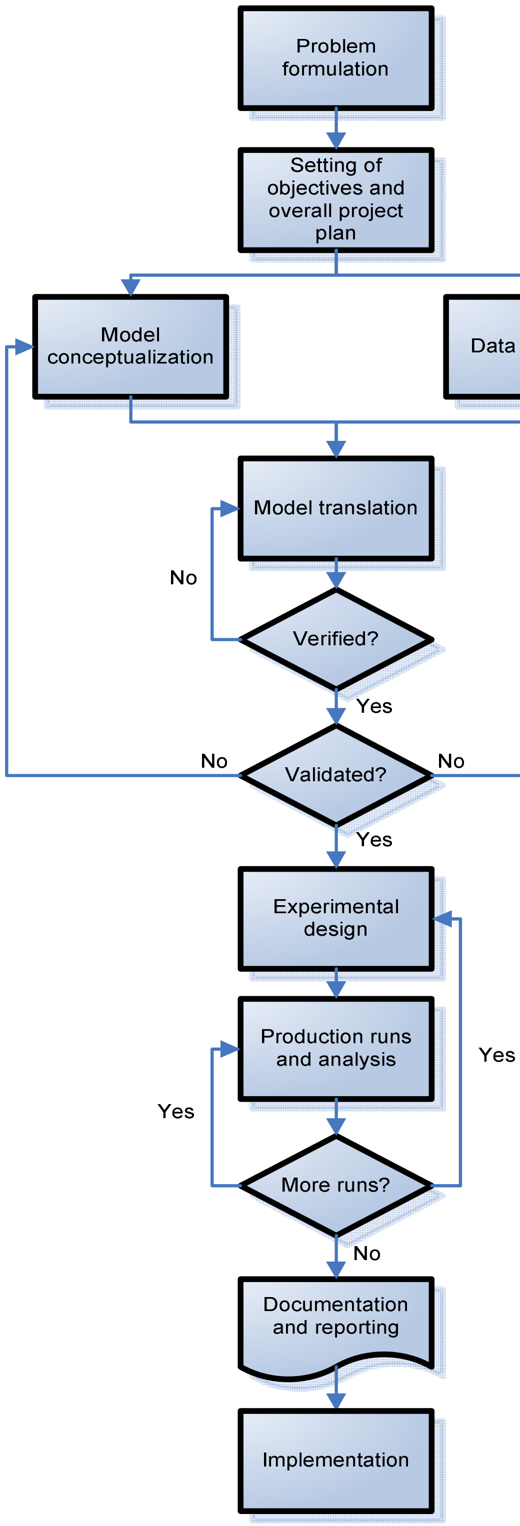

Figure 2-8 Steps in Simulation Studies (Banks, 1999)

According to Banks problem formulations, objective settings and overall project planning, model conceptualization, data collection, model translation, model verification, model validation, experimental design of scenarios, production runs of model and analysis, re-run the model, documentation and reporting, and implementation phase are the steps that should be completed in doing good simulation studies. The methodology forwarded by Banks will be applied in this thesis.

2.5.2 Spreadsheet Simulation

Simulation is a problem solving concept which not necessarily needing high requirement of computing resources. At the simplest mode, simulation can be done by doing scratch calculation on a piece of paper. Depending on the data quantity involved and depending on the size and complexity of the calculation the calculating mean will be adapted. In many cases, using a simple spreadsheet program like Excel™ is already sufficient to get a first impression of how a system should work, Seila (2005).

Spreadsheet simulation refers to the use of a spreadsheet as a platform for representing simulation models and performing simulation experiments, Seila (2005). The use of spreadsheet as a tool for doing calculation is not something trivial. The question is whether a spreadsheet program is sufficient enough for doing simulation calculation. Seila also has mentioned some of the basic capabilities that should be available in simulation software environment. Following is a list of the capabilities that must be available in a simulation software environment:

- A way to represent mathematical and logical relationships between variables in the form of computations and assignment of values, and algorithms.
- A way to generate uniformly distributed pseudorandom numbers and use them to sample observations from various distributions.
- A means to repeat the computations of the model, thus implementing replications.

The list presented is the minimal requirement a simulation software environment, but these are the necessary capabilities for the platform to be used for simulation. Most spreadsheets have these features. The following useful features are also available in most spreadsheets to make the process quick and reliable:

- A large number of functions to do mathematical statistical, database, date/time, financial and other calculations.
- Database representations and database access.
- Charting and graphing.
- Display and documentation features such as fonts, colors and geometric shapes to improve presentation.
- Automation trough scripting languages such as VBA (in the case of Excel™).

Easy to implement, can be done in a usual spreadsheet program instead of using special simulation application program, and the short period of simulation development are some of the benefits of the spreadsheet simulation. But in contra of the benefits that the method has, there are also some limitations of this spreadsheet simulation. Four important limitations of spreadsheet simulation are:

- Only simple data structure are available in spreadsheets
- Complex algorithms are difficult to implement
- Spreadsheets are slower than some alternatives
- Data storage is limited

Going down to the brief methodology side, according to Seila (2005), spreadsheet simulation simply involves the use of a spreadsheet to represent the model, do the sampling, perform the model computations and report the result. Those chains of works then will be distributed in some of cells sets as input data cells, intermediate computations cells and output data cells.

2.5.3 Simulation with DOSIMIS

DOSIMIS 4-3 is a modular-oriented graphical interactive standard simulator developed by SDZ GmbH since 1984. The simulator works in event-discrete logic and allows simulation of time-discrete material flow systems. A simulated production process can be developed graphically interactive on the screen without any certain knowledge in the area of computer science. Standard elements such as sources, sinks, work stations, buffers, vehicles etc., which in their structure represent essential modules from the material flow field, allow a rational layout by means of a menu-controlled user interface. Modules with several entrances and exits dispose of an intelligence over which local strategies such as FIFO, minimal occupation of the succeeding module etc. can be realized when controlling the object flow.

In order to evaluate the simulation results, DOSIMIS 4-3 offers a variety of tables and graphics. A dynamic presentation of the model behavior is presented within the animation. With its help, the model can be checked, or the occurrence of certain situations, such as a deadlock, can be analyzed. On the other hand, exact statistics can be kept for every module of the model, whose output can be made either in the form of tables or, in graphical forms . e.g, bar diagrams, occupation diagrams, etc.

By the complete capabilities DOSIMIS has, a various simulation study can be conducted. Valid data is the only important thing which has to be present. Even thou DOSIMIS functionality are considered complete; DOSIMIS is open to any further adjustment and modification, realizing that different companies might have different unique logic of material flow. A person can implement and incorporated an adjustment program/ supply chain library policy controller (dll) to any simulation building blocks, if the functionality provided in the DOSIMIS building blocks modules need adjustment. Involving the existence of adjustment programs, Aldarrat & Noche (2007) had defined the interactions between the developed supply chain library policy controller and DOSIMIS-3 tool which are linked by a designed interface simulation cockpit shown in the figure 2-9.

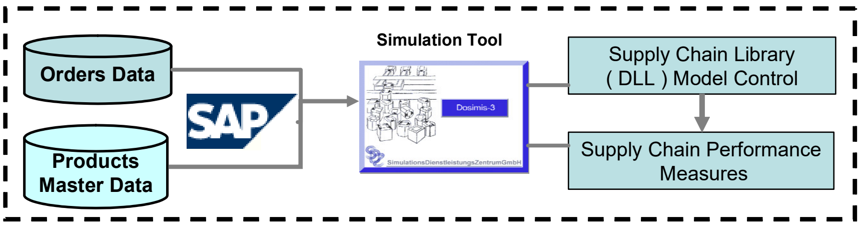

Figure 2-9 Proposed Interaction between DOSIMIS-3 and Supply Chain Library Controller (Aldarrat& Noche, 2007)

2.5.3.1 Logistical Distribution Network Simulation Tool (LDNST)

Aldarrat has incorporated many Supply Chain Library Controllers which offers complete supply chain functionalities in one integrated framework named Logistical Distribution Network Simulation Tool - LNDST. As shown by the figure 2-10, the LDNST framework is embedded with many functions such as transportation logic, warehousing logic, replenishment logic, etc.

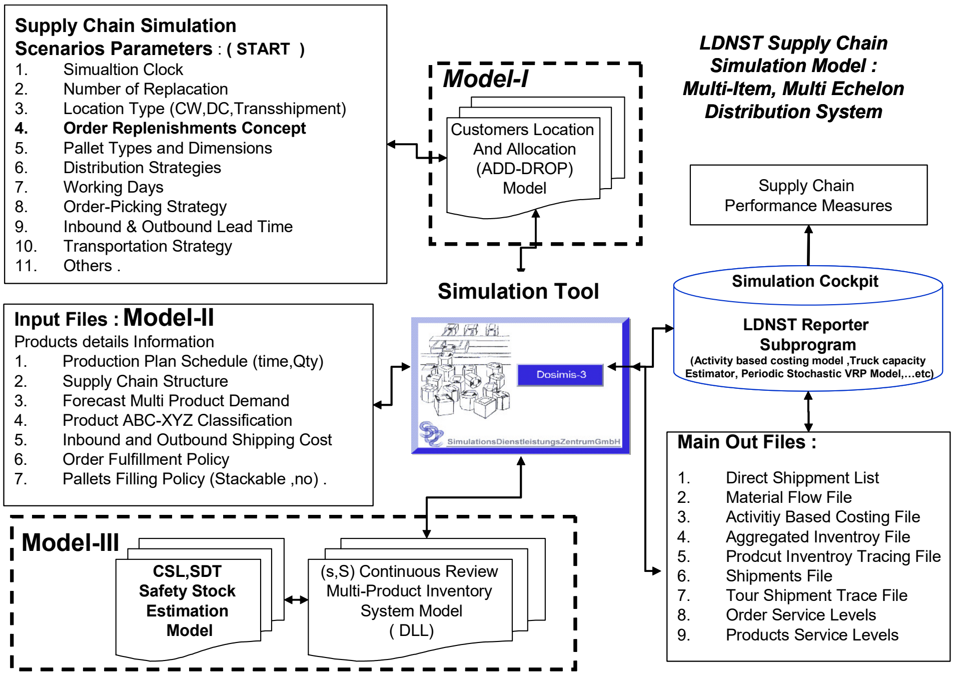

Figure 2-10 Integrated LDNST Supply Chain Simulation Framework (Aldarrat& Noche, 2007)

From the functionalities LDNST offered, the one that will be applied in this thesis is the functionality regarding transportation strategies. The transportation strategy which is strongly correlated with freight consolidation concept will be intensively studied. Thankfully, the controller which governs the replenishment strategy is already available in LNDST. So the temporal consolidation concept can be implemented easily. A user can select his/her appointed replenishment days to any simulation building blocks. The order will be automatically accumulated and replenished only at the appointed days. By the available functionality offered by LNDST, the implementation of consolidation concept should have no meaningful problem.

2.5.3.2 Simulation Modelling in DOSIMIS

Supply chain system is one of the systems which can be modelled and simulated by DOSIMIS. Figure 2-11 shows an example of a simple supply chain model representation defined by Aldarrat. By the description, the basic steps of transportation which consist of shipping consolidation phase, transportation phase, and receiving phase, are clearly translated to comprehendible DOSIMIS model.

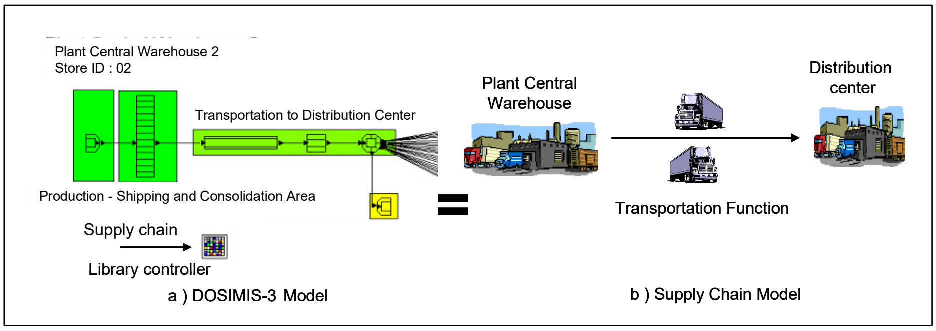

Figure 2-11 DOSIMIS-3 Supply Chain Model Representation (Aldarrat& Noche, 2007)

In term of a more complex system, an example of a system consists of one sourcing warehouse, five distribution centers, and ten end costumers is being forwarded. Figure 2-12 shows an example of the DOSIMIS model which translated from the example system. As shown, each group of building block which represent a special function of logistical node, is being controlled by a decision program connected to the Simulation Model Event Controller displayed at the bottom side of the picture.

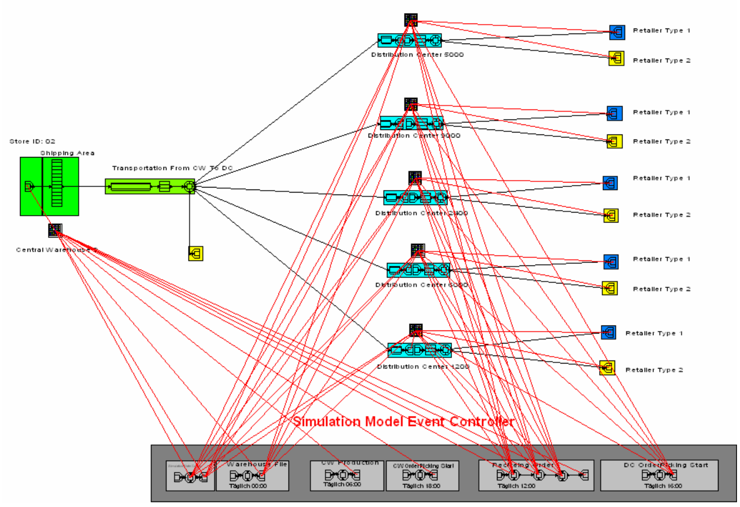

Figure 2-12 Simple Supply Chain DOSIMIS-3 Simulation Model (Aldarrat& Noche, 2007)

Chapter 3
Research Method

3.1 Introduction

The basic purpose of this thesis is to investigate the impact of different delivery frequency alternatives to the distribution cost. To get a picture of how the distribution cost behaves to different alternatives, three different delivery frequency setups will be tried out. The setups which will be tried out are the current existing delivery frequency setup, twice a week delivery frequency setup, and the weekly delivery frequency setup.

Utilizing the freight consolidation concept by applying *temporal* consolidation is not the only consolidation method analyzed in this thesis. *Warehouse* consolidation is also one method which will be analyzed. Beside the current distribution network structure which utilizes two sourcing warehouses (Bochum and Ruesselsheim), an alternative distribution scenario which utilizes only one sourcing warehouse will be studied also. By studying the corresponding effect of consolidating two sourcing warehouses into one sourcing warehouse, a better insight of available distribution cost saving potency can be gained.

In term of consolidation scenario, in total six different scenarios will be studied. The current distribution network structure with three delivery frequency setups will be the first three first scenarios studied. The second three scenarios will be the application of three delivery frequency setups to the alternative distribution structure which utilizes one sourcing warehouse. All consolidation scenarios which will be studied in this thesis are being showed by the diagram shown in the figure 3-1.

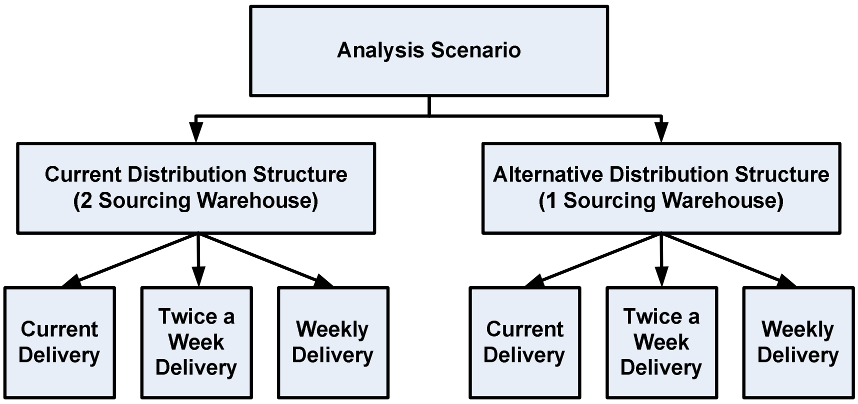

Figure 3-1 Consolidation Scenarios

In analyzing all proposed alternative scenarios, two analytical methods will be applied. Historic Data Analysis and Simulation Data Analysis will be applied to study the performance of each scenario. The following sections in this chapter will discuss these two analysis methods deeper. In addition two costing methods will also be applied, the current transportation costing method and a benchmark transportation costing method, so at the end the six consolidation scenarios will be tried out for the application of two costing methods which result total try out of twelve scenarios.

3.2 Historic Data Analysis

As the name already implies historic data analysis is a method which involves the presence of historic order invoice data of ongoing system. By the presence of historic order invoice data of ongoing system, several proposed scenarios can be tried out without the presence of generated random order data. This method is good to get a brief impression of how a system would react to the proposed scenarios

Historic data analysis applied in this thesis consists of several steps. Data extraction from Opel DDS (Direct Delivery System) and Catalyst database, data grouping and consolidation by using Microsoft Access™, and the final data analysis by the use of Microsoft Excel™ are the three major steps to complete the analysis. Figure 3-2 displays a flow chart which demonstrates the steps required.

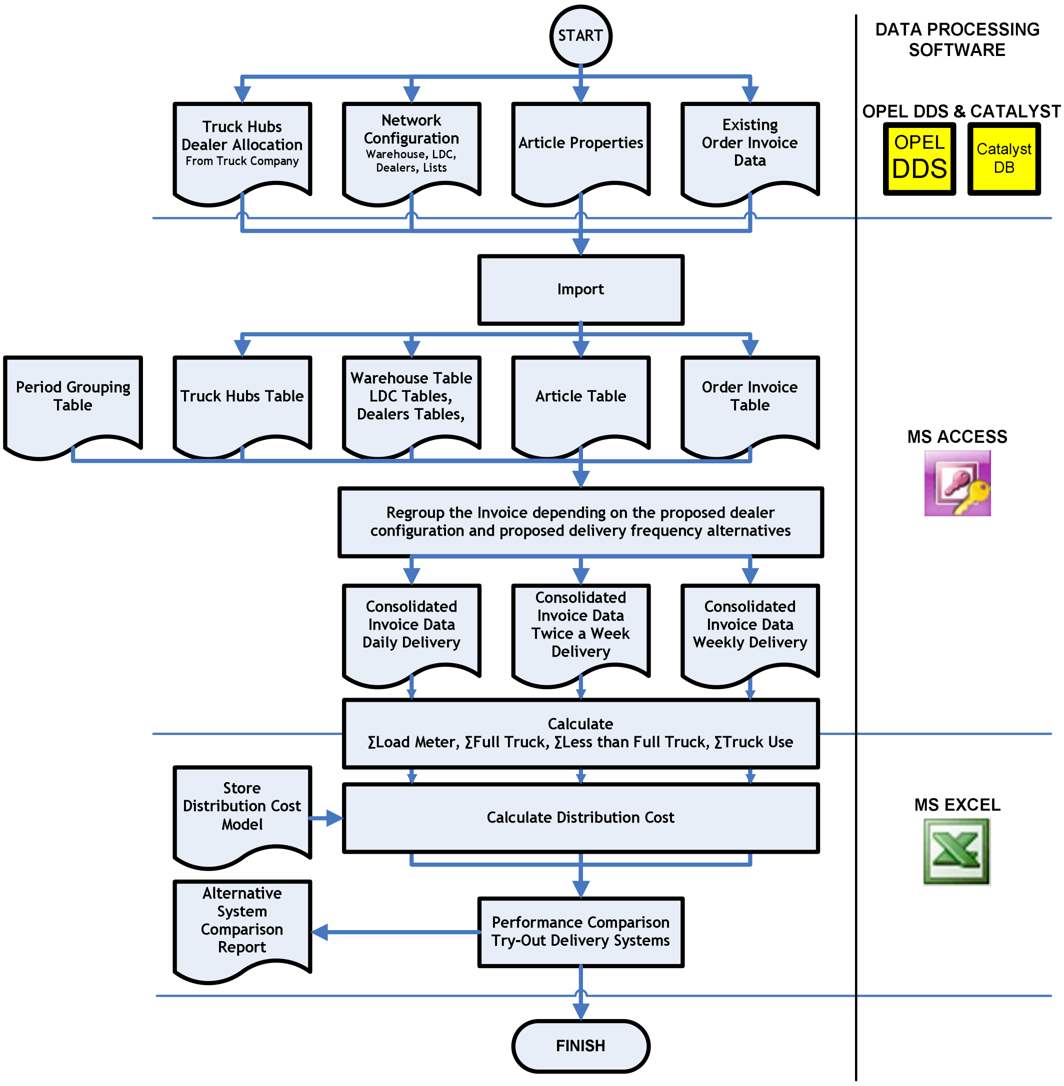

Figure 3-2 Historic Data Analysis Flow Chart

3.2.1 Opel DDS and Catalyst Data Extraction

In historic data analysis done, an enormous amount of one full year order data is being utilized. This order data which imported directly from Opel DDS contains a detailed order record of every dealer in the selected period of 2006. In order to save the import time, only records from considered important columns are being extracted.

The columns which considered important are the dealer number column, order date column, part number column, opel order number column, ordered quantity column, real quantity column, and order type column. These columns are considered important and will be involved in the next data manipulation.

The order data is not the only raw data imported for the analysis. The other data is the article properties. This article properties data is being imported from the Opel database system called catalyst. The article properties data consists of important information such as, dimension, volume, weight, price of the part, and the sourcing warehouse. These properties/parameters will be utilized further in the future analysis.

The last data which should be considered is the existing network configuration data. In this type of data, all dealers list, LDC list, trucking hubs list, and warehouses list with their corresponding name, address, postcode, and connectivity to another logistics nodes should be exist. All of these files are important to picture the current existing supply chain network and to regroup the order in the consolidation concepts. Also by manipulating these file into different dealers allocation settings, a different consolidation scenarios can be tried out also.

Truck hubs list is the input data which being separated from other logistic nodes in the diagrams presented at the figure 3-2. The reason behind this is because the truck hubs list is imported not from Opel internal database, but from the third party logistics trucking company. At this thesis the truck hubs configuration is also incorporated into the analysis since the true existing physical logistical nodes will define the maximum saving potency of the consolidation strategy.

Those order data, article properties data, and existing network configuration data (including the truck hubs data), are the basic data which should be existing at this historic data analysis. The format of the data should be importable to any database program. In this thesis Microsoft Access™ is being used for the database manipulation.

3.2.2 Database Manipulation

The database manipulation is a level of analysis which processes data input into an acceptable format for an Excel™ application to present the final report. The first step to prepare the database is to do massive table importing and linking so that every raw data prepared before (the order list, the article properties, and the network configuration) can be recognized as tables in the Access™. As soon as the importing and linking process is finished, the order list table, article properties table, dealer list table, LDC list table, warehouse table, and truck hubs table should be existed in Access™.

When the raw data imported from DDS and Catalyst already prepared in table format of Access™, then the next step of data manipulation can be started. The complete steps of the data manipulation within the database are clearly described by the flow chart showed in the figure 3-3. As shown, the basic approach which being used here is to regroup the order queries based on the parenting truck hubs, regenerate the queries based on delivery frequency alternatives for each parenting truck hub query, and at the end generate a recapitulation query which reports the performance parameters of each truck hub in different scenarios. This recapitulation queries will be useful at the final data analysis level in which the final result of the system performance at different scenario alternatives will be finally presented.

3.2.3 Final Data Analysis

As the final level of the whole method, the presentation of the distribution system performance due to application of different setting of scenarios will be done. The recapitulation queries for each truck hub in different system setups will be imported in Excel™ environment and used as a basis. Different charts showing how the distribution system setups govern the performance parameters in different delivery frequency alternatives will be generated. The charts that will be presented are stated as the points below:

- Full Truck Use - Delivery Frequency Alternatives

- Total Truck Use - Delivery Frequency Alternatives
- Transportation Cost – Delivery Frequency Alternatives
- Warehouse Setup Cost – Delivery Frequency Alternatives
- Total Cost – Delivery Frequency Alternatives

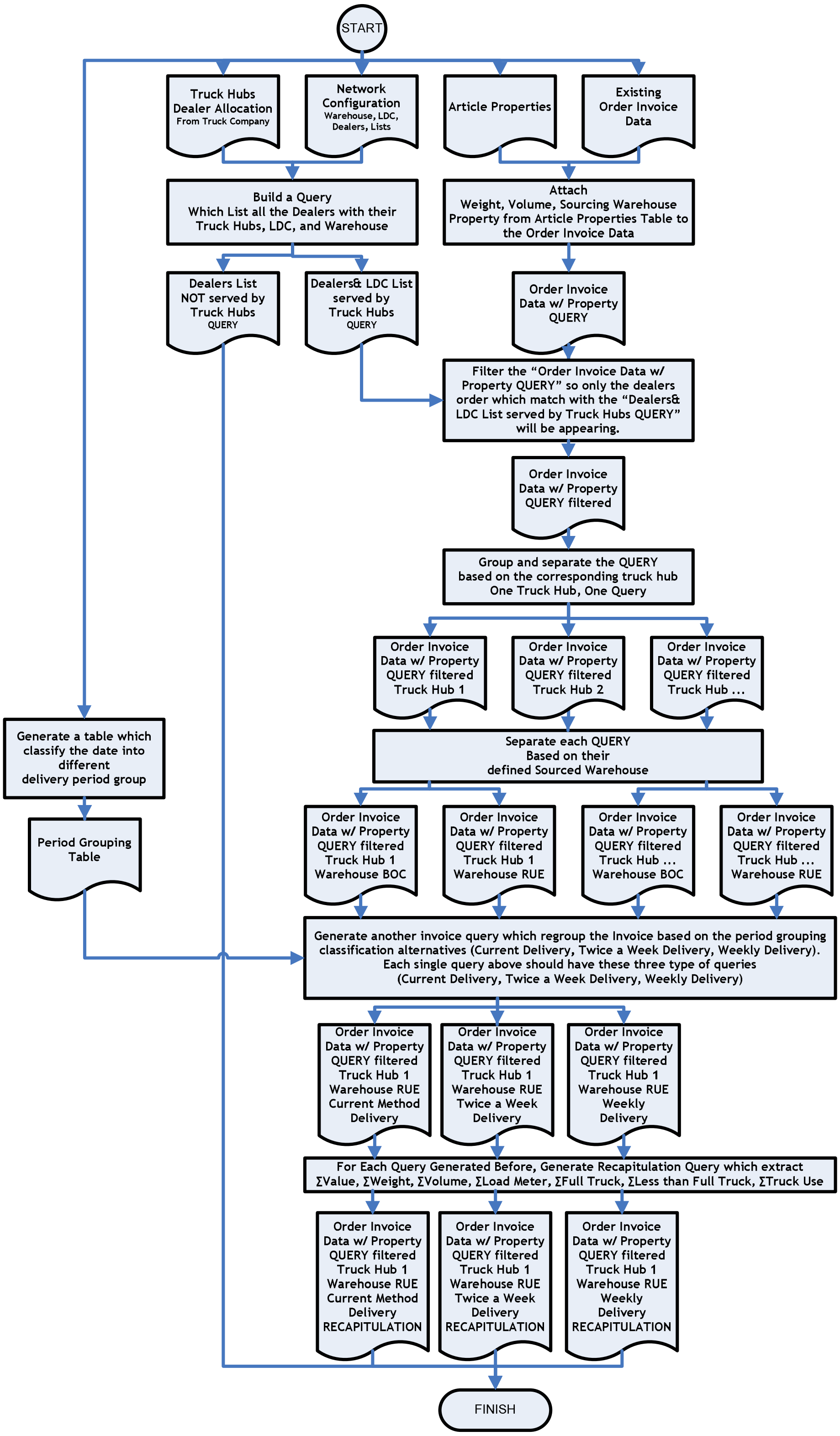

Figure 3-3 Database Manipulation Flow Chart

3.3 Simulation Data Analysis

Simulation data analysis is an analysis method which utilizes generated simulation data set as a basis. Instead of using bare historic data as points of analysis, a several dataset generated by simulation program by the use of random generator is used. The dataset generated, is a future data behavior prediction done by simulation program based on the historic data behavior characteristics imported.

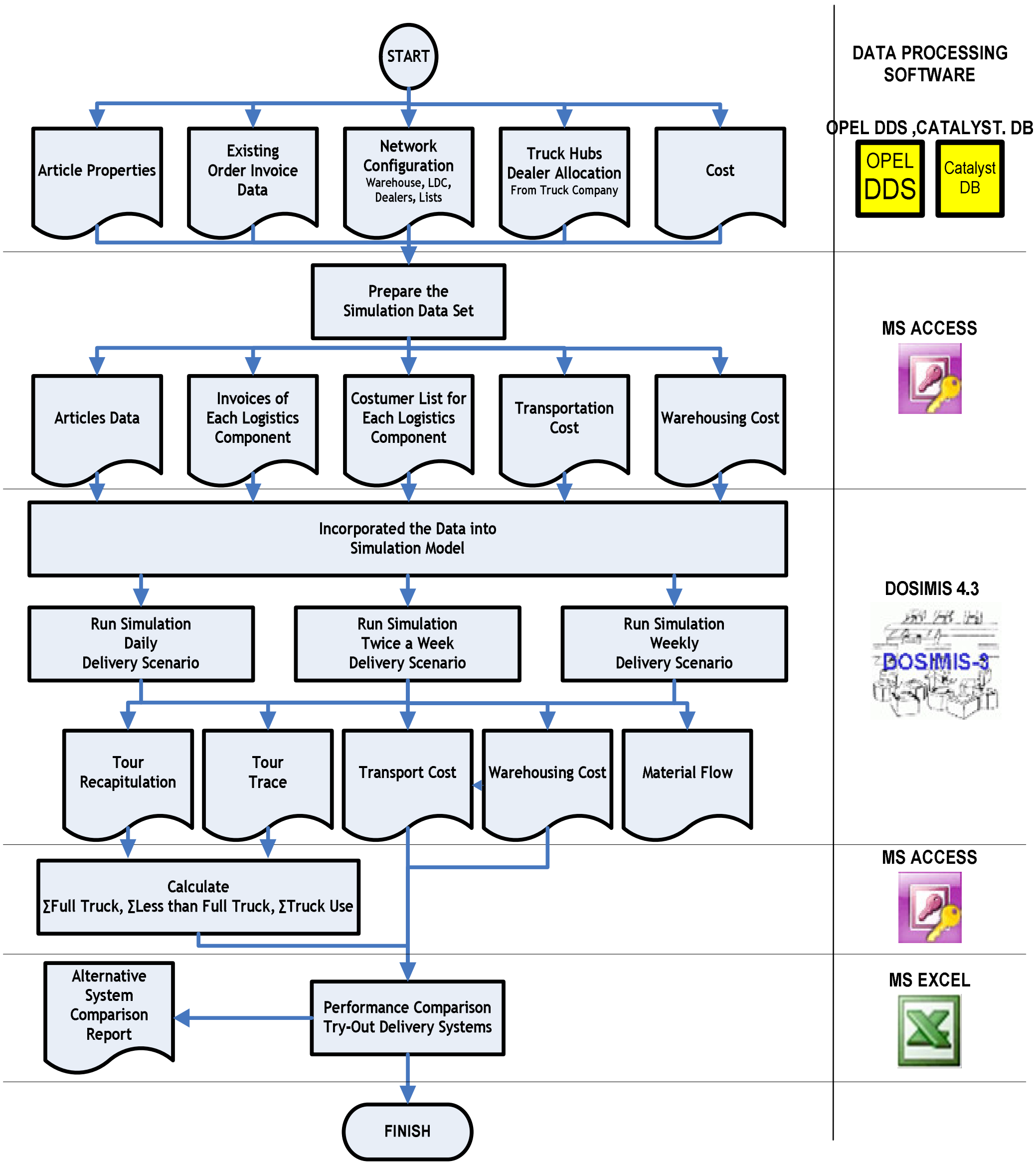

Figure 3-4 Simulation Data Analysis Flow Chart

Simulation data analysis flow chart showed in the figure 3-4 explains the detailed steps that should be accomplished to complete the analysis. Several processes need to be done considering simulation data input preparation, simulation run, and also simulation result data presentation. Those processes are also involving the use of Microsoft Access™ and Excel™, outside the simulation program itself for some data processes. The explanation of each level of data process analysis will be discussed in the following sections.

3.3.1 Simulation Data Input Preparation

The sets of data which are used at the historic data analysis are also being utilized at the Simulation Data Analysis. The data which should be available are the article data, order Invoices of each logistics node, costumer lists of each logistics node, transportation cost data, and warehousing cost data are collected from Opel databases and other sources. These data then should be prepared in Access™ in an appropriate text file format that DOSIMIS can work on.

Not like the historic data analysis, simulation data analysis treats the costing tariff data as input data and treats the costing logics as a part of simulation program. While on the historic data analysis, both the costing tariff data and also the costing logics are embedded to the programmed Access™ and Excel™ files. In this case the simulation program can be applied for any costing tariff data as long as the cost calculation logic is not changing. While in the historic data analysis if the costing tariff data some adjustments have to be done in the data processing files (MS-Access™ and MS-Excel™), which consequently cost more effort.

3.3.2 Simulation Run

Those five types of file which has already prepared by Access™ will be used by DOSIMIS in order to do the simulation and to give the result according to the selected set up scenario. After all the data input have already prepared, the simulation run for each scenario by the use of the validated simulation model can be started. The results documents that can be gained are the tour recapitulation cost, tour trace file, transportation cost, warehousing cost and the material flow files.

The files which produced by simulation process are available in the text file format. Those result files then can be further processed by Microsoft Access™ and Microsoft Excel™ to get the appropriate values which will be useful for the final result presentation.

3.3.3 Simulation Result Presentation

As the simulation result data prepared, some additional data handling processes to extract the exact parameter from the data should be done. The simulation result data are imported to Access™ environment which is able to manage big sized files. Some processes have to be done in Access™ to process the data into smaller analyzable form of data. After several recapitulation queries has already prepared, then the exporting process to the Excel™ format is needed. In Excel™ the data will be represented in various numbers of charts to make the final presentation. Like those presented in the historic data analysis, five presentation charts showing the behavior of different delivery frequency alternatives will also be presented.

Chapter 4
Real System Study

4.1 Introduction

Adam Opel GmbH after sales distribution network is considerably one of big after sales distribution network in Germany. A network consisting of one regional warehouse in Ruesselsheim, one central warehouse located in Bochum, and seventeen *Local Distribution Centers (LDC),* should serve the demand of nearly two thousand authorized retailers throughout Germany. Those three logistics components (the warehouses, LDC, and retailers) should work hand in hand in a coherent and in an efficient manner in order to provide the best service for the costumers yet with low operation cost.

Opel is using centralized information system called *Direct Delivery System (DDS)* as one of the information system tool to synchronize all of its logistics components to satisfy its costumer's need. DDS is an order allocation system applied by Opel. All of the orders which are addressed by every retailer should be addressed to DDS. DDS then will record and assign a retailer's supply responsibility to the appropriate logistic component. Deeper discussion of the information flow of each order type will be explained later in this chapter.

In general, the demands of the retailers are generally being classified into two categories, the stock order and the rush order. As the name already implies, the stock order is the order addressed by a retailer to get parts for regular daily operation while on the other side rush order is being addressed to get supply for parts which are needed urgently. A deeper discussion about these two types of order will be done in the upcoming sections.

4.2 Stock Order

As have been discussed briefly, the stock order stands for the order that addressed by retailers to Opel in order to fulfill its stock. Stock order is not an urgent order. Nevertheless, Opel still have to serve stock order in an appropriate level of service to provide high costumer satisfaction.

4.2.1 Logistics Structure Configuration

Logistics structure configuration is one primary aspect which determines the success of a supply chain strategy. The existing logistics structure of the stock order replenishment is being demonstrated by figure 4-1. A logistic structure built by group of warehouses, LDC, and retailers are working together to supply the spare part and accessory needs of Germany.

Two warehouses, Ruesselsheim warehouse and Bochum warehouse, basically are the source of all the parts which are moving in whole Germany distribution system. From the direct material flow connection point of view, the sourcing warehouses are connected to the retailers which have big sales volume and 17 LDC. Ruesselsheim warehouse and Bochum warehouse are being responsible for supplying the stock order needs of those big retailers and LDC. The big retailers and LDC will be supplied firstly from Ruesselsheim warehouse which acts as a primary warehouse for Germany distribution network. As a backup warehouse Bochum warehouse exists to supply the demands of the big retailers and LDC whenever Ruesselsheim warehouse cannot answer the demand request.

Going down to the lower the level of supply chain, 17 LDC are distributed throughout Germany to serve the stock order demands of the small retailers which are having small sales volume. Basically, the purpose of LDC partnership is to serve the rush order demands of all Germany retailers, but in term of stock orders, the LDC are functioned as the primary distribution sources for the demands of small retailers. As additional information, LDC are big retailers which contracted by Opel to serve the mentioned tasks, serving rush orders, and also a part of stock orders business.

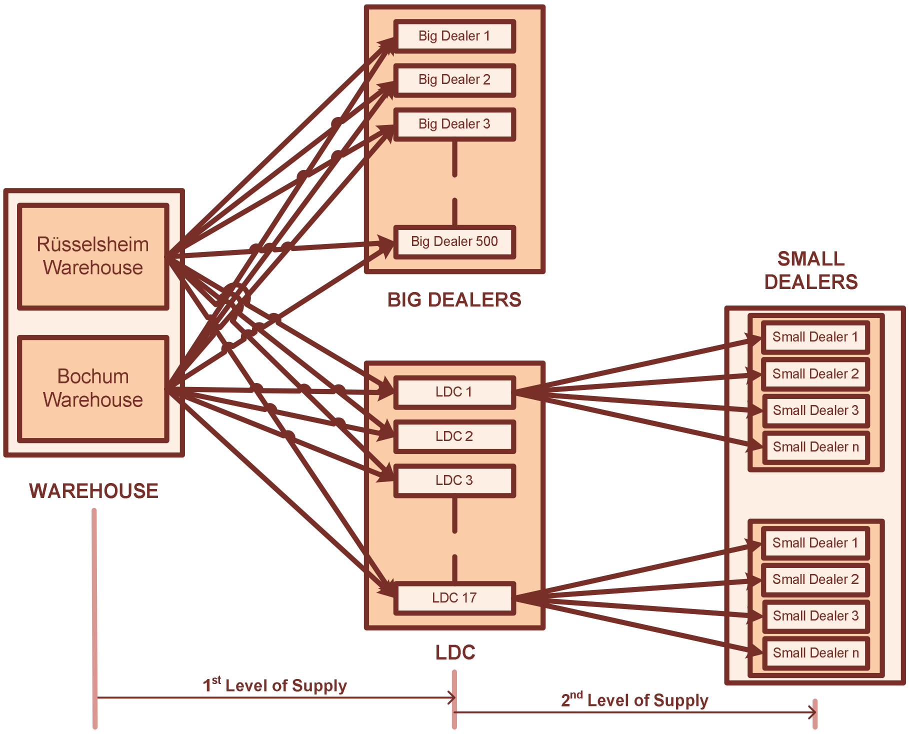

Figure 4-1 Stock Order Supply Chain Diagrams

4.2.2 Stock Order Replenishment Policy

Based on the supply chain diagram displayed by the Figure 4-1 above, the whole supply chain is built on a three echelon distribution system basis in which the supply processes can be classified into two levels of supply. The first level of supply will be defined for each parts supply sourced from the main warehouses. The second level of supply will be defined for each part supply sourced from an LDC.

For the first level of supply, retailers or LDC which are supplied directly from the main warehouses can be supplied whether in a daily or weekly basis. Based on the annual purchases volume, a replenishment frequency is determined. A retailer or an

LDC which has annual sales more than 480,000 Euro normally receives daily replenishment. A retailer or an LDC which has annual sales between 480,000 Euro and 250,000 Euro normally receives weekly replenishment. A special contract agreement can also determines the replenishment frequency setting of a retailer or an LDC.

Table 4-1 Stock Order Replenishment Frequency Categorization

Annual Sales	Supplier	Frequency
Smaller than 250,000 €uro	LDC	Weekly
Between 250,000 €uro and 480,000 €uro	OPEL	Weekly
Bigger than 480,000 €uro	OPEL	Daily

A retailer which has annual sales less than 250,000 Euro is usually being supplied by an LDC. These retailers are theoretically should be receiving their stock order replenishment in a two weeks period, but in reality Opel do the replenishment of these retailers in a weekly period. The clear categorization of the replenishment frequency categorization of all retailers is displayed by table 4-1.

4.2.3 Stock Order Information Flow

In order information flow point of view, Opel utilizes a centralized order information system called *Direct Delivery System (DDS)*. DDS collects all orders from all retailers and LDC in Germany and governs the orders replenishment assignment to an appropriate logistics component. The discussion of step by step information flow and supply assignment process in DDS will be done in the next following paragraphs.

The following steps of information flow and supply assignment process procedure is valid for each retailer and LDC within first level of supply. As the first step, if a retailer or an LDC has an order request, they should send the order request which contains detailed order lines of parts request to the DDS. After receiving the order, the DDS will check the availability of the requested parts in Ruesselsheim warehouse. If the requested parts are available there, then the parts supply assignment will be addressed to Ruesselsheim warehouse. If there is any requested part which cannot be supplied by Ruesselsheim warehouse, then DDS will check the availability of the parts in Bochum warehouse and send the remaining supply assignment to Bochum warehouse. If the is still any requested parts which are not available in Bochum warehouse, then the order lines which cannot be fulfilled will be recorded as backorder lines.

Down one level to the second level of supply side, the steps of information flow and supply assignment process is similar as the process explained at the first level of supply. In order to get the demanded parts, a retailer should send an order to DDS. Then DDS will identify the detailed order lines contained in the order request and check the availability of each part requested to the super ordinate LDC of the requesting retailer. If the requested parts are available there, then the parts supply assignment will be addressed to that LDC. If there is any requested part which cannot be supplied by the LDC, then DDS will check the availability of the parts and assign the supply task firstly to Ruesselsheim warehouse and then Bochum warehouse if Ruesselsheim warehouse is not able to supply the requested parts.

By utilizing DDS as centralized ordering system, each single order addressed by every single retailer in Germany should be identifiable by the system. By this condition, Opel expects to have full visibility and full control of its spare parts and accessory distribution throughout Germany.

4.2.4 First Level of Supply

As already defined, there are two levels of supply existing in the whole system. The first level of supply is the portion of supply which is sourced from the sourcing warehouses and the second level of supply is the portion of supply which is sourced from an LDC.

First level of supply is characterized by the high intensity of supply. Warehouses as super ordinate supplier are the logistics components which have supplied the part needs of the whole Germany. LDC and Big Retailers as sub ordinate costumers are the logistics components which consume and redistribute biggest share of total spare parts needs. To support the high intensity of supply with high level of service, a reliable transportation operation required. The discussion of the transportation operation of the first level of supply is forwarded in the following section.

4.2.4.1 Third Party Logistics Involvement

To support the high transport intensity of first level supply activities, Opel has appointed the transportation operation assignment to the third party logistic companies. These third party logistic companies have the responsibility to transport all parts from the sourcing warehouses addressed to the big retailers/LDC within the delivery performance level specified in the agreement.

The biggest portion of the first level of supply transportation assignment is being carried by a third party logistic company named Spedition Wennekamp (later called W+K). Almost all of the spare parts and accessories which sourced from the sourcing warehouses are being transported within the first level of supply stage by W+K. Some small portion of parts like cylinder heads, engines, airbags, paints, body conversion, winter tyre, and oil are transported in different channels. The thesis will analyse only the transportation channel operated by W+K since the W+K transportation cost portion holds the biggest share of the total transportation cost.

W+K has the obligation to transport the parts from the warehouse to the defined retailers or LDC within one day delivery. In accomplishing the defined delivery standard lead time, W+K utilises twelve distribution hubs throughout Germany. Each truck hub acts as a transhipment point which connected the source warehouses and all retailers and LDC in a specific region. Considering the existence of these twelve W+K's truck hubs, the complete diagram of the stock order supply chain can be demonstrated as displayed by the figure 4-2.

By the existence of twelve W+K's truck hubs, normally all the parts which are originated from Ruesselsheim warehouse and Bochum warehouse will be consolidated first in each truck hub before distributed to the big retailers and LDC within the hub's region. The application of twelve transhipment points by W+K can reduce the total transportation trip effort that should be expensed by increasing the possibility to have full truck load both in the transport trip originated from the warehouse to the truck hubs and also for the distribution trip originated from the truck hubs to the big retailers and LDC.

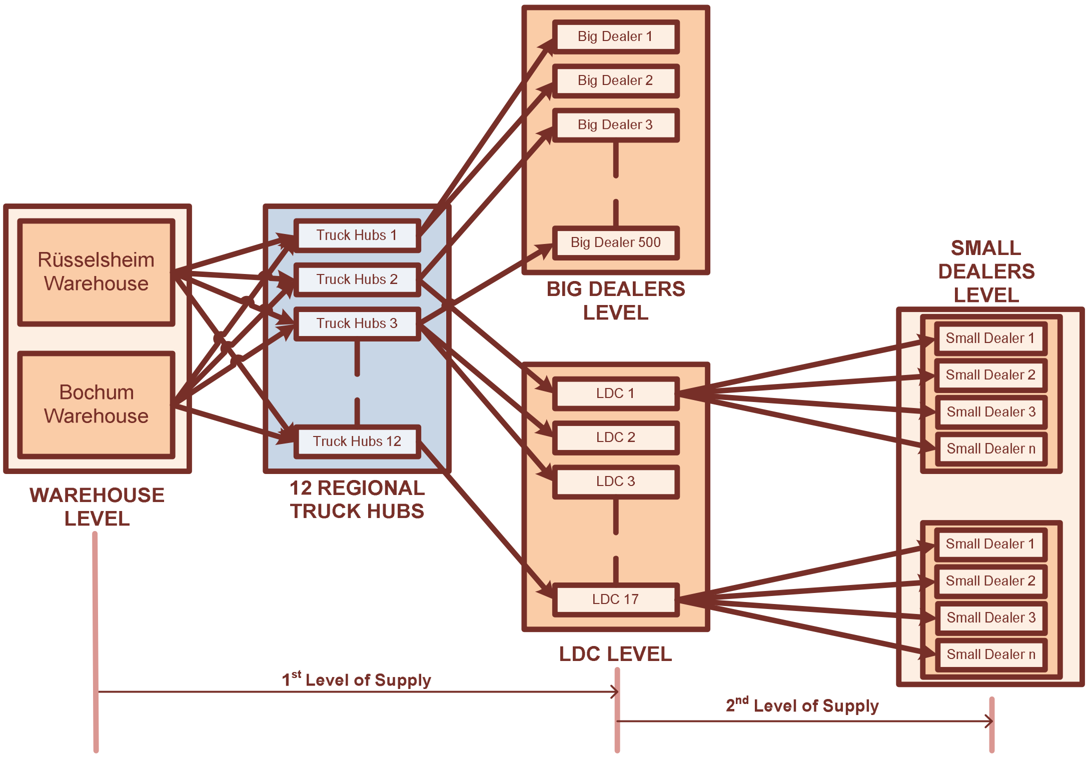

Figure 4-2 Stock Order Supply Chain Diagrams including Truck Hubs

4.2.4.2 Tariff and Cost Characteristic

Transportation charging method which has been taken as a basis to calculate the transportation cost is based on the Load Meter (LM) basis. One load meter is calculated as utilization of one meter length of a normal container area of 2.4 m x 2.5 m. Depending on the container length occupation the load meter is being calculated. With an increment of 0.1 load meter, a transportation cost of a constant number is being charged. A transportation cost constant of 111.5 €uro/LM and 92.0 €uro/LM is applied for part transportation sourced from each Bochum and Ruesselsheim warehouse.

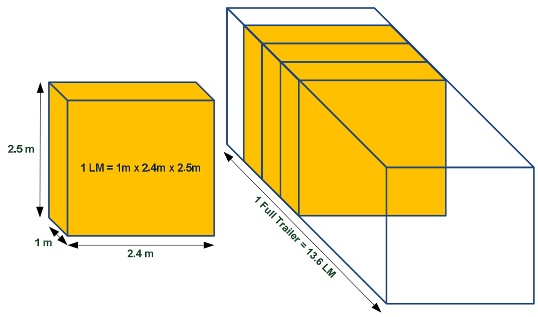

Figure 4-3 Load Meter Graphical Representation

For transporting the stock order parts sourced from Rüsselsheim warehouse or Bochum warehouse to the LDC and the big retailers which are located in whole Germany, the charge mentioned, 111.5 €uro/LM and 92.0 €uro/LM is applied in a constant flat tariff basis. Whether the destination location is far or near from the origin point, the transportation cost will be charged with an equal rate. Distance factor is not taken into consideration in the transportation charging.

In the truck utilization term, the present cost function has not token the truck utilization into account. Whether a shipment contains utilized space of 20% or 99%, both will receive the same unit transportation cost rate. The cost characteristics considering the truck utilization behaves in a similar way like the parcel transportation cost function. The cumulative cost grows linearly as the load increases as shown by the figure 4-4 below.

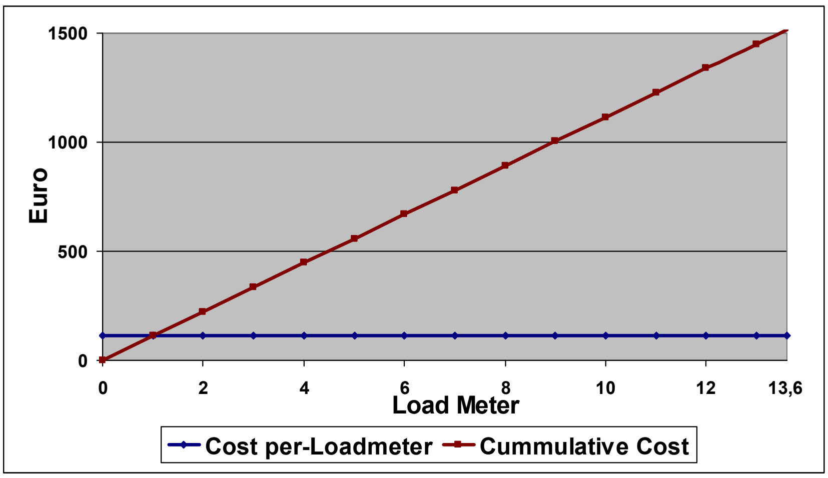

Figure 4-4 Load Meter Costing Characteristics

4.2.4.3 Little Stock Order Policy

Opel has a special policy for handling the small sized stock order sent by the retailers. For each stock order request with a total shipment size less than 20 kgs, Opel will sent the order request via an express carrier which offer a next day delivery service which is a lot faster than a normal shipment which costs three days at maximum. This could be considered as an extra service that a retailer could get if they request stock order in small amount.

In normal transportation sight, this policy actually supports the act of avoiding small shipment for the normal carrier. By this policy, small shipment which leads to the low utilized truck space and expensive unit cost shipping can be avoided

4.2.5 Second Level of Supply

The second level supply is considered every stock order supplied by an LDC to small retailers. 17 LDC are present in the whole Germany to support also the distribution of stock orders of the retailers which have small value of sales. Considering the sales volume of the subordinate costumers, the subordinate costumers which are receiving their stock orders from LDC normally have an annual sales volume less then 250,000 Euro. This value of annual sales shows the smaller intensity of transportation activity considering first level of supply. Therefore low intensity of supply due to low demand of costumers is being the key characteristics of the second level of supply of stock order.

4.2.5.1 Local Distribution Centre

The full service responsibility of the second level of supply is assigned totally by Opel to its 17 LDC spread out throughout Germany. In term of stock order, Each LDC is being responsible to serve the spare part and accessory needs of a regional group of small retailers at an appropriate service level. However, Ruesselsheim warehouse and Bochum warehouse are present to provide supply back up for an LDC in a case that an LDC does not have the requested parts from its sub ordinate costumer.

LDC seem to have a complete authorization to coordinate the material flow of rush order and stock order within second level of supply. However by the existence of DDS, Opel is expecting to have the full control of its spare parts and accessory distribution. As already explained before, all Germany retailers should make the order via DDS and DDS will define which logistics components will supply the order request. Therefore, the LDC will not receive the order directly from its subordinate retailers, but will receive the order via DDS.

The second level of supply activities will not be incorporated at the analysis of this thesis analysis since the full on field operational policy is governed by the contracted LDC not Opel. However to get an idea of how the LDC system works, a brief description will be forwarded.

4.2.5.2 Transportation Operation

For the transportation operation of subordinate retailer delivery service, in general each LDC has several different routes/ transportation trip loops to serve its retailer. Each route/ transportation trip loop is responsible of serving one group of retailers. As a remark also, the transportation trip loop which is being used to transport the stock order delivery is also being used for the normal rush order delivery. Consequently, in one transportation trip loop the shuttle will carry the rush order parts and the stock order parts also. By that condition, not only the stock order retailers are incorporated in the loop but also the rush order retailers, in fact the rush order retailers are the primary members of the transportation trip loop. The graphical representation of how the LDC transportation trip loop system works is displayed by figure 4-5.

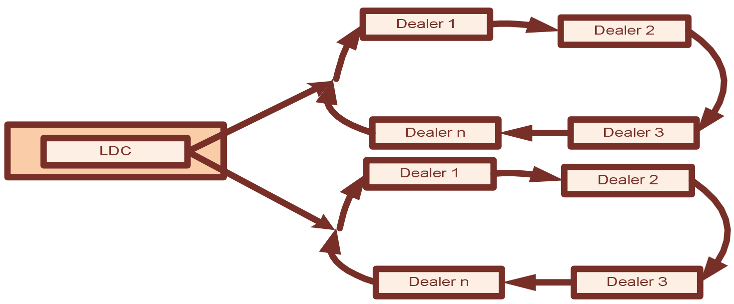

Figure 4-5 LDC Transportation Trip Loops

4.2.5.3 Tariff and Cost Characteristics

The distribution cost for second level of supply chain is being charged on the price value of the part basis. For the service of the stock order of the second level of supply, LDC get a commission of 9% of the parts price value from Opel for each part delivered to the end retailers. The mentioned charge is the only distribution charge that Opel should pay. It is already including the ordering cost, warehousing cost, transportation cost, and any other cost. In logistics point of view, by the application of this charging method, the only parameter which is affecting the distribution cost is the price of a part. No matter how small and light a part is, if the value of the part is expensive then the distribution cost is also high, vice versa, no matter how big and heavy a part is, if the value of the part is cheap the corresponding price will also be consequently low.

4.3 Rush Order

Different from the stock order which is addressed by a retailer to get parts for regular daily operation, basically rush order is a parts request made by a retailer to fulfill an urgent need. Therefore rush order should be fulfilled within very short period of time. A reliable logistics structure should operate in an effective way to be able to serve high parts availability, flexibility, reactivity, and short time response.

The rush order supply activities will also not be incorporated at the analysis of this thesis analysis; however a brief description of rush order operation will be forwarded in the following sections.

4.3.1 Logistics Structure Configuration

In order to be reactive to the rush order requests of all retailers in whole Germany distribution network, 17 LDC are spread out in different regions. Each LDC is responsible of the rush order requests of its subordinate retailers within its region, whether it is big retailers or small retailers. Even thou the discussion of the LDC task to supply small retailers stock order is already done at the previous sections, actually the primary task of this LDC concept is to serve the rush orders.

The structural arrangement of the stock order can be considered as three echelon system. The first echelon is the warehouses, the second echelon is the LDC, and the third echelon consists of the retailers. By this setup the LDC existence in the rush order distribution are really vital, because it functioned of building regional reactive bridges between Opel warehouses and all retailers. The graphical representation of the structure is shown by the figure 4-6. By the figure, the retailer is grouped differently between big and small dealers to be able to adapt easily the picture from the previous stock order structure diagram.

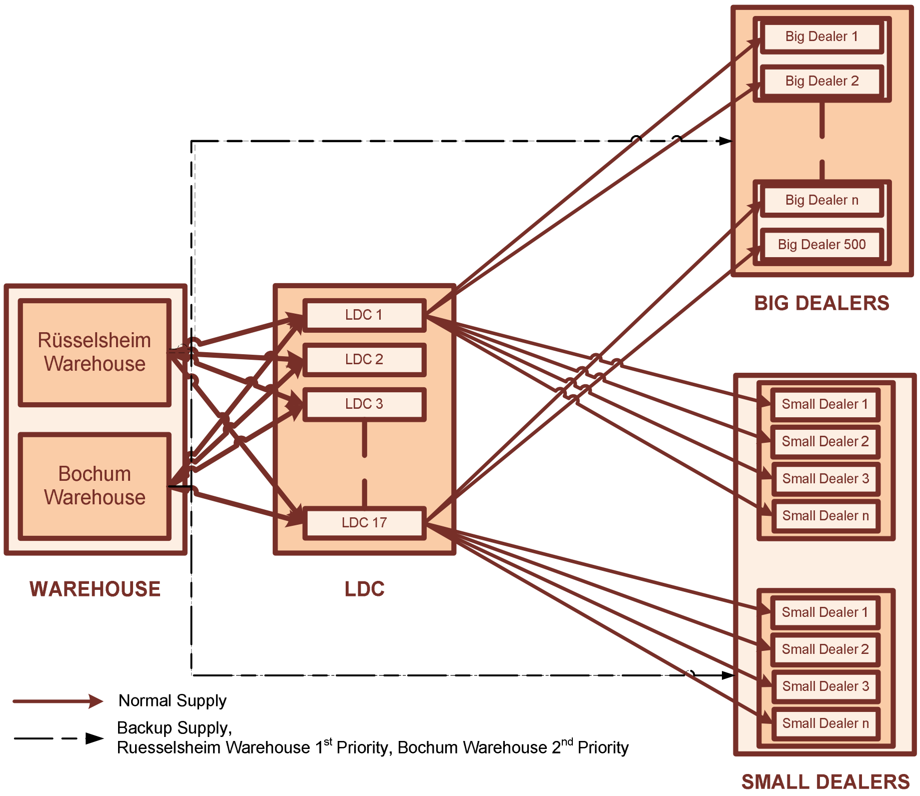

Figure 4-6 Rush Order Supply Chain Diagrams

4.3.2 Rush Order Replenishment Policy

Each rush order request coming from each retailer should be served in a same day delivery or at latest next day delivery depending on the cut off time. Not only the rush order request, but also the little stock order request which has been discussed before is also being treated with the same service like rush order. The order cut off time and the latest time at which retailers should receive their rush order or little sock order request is stated by the table 4-2.

Table 4-2 Rush Order Replenishment Cut Off and Response Time

Ordering Cut Off time	Delivery Time
Day no 1. Before 09.30	Day no 1. Before 14.00
Day no 1. Between 09.30 and 18.00	Day no 2. Before 08.00 – 09.00

4.3.3 Rush Order Information Flow

The information flow which being used in the rush order ordering activities is similar with the normal second level of stock order supply information flow discussed before. Each retailer, whether it is a big or a small retailer, should send every order to DDS. DDS will record the order and then assign the order supply firstly to the corresponding LDC. If the corresponding LDC does not have any stock, then the supply task will be assigned to Ruesselsheim warehouse or Bochum warehouse as the first and second priority of delivering back up supply of rush order. If there is still no stock available at any warehouse in Germany, then the rush order supply will be referred to the neighboring warehouses in the neighboring countries in Europe (which are out of the scope of the analyzed system). If there is no neighboring warehouse in Europe which able to supply the order request, then the order request will be noted down as a backorder line. The full picture of Germany rush order supply is incorporated in the rush order supply chain diagram in the figure 4-6.

4.3.4 Tariff and Cost Characteristic

By the discussion at the previous section, considering the source of supply, two types of rush order supply can be defined. The normal rush order supply which is sourced from an LDC and the rush order backup supply which is supplied either by Ruesselsheim warehouse or Bochum warehouse are the two types of rush order supply exist.

On the normal rush order supply side, the transportation cost is being charged by LDC on a percentage of price value of the parts being transported basis. For the normal rush order supply, Opel is being charged 13.5% from the price value of the parts which are being transported. Again the charging method is only consider the price parameter as a basis of calculation, without considering the logistics properties of the transported parts such as weight or volume.

On the rush order backup supply side, Opel is charged by the forwarder company in a weight basis. A transportation constant value of 1.16€/ kgs is applied to any parts sourced from the sourcing warehouses. This type of transportation cost charging is typical charge which inline with the parcel costing function discussed at the theoretical background chapter.

4.4 Warehousing

Ruesselsheim warehouse and Bochum warehouse are the two main warehouses which are supplying nearly all of the spare part and accessory needs of the whole Germany distribution system. All of the spare part movement throughout Germany mostly is originated from one of these two warehouses.

Ruesselsheim warehouse is the assigned *Part Distribution Centre (PDC)* for Germany. PDC is responsible of all the parts distribution within a country. Ruesselsheim warehouse is Germany official PDC. Therefore all the parts demands from any Opel retailers in Germany should be rooted firstly to Ruesselsheim warehouse.

Bochum warehouse acts as a source warehouse for nearly all of the Opel spare parts and accessory in Europe. In Germany's Opel spare part and accessory distribution system, Bochum act as a support for Ruesselsheim warehouse providing backup supply in a case Ruesselsheim warehouse does not have the required parts from its retailers.

The daily operation assignment of these two warehouses is being subcontracted to a third party logistics partner. This third party logistics partner is responsible for all the material handling processes in the warehouse.

For the responsibility that has been taken in the warehousing side, Opel has to pay the corresponding charges. In one model, Opel is charged per warehousing activity basis. At this model, the warehousing cost into several cost components regarding the activity component. The whole warehousing cost is built by the cost components which classified as, receiving cost, storing cost, pick pack ship (PPS) cost, and labor cost.

Going down to the charging value, the receiving cost is defined as zero charge by the reference model. For storing cost, two categories of storing cost are introduced, outdoor storing and indoor storing. Outdoor storing charge is set on volumetric basis, for each meter cube Opel is being charged for 12.86 Euro. At the indoor storing charge side, the cost is calculated annually based on financial inventory. At the Pick, Pack, and Ship (PPS) cost and also Labor cost side, the charging method which applied is calculated per order line served. Both PPS cost and also labor cost each charged 6.7 Euro per order line.

At this thesis analysis receiving cost, PPS cost, and labor cost are the cost components which will be incorporated to the analysis. These costs elements are the elements which exist as activity sensitive cost elements. On the other side, inventory cost which accounts for indoor and outdoor storing cost is not being incorporated in the analysis.

Chapter 5
Simulation Model Development

5.1 Introduction

This chapter discusses the modeling phase of thesis study. Both cost modeling and simulation model modeling will be discussed thoroughly. The cost models developed here will be implemented in the historic data analysis study and also the simulation study. On the other side, the simulation model developed here is the one which will be applied in the DOSIMIS simulation environment.

5.2 Cost Modeling

The cost modeling which has been done here, basically considers the transportation cost formulation and warehousing cost formulation. In the transportation cost model side, the existing system formulation and also the benchmark cost formulation will be modeled. In the warehousing cost model formulation side, only the existing distribution correlated warehousing cost will be formulated in a mathematical model here.

5.2.1 Existing Transportation Cost Model

As already discussed, current transportation cost is calculated based on the load meter basis. The total transportation cost charge is a product of a costing constant and the amount of utilized load meter. Since the costing constant applied for

Bochum warehouse is different from the one which is applied for Ruesselsheim warehouse, the total transportation cost is being built by the total transportation cost of each sourcing warehouse cost element as stated by the formula 5.1 and 5.2 here:

$$C_{tr} = C_{tr-BOC} + C_{tr-RUE} \qquad \textbf{(5.1)}$$

$$C_{tr} = k_{tr-BOC} \cdot LM_{BOC} + k_{tr-RUE} \cdot LM_{RUE} \qquad \textbf{(5.2)}$$

where:

C_{tr}	= Total Transportation Cost	(Euro)
C_{tr-BOC}	= Transportation Cost Bochum	(Euro)
C_{tr-RUE}	= Transportation Cost Ruesselsheim	(Euro)
k_{tr-BOC}	= Transportation Cost Constant Bochum	(Euro/LM)
k_{tr-RUE}	= Transportation Cost Constant Ruesselsheim	(Euro/LM)
LM_{BOC}	= Total Load Meter Number Bochum	(LM)
LM_{RUE}	= Total Load Meter Number Ruesselsheim	(LM).

Each sourcing warehouse should serve the demands of its LDC and retailers. Total loading amount which have to be served by a sourcing warehouse is a summation of loading amount which transported to the LDC and the retailers. Those LDC and retailers will be supplied physically by the warehouses via their corresponding truck hub as a transshipment point. Therefore, the total number of loading unit which is served by a warehouse can also be formulated as a summation of all loading unit request from LDC and retailers which is collected at their truck hubs as stated by the equation 5.3 below. The equation shows the calculation for Bochum warehouse, which also be valid for Ruesselsheim warehouse.

$$LM_{BOC} = \sum_{TH-BOC} \left(\sum_{LDC} lm_{ldc} + \sum_{DLR} lm_{dlr} \right) \qquad \textbf{(5.3)}$$

where:

lm_{ldc}	= LDC's Load Meter Request	(LM)
lm_{dlr}	= Retailer's Load Meter Request	(LM)
LDC	= LDC Set	
DLR	= Retailer Set	

TH-BOC = Bochum Truck Hubs Set.

After discussing the total loading unit carried by a sourcing warehouse, a comprehensive total transportation cost can be defined. Total transportation cost is a summation of each sourcing warehouse's transportation cost. In which, total transportation cost of a warehouse is a product of transportation cost constant and the total number of loading unit which is served by the warehouse via its subordinate truck hubs. The total transportation cost formulation is defined by the equation 5.4 below:

$$C_{tr} = \sum_{WH}\left(k_{tr-WH}\cdot\sum_{TH}\left(\sum_{LDC} lm_{ldc} + \sum_{DLR} lm_{dlr}\right)\right) \qquad \textbf{(5.4)}$$

where:

WH = Warehouse Set

k_{tr-WH} = Transportation Cost Constant for Warehouse (Euro/LM)

TH = Truck Hubs Set.

5.2.2 Benchmark Transportation Cost Model

The benchmark transportation costing method which will be applied for the comparison system is the costing method which incorporated the freight consolidation concept. By this benchmark transportation costing method, the unit freight cost per load unit will vary depend on the shipping condition.

Truck utilization and travel distance are two factors which define the condition for determining the unit freight cost. Higher truck utilization value will lead to cheaper unit cost. On the other governing parameter side, further traveling distance will lead to more expensive unit cost value. Equations below show the mathematical definition of truck utilization (equation 5.5) and the dependability of freight unit cost value to the truck utilization and traveling distance of a shipment (equation 5.6).

$$\eta_s = \frac{V_s}{V_{\max}} \qquad \textbf{(5.5)}$$

$$\alpha_s = f(\eta_s, \delta_s) \qquad \textbf{(5.6)}$$

where:

η_s	= Truck Utilization	(%)
V_s	= Utilized Truck Space	(m^3)
V_{mac}	= Maximum Truck Space Capacity.	(m^3)
α_s	= Freight Unit Cost	($Euro/m^3$)
δ_s	= Traveling Distance of a Shipment	(km).

Total transportation cost that should be paid is a summation of the transportation charge of all shipments sourced from the sourcing warehouses to end retailers and LDC. The shipments between the sourcing warehouses to retailers and LDC incorporate the existence of a truck hub between them. A truck hub acts as a consolidation point of the warehouses shipments to the truck hub's sub ordinate retailers and LDC. Therefore, the total transportation cost can also be formulated in a hierarchy of warehouses, truck hubs, and down to the retailers/LDC level, defined in the equation 5.7 below.

$$C_{tr} = \sum_{WH}\left(\sum_{TH}\left(\sum_{LDC} V_s \cdot \alpha_s + \sum_{DLR} V_s \cdot \alpha_s\right)\right) \quad \textbf{(5.7)}$$

To have the maximum benefit of freight consolidation concept in term of increasing the transportation utilization, truck hubs concept as consolidation points is applied. Before being shipped, all order request addressed by retailers and LDC will be consolidated first at the corresponding truck hub. After the order being consolidated, then the optimized number of transportation trucks can be set by dividing the total amount of shipment with the trailer maximum volume capacity as stated by the equation 5.8. The result of the division will show the number of full truck load transportation shipment and a fraction of one shipment of less than truck load transportation. The total truck number requirement is a summation of full truck load trucks and one less than full truck load truck as shown in equation 5.10.

$$\frac{(V_{LDC} + V_{DLR})}{V_{\max}} = n_{FTL} + \eta_{LTL} \qquad \textbf{(5.8)}$$

$$\eta_{LTL} = \frac{[V_{LDC} + V_{DLR}] - [V_{\max} \cdot n_{FTL}]}{V_{\max}} \qquad \textbf{(5.9)}$$

$$n_{TR} = n_{FTL} + 1 \qquad \textbf{(5.10).}$$

where:

V_{LDC}	= Total Volume of LDC Order within a Truck Hub Group (m^3)
V_{DLR}	= Total Volume of Retailers Order within a Truck Hub Group (m^3)
n_{FTL}	= Number of Truck with Full Truck Load
η_{LTL}	= Utilization number of the Less than Truck Load truck (%)
n_{TR}	= Total Number of Truck Requirement.

In term of full truck load shipment and less than full truck load shipment, the total transportation cost defined before can be redefined. As already discussed, the freight unit cost rate is determined by truck utilization parameter and traveling transport distance value. Regarding the distance parameter to define the unit cost rate, a group of retailers and LDC which has the same super ordinate truck hub will share the same representative distance value. The representative distance value is defined by doing a weighted average of annual volume of shipment and the distance of each retailer/LDC to the corresponding warehouse as stated in the equation 5.11.(this equation not only valid for the distance regarding Bochum warehouse, but also valid for Ruesselsheim warehouse). The resulting distance value then will be taken as the truck hub representative distance which will be used by all the retailers and the LDC within a specific truck hub group.

$$\delta_{TH-BOC} = \frac{\sum_{LDC}(V_s \cdot \delta_{sBOC}) + \sum_{DLR}(V_s \cdot \delta_{sBOC})}{\sum_{LDC} V_s + \sum_{DLR} V_s} \qquad \textbf{(5.11)}$$

where:

δ_{TH-BOC}	= Representative Truck Hub Distance to Bochum warehouse (km)
δ_{sBOC}	= Distance between a retailer/LDC to Bochum warehouse (km).

After defining the truck hub representative distance group of LDC and retailers within one truck hub, the complete transportation cost definition for a specific truck hub can be defined. Total truck hub cost is a summation of the total full truck load transportation cost and the less than truck load transportation cost. As defined before, benchmark transportation unit cost applied will be governed by the truck utilization and the truck hub representative distance. Therefore the full equation of truck hub transportation cost is stated in equation 5.12 below.

$$C_{tr-TH} = n_{FTL} \cdot V_{FTL} . \alpha_{FTL-\delta_{TH}} + V_{LTL} \cdot \alpha_{LTL-\delta_{TH}} \qquad \textbf{(5.12)}$$

where:

C_{tr-TH}	= Truck Hub Transportation Cost	(Euro)
n_{FTL}	= Number of Full Truck Load Shipment	
V_{FTL}	= Volume of one Full Truck Load	(m^3)
V_{LTL}	= Volume of one Less than Full Truck Load	(m^3)
$\alpha_{FTL-\delta_h}$	= Unit Cost of Full Truck Load Shipment	(Euro/m^3)
$\alpha_{LTL-\delta_h}$	= Unit Cost of Less than Full Truck Load Shipment	(Euro/m^3).

After defining the transportation cost for each truck hub, total transportation cost then can be defined as a summation of each truck hub transportation cost to the sourcing warehouses. Equation 5.13 shows the definition of total transportation cost.

$$C_{tr} = \sum_{WH} \left(\sum_{TH} C_{tr-TH} \right) \qquad \textbf{(5.13)}$$

5.2.3 Existing Warehousing Cost Model

Current warehousing cost model consists of four cost elements. Receiving cost, storing cost, pick-pack-ship cost, and labor cost are the cost elements that build the whole total warehousing cost. The basic equation of warehousing cost is defined by the equation 4.1.

$$C_{wh} = C_{rv} + C_{iv} + C_{pps} + C_{lb} \qquad \textbf{(5.14)}$$

where:

C_{wh}	= Warehousing Cost	(Euro)
C_{rv}	= Receiving Cost	(Euro)
C_{iv}	= Storing Cost	(Euro)

C_{pps} = Pick, Pack, and, Ship Cost (Euro)

C_{lb} = Labor Cost (Euro).

Three of four elements are formulated in correlation with the number of order lines. Receiving cost, pick-pack-ship cost, and labor charge, are the cost elements which charged by the number of order line. On the other side, the storing cost is being charged by the volumetric parameter and also by the value of the goods parameter. In this thesis analysis, the inventory holding cost/ storage cost is not being taken into account. Therefore, the storage cost is leaved undefined.

$$C_{wh} = (k_{rv} \cdot L_D) + C_{iv} + (k_{pps} \cdot L_D) + (k_{lb} \cdot L_D) \quad \textbf{(5.15)}$$

$$C_{wh} = ((k_{rv} + k_{pps} + k_{lb}) \cdot L_D) + C_{iv} \quad \textbf{(5.16)}$$

$$C_{wh} = (k_{tot} \cdot L_D) + C_{iv} \quad \textbf{(5.17)}$$

where:

k_{rv}	= Receiving Cost Constant	(Euro/Line)
k_{pps}	= Pick, Pack, and, Ship Cost Constant	(Euro/Line)
k_{lb}	= Labor Cost Constant	(Euro/Line)
k_{tot}	= Total Cost Constant	(Euro/Line)
L_D	= Germany's Total Number of Order Line	(Line).

At the equation 5.17 defined above, the clear description of how the receiving cost, pick-pack-ship cost, and labor cost being charged is clearly described. Since those three cost elements are being calculated by a linear constant in relation to Germany's total number of order lines L_D, the constant of each cost elements can be merged into one constant k_{tot} to simplify the formulation. As have been stated before, the storage cost is not being taken into further consideration; therefore further definition of storage parameter C_{iv} is not defined further.

Germany's total number of order line is the only parameters which govern the magnitude of total warehousing cost. Germany's total number of order line is built by the number of order lines served by Bochum and Ruesselsheim warehouse. Each warehouse serves order request lines addressed by LDC and retailers throughout

Germany. The complete definition of how Germany's total number of order line being built is defined by the equation 5.18 and equation 5.19 below.

$$L_D = L_{BOC} + L_{RUE} \qquad \textbf{(5.18)}$$

$$L_D = (L_{LDC} + L_{DLR})_{BOC} + (L_{LDC} + L_{DLR})_{RUE} \qquad \textbf{(5.19)}$$

where:

L_{BOC}	= Bochum's Total Number of Order Line	(Line)
L_{RUE}	= Ruesselsheim's Total Number of Order Line	(Line)
L_{LDC}	= LDC's Total Number of Order Line	(Line)
L_{DLR}	= Retailer's Total Number of Order Line	(Line).

In the simulation model, the delivery of the orders addressed by LDC and retailers to the warehouses are firstly being consolidated at the truck hub level before consolidated at the warehouse level. Therefore at the upcoming equation the order lines which are addressed to the warehouse are also being grouped by the corresponding truck hub in order to get an inline calculation formula with the one present at the transportation cost and simulation model. The regrouping of the equation actually does not bring any effect to the end result, since each retailer or LDC cannot has more than one connection to the truck hubs. The reformatting of the calculation formula as shown in the equation 5.20 and equation 5.21, bring the formula to a comprehensive simulation model formula.

$$L_D = \sum_{TH-BOC}\left(\sum_{LDC} l_{ldc} + \sum_{DLR} l_{dlr}\right) + \sum_{TH-RUE}\left(\sum_{LDC} l_{ldc} + \sum_{DLR} l_{dlr}\right) \qquad \textbf{(5.20)}$$

$$L_D = \sum_{WH}\sum_{TH}\left(\sum_{LDC} l_{ldc} + \sum_{DLR} l_{dlr}\right) \qquad \textbf{(5.21)}$$

where:

l_{ldc}	= LDC's Order Line	(Line)
l_{dlr}	= Retailer's Order Line	(Line).

5.3 Simulation Model Modeling

In this section the modeling process of the existing distribution network will be discussed. Not only the modeling process of existing distribution system operation will be discussed, but also the process of modeling of the alternative scenario which consolidates the existing sourcing warehouses into one sourcing warehouse will also be discussed.

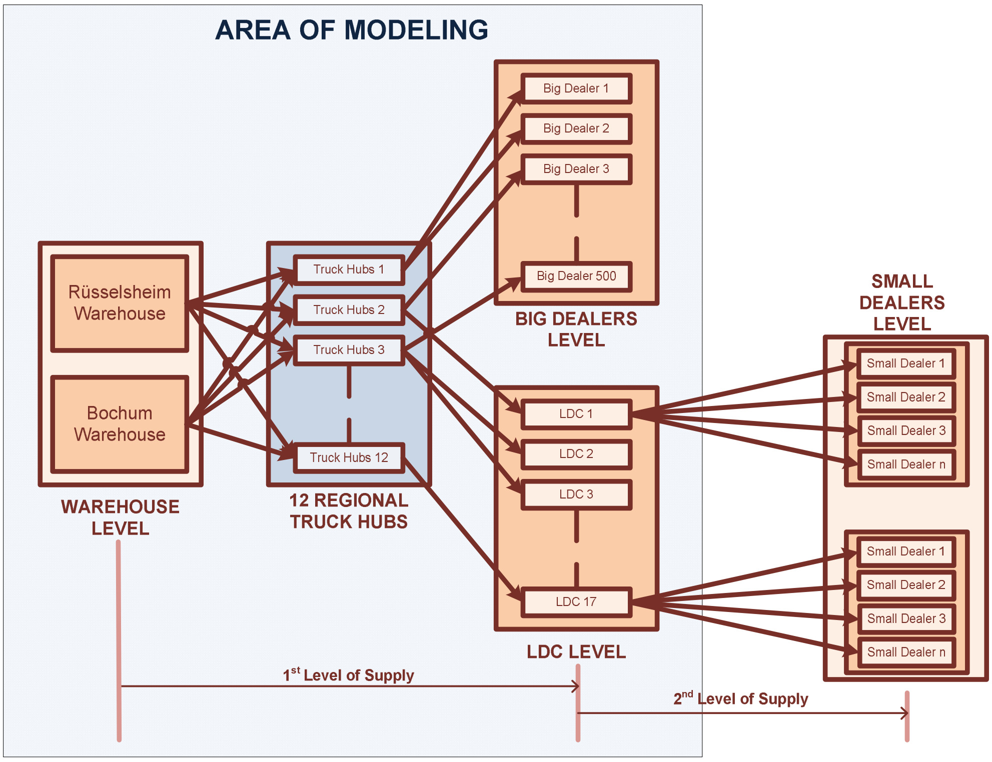

Figure 5-1 Area of Modeled Supply Chain Network

As already discussed, the current distribution network consists of three level of echelon. Warehouse Level, LDC/Big Retailers Level, and Small Retailers Level are the three echelon inventory system which build complete distribution network. Between the warehouse level and the LDC/Big Retailers Level, twelve regional truck hubs of third party logistics exist. The supply chain which connects the sourcing warehouses, regional truck hubs and the LDC/Big Retailers level is the area of analysis which will be modeled and analyzed at the simulation study as shown in the figure 5-1. The chain between LDC and the small retailers is considered out of the scope of the analysis, since it is out of Opel direct responsibility.

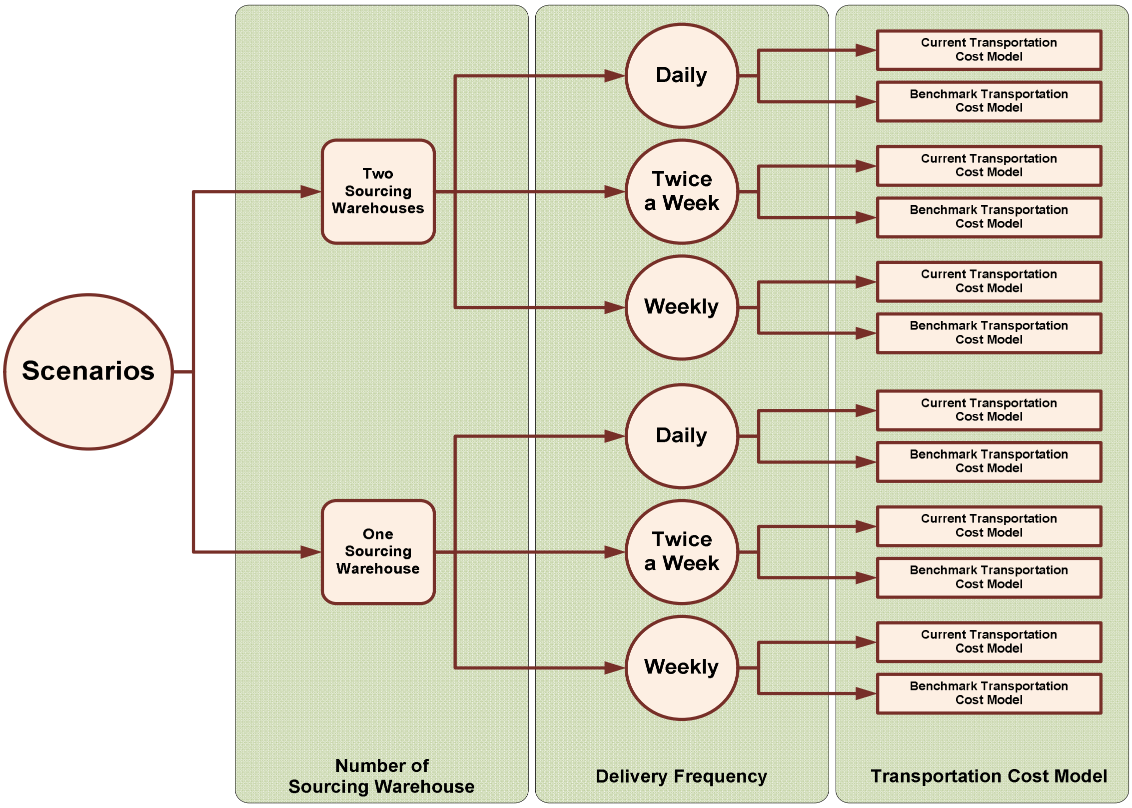

Figure 5-2 Simulation Model Scenarios

The alternative scenario which will be tried out is clearly described by the figure 5-2. By doing policy combination of the number of the sourcing warehouse, the delivery frequency, and the transportation cost model, totally twelve scenarios will be analyzed.

5.3.1 Two Sourcing Warehouses Scenario

Two sourcing warehouse scenario is the scenario which adapt the current condition of Opel spare part distribution network. In modeling the simulation model, the existing system should be carefully analyzed to get a good representative simulation model. As we can see from the figure 5-3, the network logistics nodes are being mimicked in one to one representation model.

By the developed DOSIMIS model adapted form the LDNST, direct and clear representation of two sourcing warehouses, twelve truck hubs, and the group of big retailers and retailers is showed by the arrangement of the simulation building blocks. The material and information flow connections which exist between the logistics nodes are also showed clearly by the line connecting the building blocks. A direct representation of the existing model to the simulation model is graphically obvious.

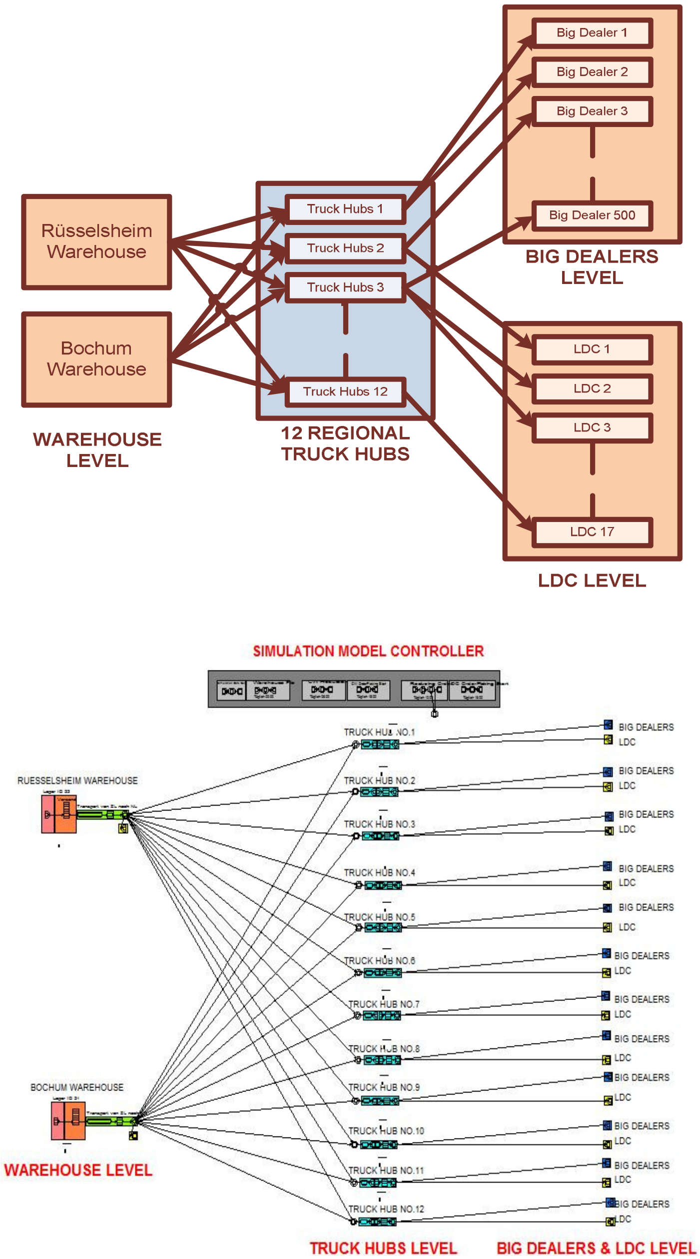

Figure 5-3 Two Sourcing Warehouse Scenario Simulation Model

After having the structural distribution network built in the simulation model, the logic of operation is the next issue to be done. The working procedure of the simulation run should be inline exactly as the defined scenarios. As already defined, in each sourcing warehouse policy a try out of six sub scenarios will be done. Therefore each of the sub scenarios should be implemented correctly in the logic of the model.

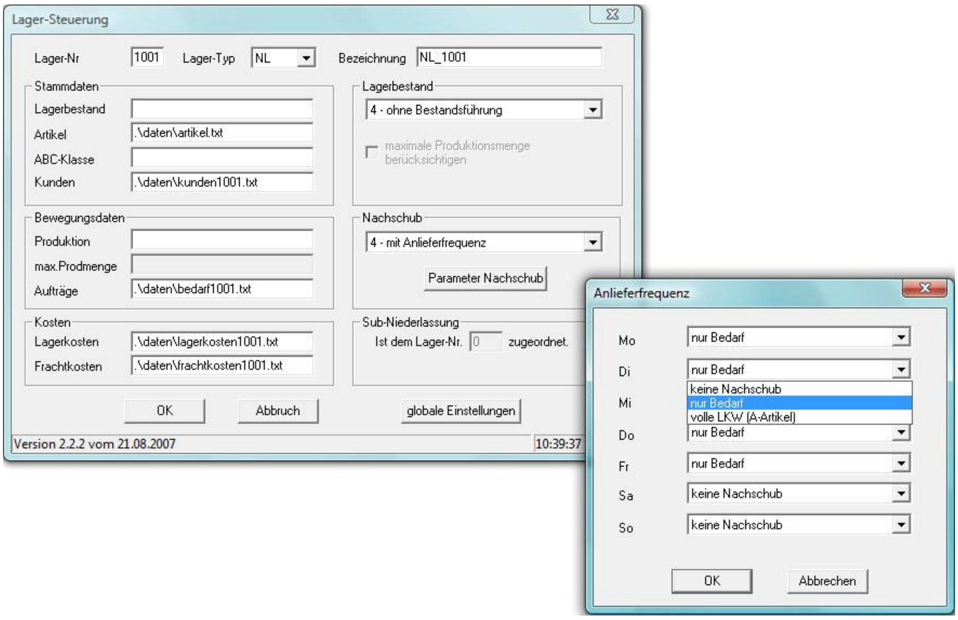

Figure 5-4 Delivery Frequency Setting Input Forms

Six subs scenarios which will be applied are basically related to the policy regarding costing method alternatives and delivery frequency alternatives. The costing method alternative policy can be implemented in the simulation by adjusting the imported transportation cost input file. As can be seen at the figure 5-4, as one of the input data beside articles data, costumer nodes data, invoices data, and warehouse costing data, transportation costing data input will govern the calculation logic which being used. To apply different costing method alternative, different costing input data with a specific format should be inputted.

The delivery frequency alternative policy is implemented in the simulation model by doing a direct set up in the DOSIMIS model. An adjustment program has been developed to adapt the desired delivery policy logic. This adjustment program can be applied to any set of simulation building blocks which represent any level of logistics node. In this thesis the adjustment is being applied to all truck hubs representative. So for each single truck hub, the delivery policy alternative can be defined by simply choosing one of the alternatives available in the delivery frequency input form. The input form that defines the replenishment logic is also shown by the Figure 5-4.

As the structural modeling and the simulation logic definition already completed, then the only thing to do is to fill up the parameters required in the global setting form and also the simulation parameter form showed in the figure 5-5. After those two forms have been filled completely, the simulation is ready to be started.

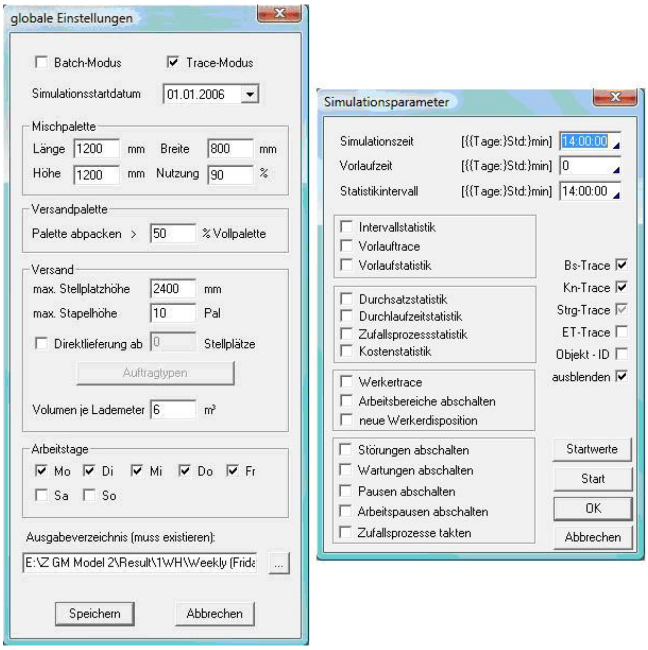

Figure 5-5 Global Setting and Simulation Parameter Input Forms

5.3.2 One Sourcing Warehouse Scenario

One sourcing warehouse policy is being carried out to study the amplification effect of the freight consolidation by doing *warehouse* consolidation concept. Having two sourcing warehouses scenario model developed, developing one source warehouse simulation model requires no considerable effort.

The structural distribution system simulation model developed in the two sourcing warehouses can be adapted easily by deleting one of the sourcing warehouses representation exists. The complete figure of the structural simulation model building of this one sourcing warehouse concept is displayed by the figure 5-6.

By reducing the number of warehouses, the reduction of material and information connections between the truck hubs and the sourcing warehouses will be reduced logically by half. By this condition the expected shipment density will be increased. Therefore, the consolidation effect benefit should increase considerably.

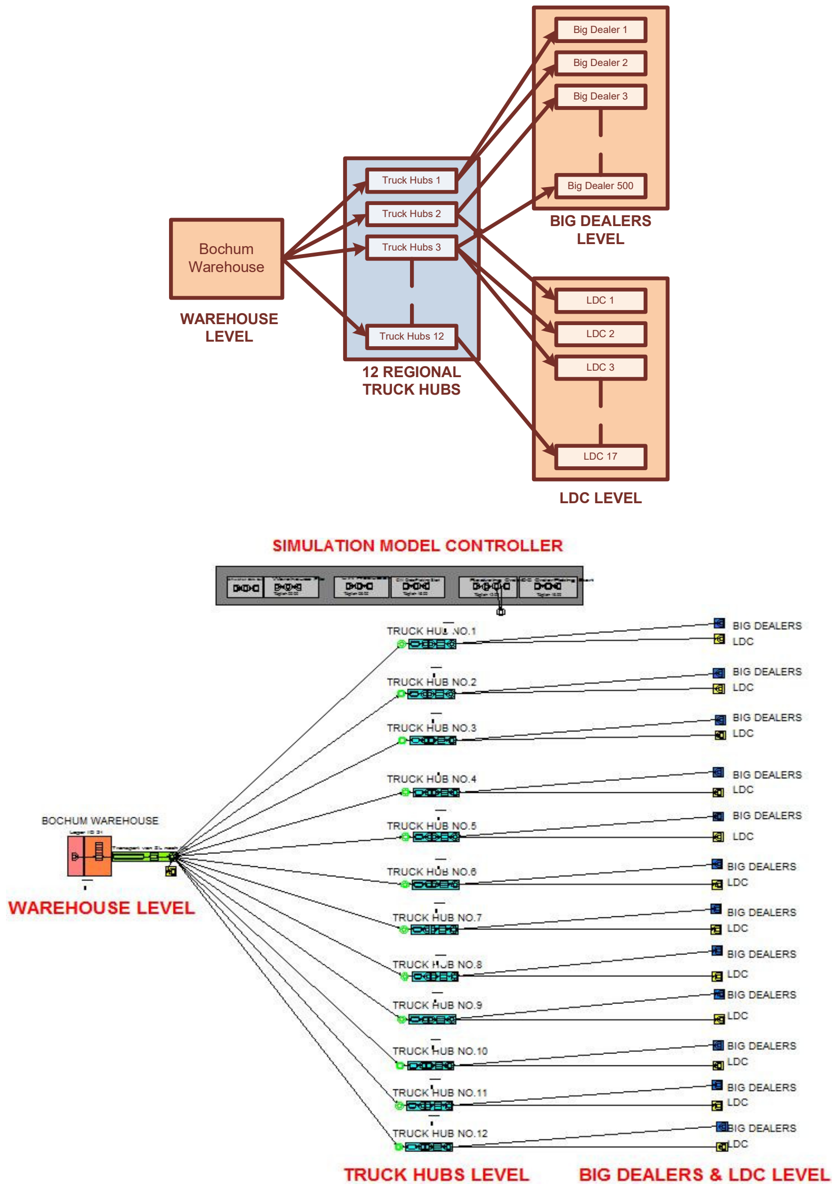

Figure 5-6 One Sourcing Warehouse Scenario Simulation Model

The structural simulation model modification is not the only thing that should be modified in the new concept. In addition, the input files are also being a subject of modification. In the support of constant demand allocated by the retailers and LDC, all of the invoice requested to the deleted warehouse should now be addressed to the remaining warehouse. In concrete, the invoices lines which are addressed to the deleted warehouse should be removed and allocated to the remaining warehouse invoice input data. By this condition the modeled single warehouse will represent the service of all the demand of the retailers and LDC which used to be carried out together with the deleted warehouse.

After done with the structural simulation model review, building up the logic of six alternative scenarios which will be tried out require just the exact minimum effort as did in the two sourcing warehouse concept. Each combination of different costing method input files and adjustment of the delivery frequency setting should be inputted completely in the corresponding forms to do the simulation run.

As already implied by the preceding sections, the simulation model modeling in DOSIMIS requires unsophisticated method. To run a simulation study model, a person needs to do two basic steps. First step is to build a physical simulation model which represents the analyzed system and the second step is to fill in the parameters in the appropriate forms to govern the exact logic of the analyzed system. After two steps is already completed then the simulation run can be started and the result of the simulation can be analyzed.

Chapter 6
Result Analysis

6.1 Introduction

As already defined, the main purpose of this thesis study is to investigate the impact of applying different delivery frequency alternatives to distribution cost. To understand how the distribution cost behaves to delivery frequency parameter, different alternatives of delivery frequency (daily, twice a week, and weekly) scenario are being tried out to the existing system model. For further information, the distribution cost which will be analyzed in this thesis consists of pick-pack-ship cost and the load meter transportation cost.

Study of distribution cost behavior to delivery frequency setup alternatives which can also be categorized as the study of temporal shipment consolidation is not the only subject that will be analyzed. The study of warehouse consolidation scenario which merges the existing system’s two sourcing warehouses into only one sourcing warehouse in different delivery frequency scenario will also be done. By studying additional system which implements warehouse consolidation concept, a better insight of the available distribution cost saving potencies can be gained.

More effort to achieve more distribution cost saving is also being attempted by applying a benchmark transportation costing system into the two mentioned system models (current distribution system and one sourcing warehouse distribution system). A benchmark transportation costing system which incorporates the distance parameter and the truck utilization parameter in the definition of transportation charging value will be tried out and compared against the current transportation costing system which adopts a flat rate parcel transportation costing system.

By the trying out two different costing systems to the two distribution system alternatives each in three different delivery frequency setups (daily, twice a week and weekly), in total twelve scenarios will be tried out. Those twelve scenarios will be tried out to get an understanding of the responses of warehousing pick-pack-ship cost and transportation cost in each scenario. To achieve the understanding two methods will be applied, historical data analysis study and simulation study. The presentation and the discussion of the results of each study will be explained further in this chapter.

6.2 Historical Data Analysis

Historical data analysis is a simple yet useful method to get sufficient knowledge of the current system responses to the application of the alternative scenarios. This method involves a spreadsheet analysis try out to the existing historical data which has been imported massively. Even though the data processing of this method takes longer time especially when the size of the data analyzed is massively big, this method is easy to understand and easy to apply. By the application of historical data analysis method, the behavior of the analyzed system to the application of different operation scenarios in term of distribution cost (pick-pack-ship cost and transportation cost) will be presented as a part of this chapter.

6.2.1 Pick-Pack-Ship Cost

Pick-pack-ship cost is the only part of warehousing cost which is incorporated in this thesis study. The reason behind the incorporation of PPS cost is because PPS cost has strong relationship with the delivery replenishment activity. Each delivery replenishment activity is always accompanied by PPS activities. Therefore eventhough PPS is considered as a part of warehousing cost, this parameter is incorporated in this thesis study due to its strong relationship with distribution process.

6.2.1.1 Current Distribution Network System

As already defined in the simulation model development chapter, PPS cost value is governed by the amount of total order line quantity in a linear function. The effect of applying temporal consolidation to the existing distribution system in term of total number of order lines is shown by the figure 6-1 below. As indicated by the figure, the adjustment of delivery frequency into a longer period of delivery replenishment causes the decrease of the total number of order lines.

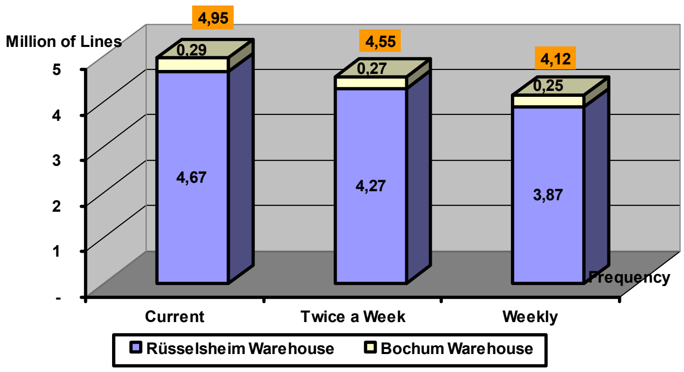

Figure 6-1 Annual Number of Order Lines - Delivery Frequency Chart

In this thesis study the demand rate is assumed to be constant no matter the different delivery frequency scenario applied, by setting up the delivery frequency in a longer period, the chance of triggering the order lines which contain the same part number by a specific retailer will be avoided. Retailers will be stimulated to send fewer order requests, in a longer period, yet with a bigger order size per request. As the total number of lines is going down along with the increasing period of delivery, consequently the PPS cost will also be sunk down as displayed by figure 6-2.

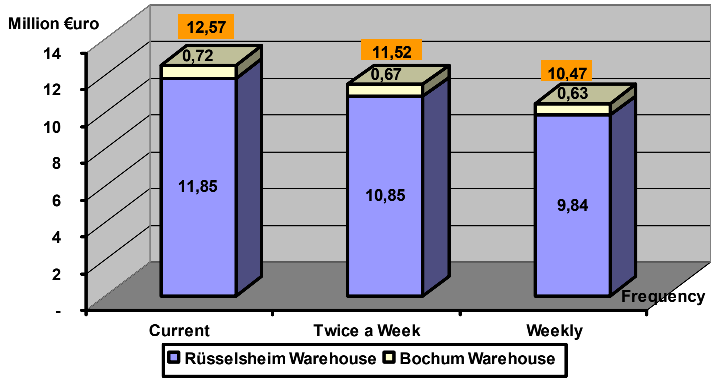

Figure 6-2 Annual PPS Cost - Delivery Frequency Chart

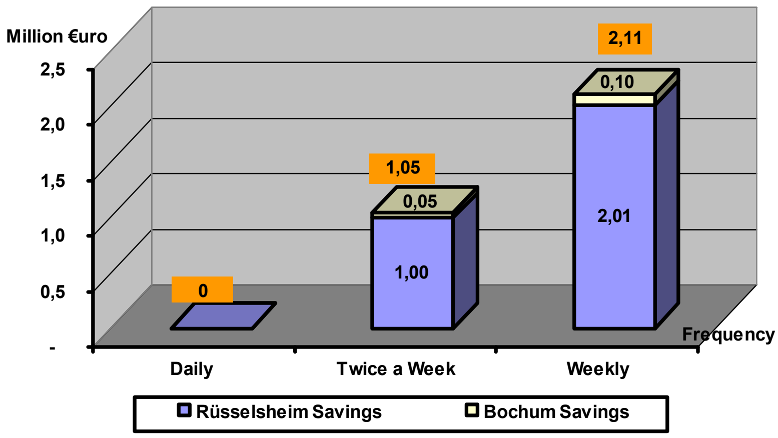

Figure 6-3 PPS Cost Savings - Delivery Frequency Chart (€uro)

With the decreasing value of PPS cost along with the increase of the delivery period, a considerable amount of saving can be gained. Figure 6-3 and figure 6-4 show the existing saving potency that can be gained by doing temporal consolidation in term of money value and percentage of money value saving. Figure 6-3 shows the possibility of gaining total PPS cost saving of 2.11 Million €uro by adjusting the replenishment period setup of all of big retailers and LDC delivery into weekly period. On the other side, figure 6-4 shows the total saving potency that can be gained in percentage format. By the figure 6-4, it is clear that the Total PPS saving is mainly governed by Ruesselsheim PPS cost saving, since most of the parts distributed are sourced from Ruesselsheim warehouse as Germany's LDC.

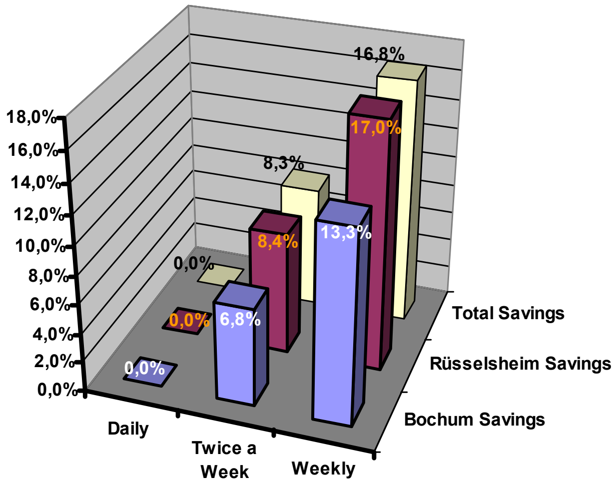

Figure 6-4 PPS Cost Savings - Delivery Frequency Chart (Percentage)

6.2.1.2 One Sourcing Warehouse System

In one sourcing warehouse system, all big retailers and LDC order requests will be supplied from one warehouse only. Therefore, all of order lines which are use to be identified as request lines of two different warehouses (figure 6-1) will be summed up into one total Germany number of order lines (highlighted in the orange label). This addition of two request lines of two warehouses can be agreed since each warehouse is assumed to supply specific spare parts.

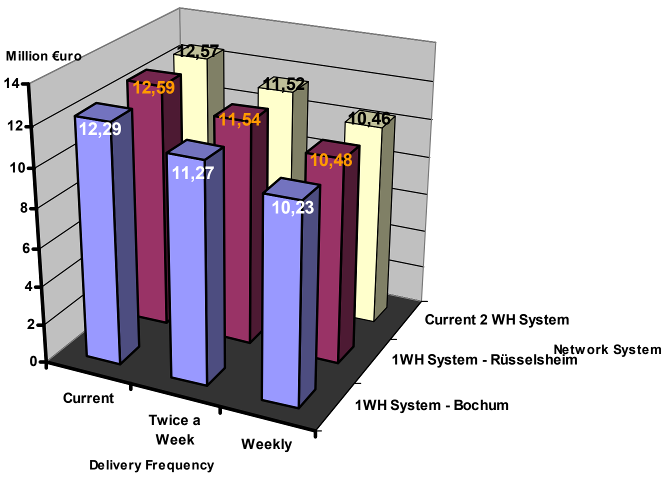

Figure 6-5 Annual PPS Cost - Delivery Frequency – Network System Chart

The decreasing total number of order lines as the period of delivery triggering is being extended will also naturally lead to decreasing value of the PPS cost. The PPS cost for one sourcing warehouse system incorporates the use of one PPS constant value, whether Bochum PPS costing constant (2,48 Euro/Line) or Ruesselsheim PPS costing constant (2,54 Euro/Line). Compared to the PPS cost of the existing system which utilizes the combination of two PPS costing constants, the total value of PPS cost of one sourcing warehouse system will be whether cheaper or more expensive regarding the constant used. As displayed by the figure 6-5, total PPS cost of one sourcing warehouse is either more expensive (Ruesselsheim Warehouse) or cheaper (Bochum Warehouse) than the existing current two sourcing warehouses system. As can be seen from the picture, Bochum warehouse which is settled up as the only sourcing warehouse system setup has the cheapest annual PPS cost value due to its cheap PPS costing constant, on the other side Ruesselsheim warehouse PPS cost value stands as the most expensive position compared to any tried out systems.

After defining the PPS costs for each system in the pre defined delivery frequency scenarios, the potential saving number that can be achieved can be calculated. Figure 6-6 shows the amount of saving percentage that a system can gain in each delivery frequency setup. As can be seen, the maximum saving value of 18,6% calculated relatively to the current system PPS cost can be gained by utilizing Bochum sourcing warehouse as the only sourcing warehouse in weekly delivery period scenario. In minimum saving level bound point of view, the utilization of Ruesselsheim warehouse as the only sourcing warehouse within the current delivery frequency scenario leads to deficit PPS costing charge deficit of 0.1% calculated relatively to the PPS cost of the current system. This phenomenon expelled a fact that warehouse consolidation does not guarantee the PPS cost saving achievement, especially when the PPS costing constant of the merged warehouse is bigger than the current system representative PPS costing constant. Temporal consolidation is the shipment consolidation strategy which always gives significant savings of PPS cost.

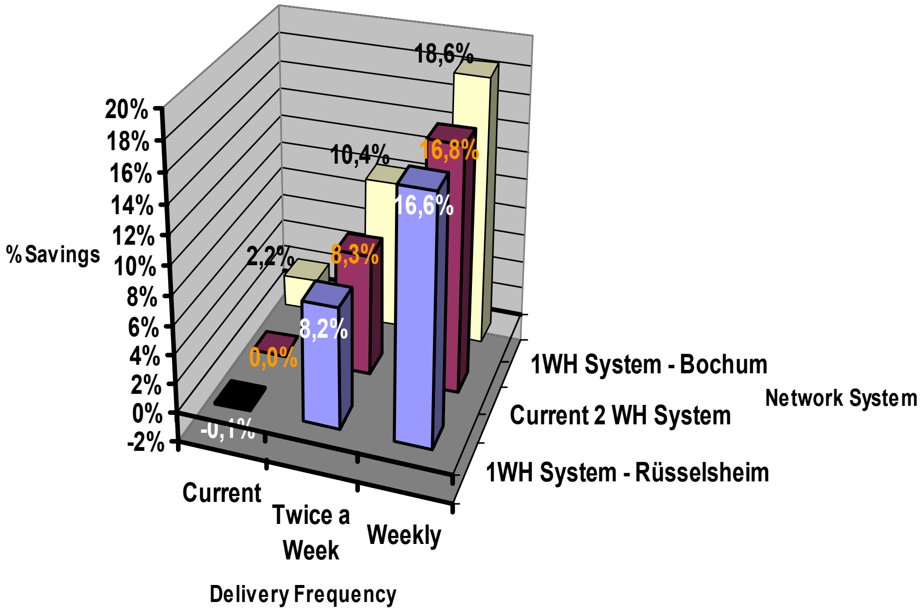

Figure 6-6 Annual PPS Cost Savings - Delivery Frequency – Network System Chart

6.2.2 Transportation Cost

In this section the effect of applying temporal consolidation and warehouse consolidation to the transportation cost value behavior will be analyzed. In addition, two different costing methods will be applied to get a better perspective of the analyzed systems behavior in different try out scenarios corresponding to each costing method.

6.2.2.1 Current Distribution Network System

A data extraction of one year historical data has been done in order to get the value of annual orders of the first level of supply in term of cubic meter. Taking the truck utilization factor value of 100% as a basic assumption, annual load meter requirement value can be calculated. With the assumption that the demand rate will not be affected by any delivery frequency adjustment process, the total annual load meter requirement for each delivery frequency replenishment scenario will stay at the constant level as displayed by the figure 6-7 below.

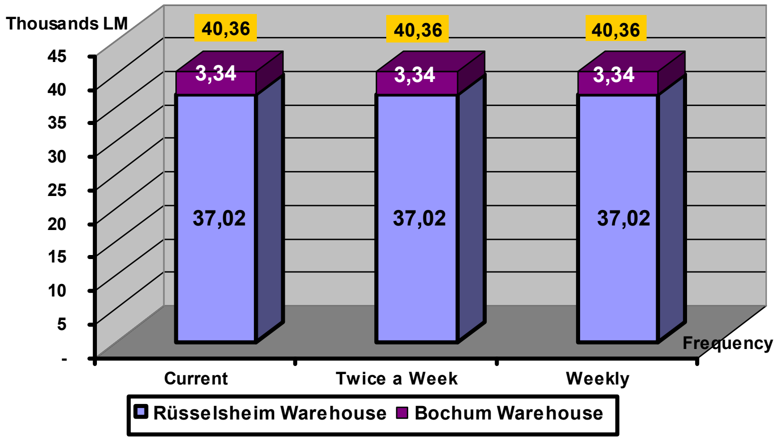

Figure 6-7 Annual Load Meters Requirement

The constant value of annual load meters requirement will produce an increasing density of shipment in an increasing period of delivery replenishment. In a condition of increasing period of delivery replenishment, constant demand rate of spare parts should be served in less frequent replenishments, consequently this situation stimulates an increasing shipment size per replenishment.

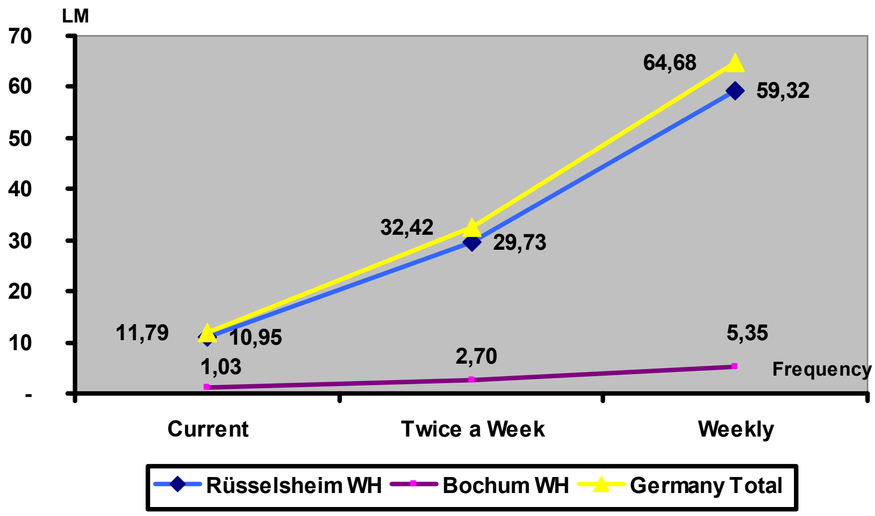

Figure 6-8 Load Meter Average Value per Replenishment per Truck Hub

The increase of replenishment size per-single replenishment stimulates the increase of total full truck use transportation. Figure 6-9 shows how the number of full truck load transportation behaves to each delivery frequency setup scenario. As shown by the figure, the full truck load transportations number increases as the delivery frequency setup gets rarer.

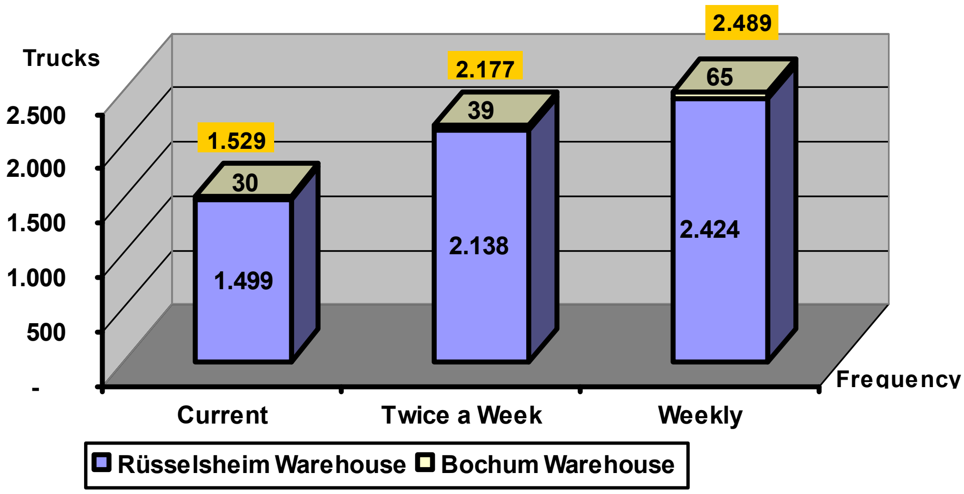

Figure 6-9 Annual Full Truck Load Transportation Requirements

In opposite to the indication showed by the full truck load transportations behavior, the number of less than truck load transportations is decreasing significantly as the delivery frequency setup gets rarer. As shown by the figure 6-10 below, the number of LTL trucks decreases significantly. As an extreme indication, the number of LTL truck transportation reduces from 6,639 to 1,248 which account for more than 81% saving by simply switching the current delivery replenishment setup into weekly delivery replenishment setup.

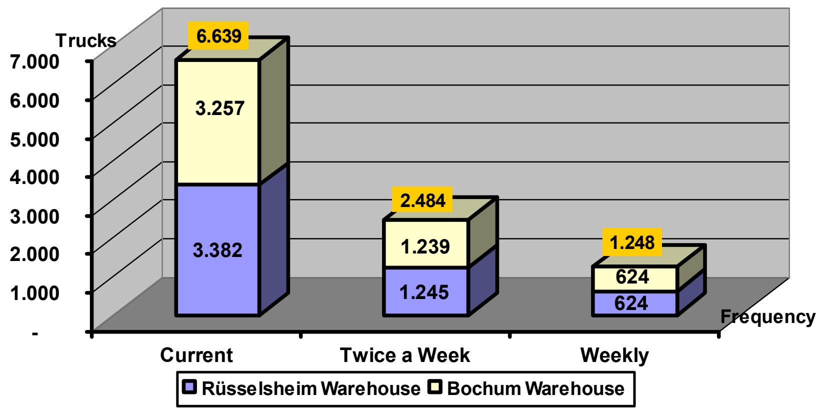

Figure 6-10 Annual "Less than Truck Load" Trucks Requirement

Total number of trucks need is a summation of FTL trucks and LTL trucks requirements. Therefore the results gained before, which are annual FTL trucks requirement performance and annual LTL trucks requirement performance, should be combined together to produce total trucks requirement performance as shown in the figure 6-11 below. As shown, the increasing number of FTL trucks need is combined with the number of LTL truck need which is decreasing in an even bigger rate. As a final result, decreasing number of total trucks needs in an increasing period of delivery replenishment setups is produced.

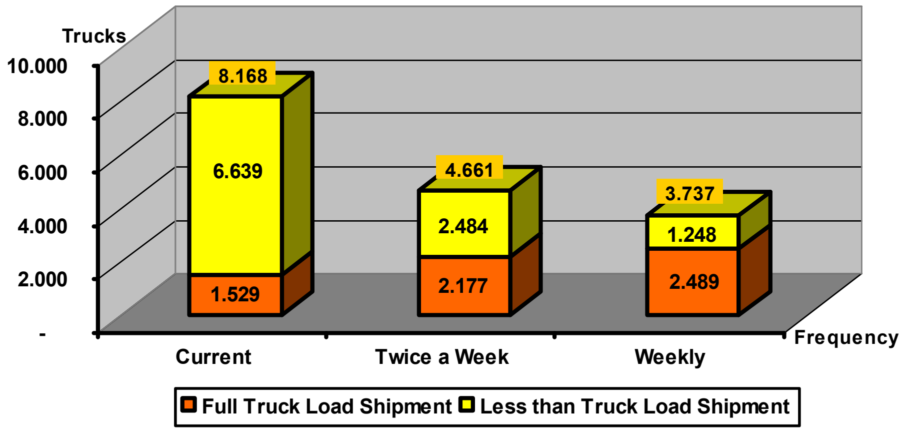

Figure 6-11 Annual Total Trucks Requirement

As shown by the figure 6-12, in a term of trucks saving, massive truck use savings of 42.9% and 54.2% exist by the application of twice a week and weekly delivery frequency to the existing system. This indicates that the potency of gaining saving by applying temporal consolidation strategy is significantly high. The fact that the LTL transport is dominating the transportation of current delivery system indicate big potency of doing any shipment consolidation strategy to convert LTL trucks dominated transportation into a total transportation which is more dominated by FTL trucks transport which at the end will decrease the amount of total truck requirement drastically.

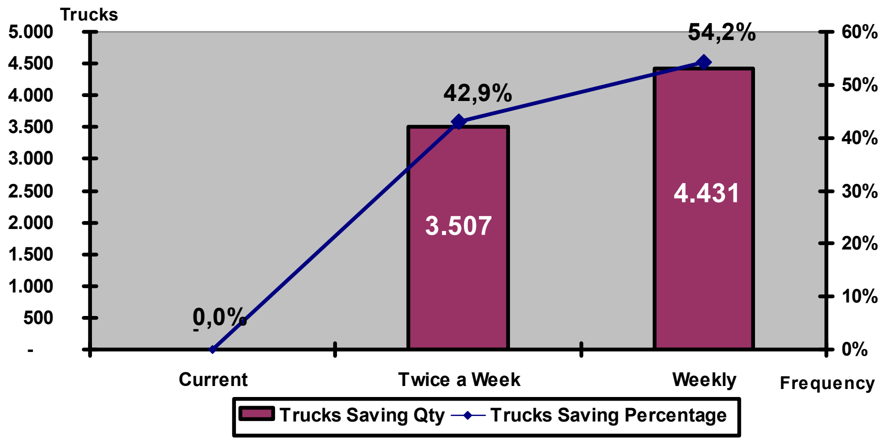

Figure 6-12 Annual Total Trucks Savings

Eventhough the number of total truck needs decreases drastically along with the application of rarer delivery frequency policy, the transportation charge which should be paid stays at the constant level. Since the transportation cost is charged based on the total load meter transported which is assumed to be constant, the chance of having transportation cost discount is nearly nothing. Therefore the effort of applying temporal consolidation strategy which indeed reduces the total number of trucks need will not has any effect to the end transportation cost, since at the end the total number of volumetric transported parts is still the same. A chart shown in figure 6-13 displays the constant amount of annual transportation cost of the existing system in different replenishment scenario.

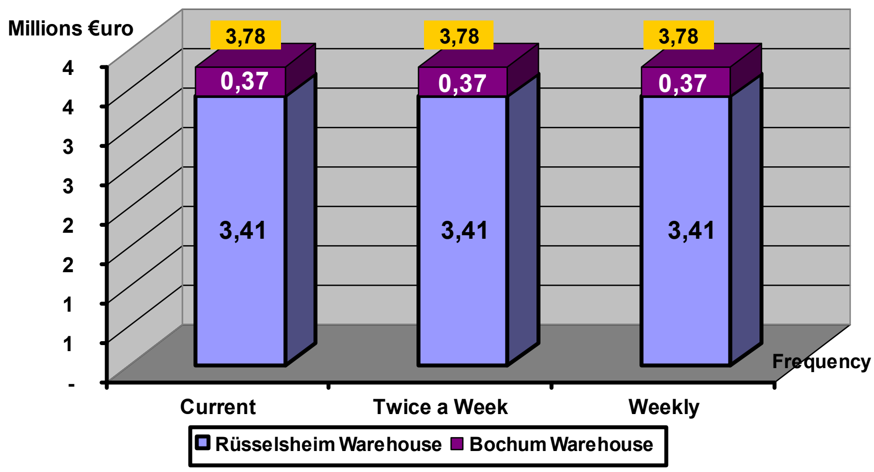

Figure 6-13 Annual Transportation Cost Expenses

The application of temporal shipment consolidation will not reduce the amount of load meters need to be transported, however it reduces the amount of transportation effort that should be done. The number of trucks requirement saving gained by the shipment consolidation strategy is considered useless by the current transportation costing method since it counts only the total end number of transported goods and not taking the truck utilization issues into account. Therefore a try out of a benchmark transportation costing method which is expected can utilize the benefits from the shipping consolidation effort will be tried out later to seek the possibility of gaining transportation cost savings by the application of a reasonable way of costing.

6.2.2.2 One Sourcing Warehouse System

One sourcing warehouse system is being tried out in order to seek the possibility to gain transportation cost saving by applying warehouse consolidation concept. Warehouse consolidation is applied to reduce the total number of trucks requirement by consolidating the LTL trucks transportation triggered by each sourcing warehouse into FTL trucks transportation in a way of consolidating the number of sourcing warehouses itself.

A comparison of FTL trucks requirement number in different delivery frequency scenario between the existing two sourcing warehouses distribution system and the benchmark one consolidation sourcing warehouse distribution system is clearly displayed by the figure 6-14. The figure shows that the one sourcing warehouse system triggers more FTL trucks transportation than the current system. This happens while the LTL transportations which used to be triggered by two sourcing warehouses are being consolidated into FTL trucks transportation in the consolidated warehouse system.

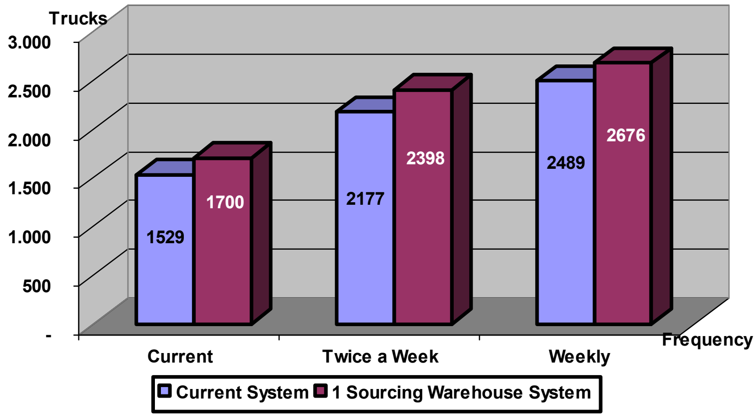

Figure 6-14 Annual Full Truck Load Transportations Requirement

Significant saving of LTL trucks numbers gained by the application of one consolidation warehouse system is clearly shown by figure 6-15. By the indication presented, it is clear that the potency of utilizing the high number of LTL trucks of the current system which sourced from two warehouses is considerably high. Just by consolidating the sourcing warehouse without doing further temporal consolidation a reduction of total LTL transportation number from 6,639 to 3,423 which accounts for a 48.4% saving can be achieved. The application of warehouse consolidation concept along with application of temporal consolidation can gain higher savings, a reduction of LTL transportation number from 6,639 to 624 which account for 90.6% saving is an indication of how powerful the total consolidation strategy can be.

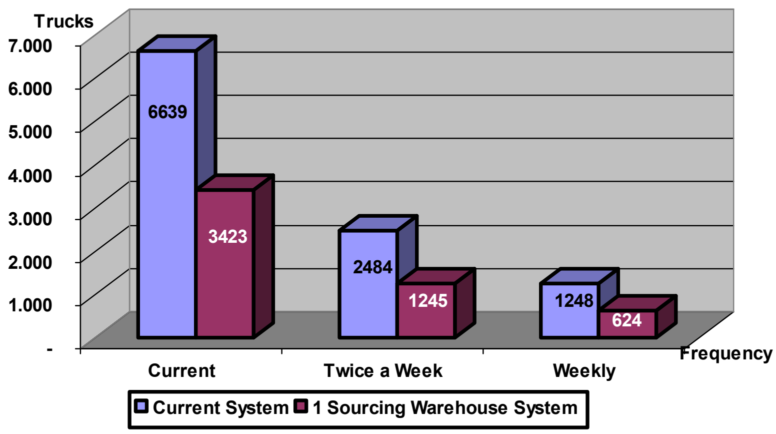

Figure 6-15 Annual "Less than Truck Load" Trucks Requirement

After discussing the increase of FTL trucks requirement and the decrease of LTL trucks requirement by applying warehouse consolidation concept in different delivery frequency scenarios, the next step is to summarize the both indications into an annual total trucks requirement chart. Figure 6-16 shows the annual total trucks requirement which is a product of summation of the LTL and FTL requirement discussed before.

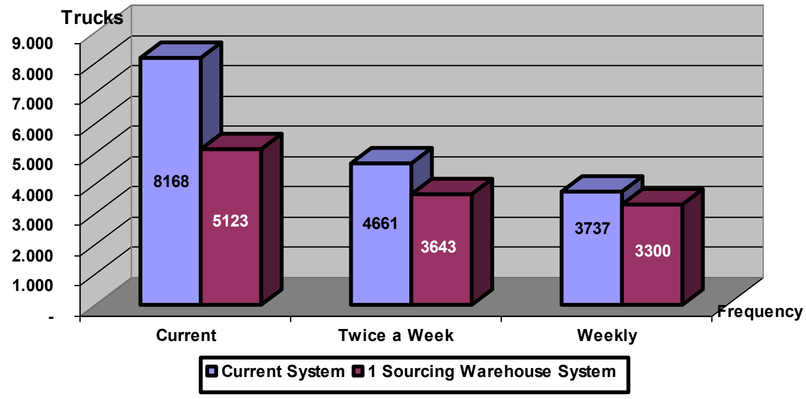

Figure 6-16 Annual Total Trucks Requirement

As shown by the figure 6-16, the biggest significant total trucks requirement difference between two systems in a specific delivery scenario exists in the daily delivery frequency setup. As the period of delivery getting longer the total trucks requirement number is decreased but the trucks requirement number difference between those systems is getting smaller. This phenomenon appears because the biggest amount of LTL trucks is already converted to FTL trucks by the application of temporal consolidation, therefore the number of LTL trucks left which can be consolidated by the warehouse consolidation concept is decreasing drastically.

In a term of total truck needs saving percentage relative to the current operation of existing system, figure 6-17 summarize the saving which can be achieved by each system in each delivery frequency scenario in percentage form. By the figure shown, a maximum saving of 59.6% of total number of required trucks relatively to the number of trucks needed by the current system can be gained by applying the warehouse consolidation concept of one sourcing warehouse in weekly delivery frequency mode.

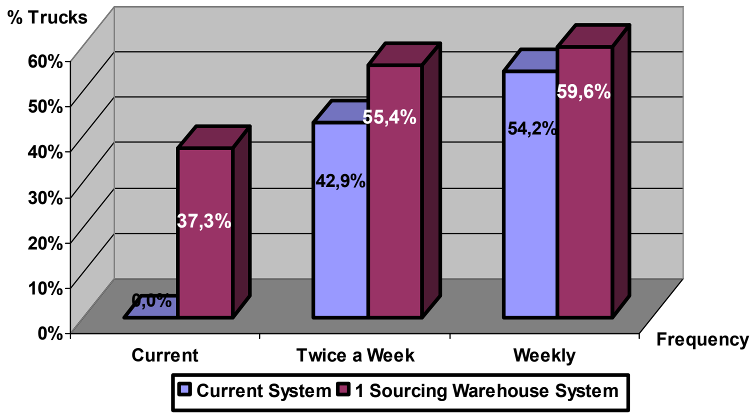

Figure 6-17 Annual Total Trucks Saving

Contradictive with the great saving potency which exists by the application of the shipment consolidation strategy, the total annual transportation cost shown in the figure 6-18 shows no improvement at all. The total annual transportation cost remains constant consider less the applied delivery frequency scenario. Opel should pay the same amount of transportation charge simply just because the amount of total volumetric load is constant. The number of utilized trucks does not incorporated into account. However if the shipment consolidation concept will be applied, a review of a reasonable costing system which account the truck utilization of each travel should be incorporated so that the effort of decreasing the transportation effort will be beneficial not only for the transportation company but also Opel as the hiring company.

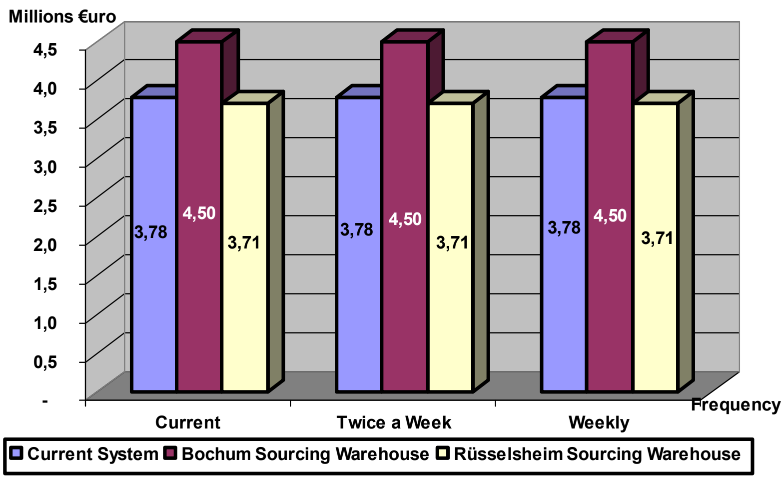

Figure 6-18 Annual Transportation Cost Expenses

Acknowledging the insensitivity of the current costing method problem, a benchmark costing method which incorporated the truck utilization value and the traveling distance for determining the transportation charge per single transport is applied. As shown by the figure 6-19, the benchmark costing method has a behavior with the same tendency as the truck use charts displayed before. Decreasing cost as the delivery period getting longer phenomena, works in rhyme with the total truck requirement charts. Therefore the benchmark costing method somehow is reflecting a more reasonable way of charging.

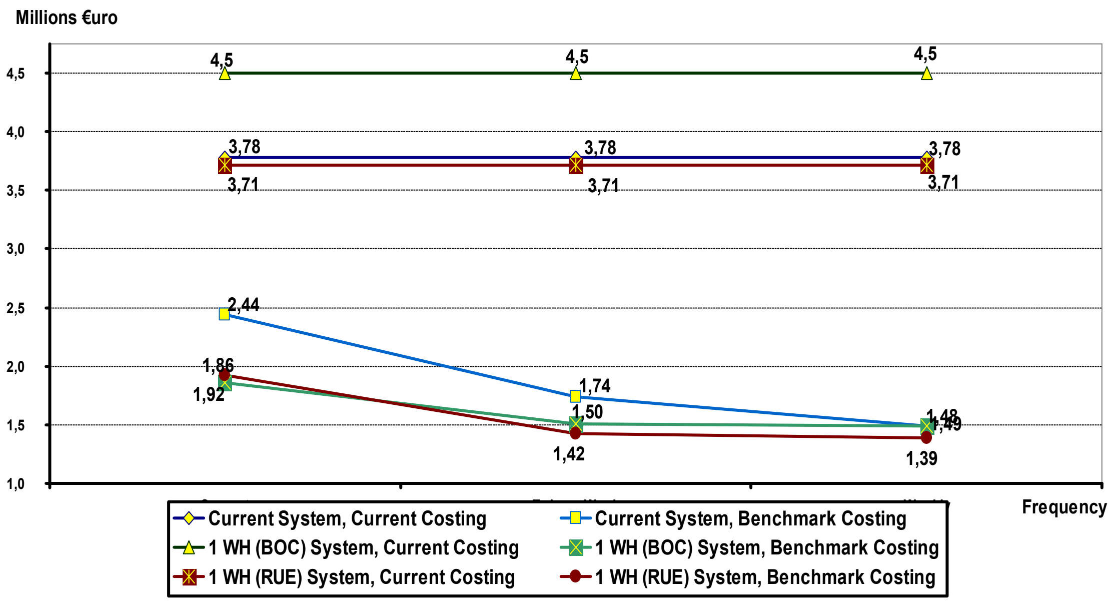

Figure 6-19 Annual Transportation Cost Comparison

However the value of the benchmark transportation cost is too small compared to the current total cost. The benchmark costing method which is imported from a non automotive industry is causing the comparison between two costing method is not going smoothly because different weighing factor of the benchmark costing method constants exists. Nevertheless, the transportation costing method which incorporates the truck utilization value and the traveling distance is considered as a better costing method than the current Load Meter based costing system in terms of reasonability of charging method.

6.3 Simulation Result Analysis

In this simulation result analysis, interpretations of the simulation result data set which is produced from the designed simulation buildings run are done. The exact parameters which have been analyzed in the historical data analysis will be also analyzed here. By the study of two dataset results gained from historical data analysis and simulation result analysis, a better perspective of the system reaction to the consolidation strategies in response to the historical dataset and to the generated random dataset can be achieved.

6.3.1 Pick-Pack-Ship Cost

Pick-pack-ship cost as one of the important element of warehousing cost which has strong relationship with the delivery replenishment activity is again analyzed in this simulation study. The behavior of PPS cost to various delivery frequency replenishment setups in different sourcing warehouse number setups is forwarded. The comparison between the results which are gained from the simulation study and the results which are gained from historical data analysis is also becoming one of the interest points in this section.

6.3.1.1 Current Distribution Network System

Pick-Pack-Ship cost analysis should be started from the analysis of number of order lines parameter since the parameter is the only governing measurement in defining the total PPS cost. The summary of the order lines parameter dataset generation done by the simulation program is shown from the values inputted in the table 6-2. At the table, the dataset which is utilized in the simulation study and the dataset which is utilized at the historical data analysis are being shown together, to ease the comparison. As shown, at the existing system configuration (two sourcing warehouses setup), the simulation study generated order lines number and the historical study order lines number is different by a value of 14.92%. This means that dataset which is generated in the simulation study triggers a lower number of ordering events. This phenomenon does not necessarily means that the total size of order volume will also be decreased, as will be shown in the upcoming transportation cost section, the total size of order volume within the analyzed period will be still the same. This two facts, low number of order lines and constant value of order volume size, produces high ordering density of the order lines exist in the simulation dataset.

Table 6.2 not only includes the order lines number comparison utilized in the historical data analysis and the one utilized in the simulation result study, the comparison of the PPS cost amount and the PPS cost saving value results calculated in each study is also presented. As can be seen at the simulation data study part, the value of PPS cost decreases from a value of 10,694,569 Euro into 6,841,472 Euro which account for 36% savings due to an adjustment of delivery frequency from the current method to the weekly method. While on the other hand at the historical data study, the value of PPS cost decreases from a value of 12,570,285 Euro into 10,463,525 Euro which account for 16.8% savings for the same adjustment.

As a remark, the big range of deviation between the simulation result study and the historical data analysis is something common, since the dataset utilized in two studies is different, one comes from historical data set and the other comes from the random data generation. However the system behavior is still the same. The system will receive PPS cost savings resulted from reduced number of consolidated order lines.

Table 6-1 Annual Transportation Cost Comparison

Lines 2WH (Order Lines)

	Simulation Dataset			Historical Dataset			Deviation		
	Rüsselsheim	Bochum	Total	Rüsselsheim	Bochum	Total	Rüsselsheim	Bochum	Total
Current	3.961.514	254.969	4.216.483	4.665.016	290.784	4.955.800	15,08%	12,32%	14,92%
Twice a Week	3.169.366	216.725	3.386.091	4.272.687	271.064	4.543.751	25,82%	20,05%	25,48%
Weekly	2.512.073	185.809	2.697.882	3.873.319	252.135	4.125.454	35,14%	26,31%	34,60%

Cost 2WH (€uro)

	Simulation Dataset			Historical Dataset			Deviation		
	Rüsselsheim	Bochum	Total	Rüsselsheim	Bochum	Total	Rüsselsheim	Bochum	Total
Current	10.062.246	632.323	10.694.569	11.849.141	721.144	12.570.285	15,08%	12,32%	14,92%
Twice a Week	8.050.190	537.478	8.587.668	10.852.625	672.239	11.524.864	25,82%	20,05%	25,49%
Weekly	6.380.665	460.806	6.841.472	9.838.230	625.295	10.463.525	35,14%	26,31%	34,62%

Savings 2WH (€uro)

	Simulation Dataset			Historical Dataset			Deviation		
	Rüsselsheim	Bochum	Total	Rüsselsheim	Bochum	Total	Rüsselsheim	Bochum	Total
Current	-	-	-	-	-	-	0,00%	0,00%	0,00%
Twice a Week	2.012.056	94.845	2.106.901	996.516	48.906	1.045.421	-101,91%	-93,94%	-101,54%
Weekly	3.681.580	171.517	3.853.097	2.010.910	95.850	2.106.760	-83,08%	-78,94%	-82,89%

Savings 2WH (%)

	Simulation Dataset			Historical Dataset			Deviation		
	Rüsselsheim	Bochum	Total	Rüsselsheim	Bochum	Total	Rüsselsheim	Bochum	Total
Current	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,00%	0,00%	0,00%
Twice a Week	15,0%	20,0%	19,7%	6,8%	8,4%	8,3%	-8,22%	-11,59%	-11,38%
Weekly	27,1%	36,6%	36,0%	13,3%	17,0%	16,8%	-13,83%	-19,62%	-19,27%

To show the simulation study results, figure 6-20 shows the graphical representations of the PPS cost behavior and PPS cost saving behavior of two sourcing warehouses system in various delivery frequency setups. From the simulation study, the potency of achieving total 3.85 Million Euro saving which accounts for 36% saving of pick-pack-ship cost is embraced. In term of percentage, this value is extremely bigger than the one achieved at the historical data analysis by 19.27% difference.

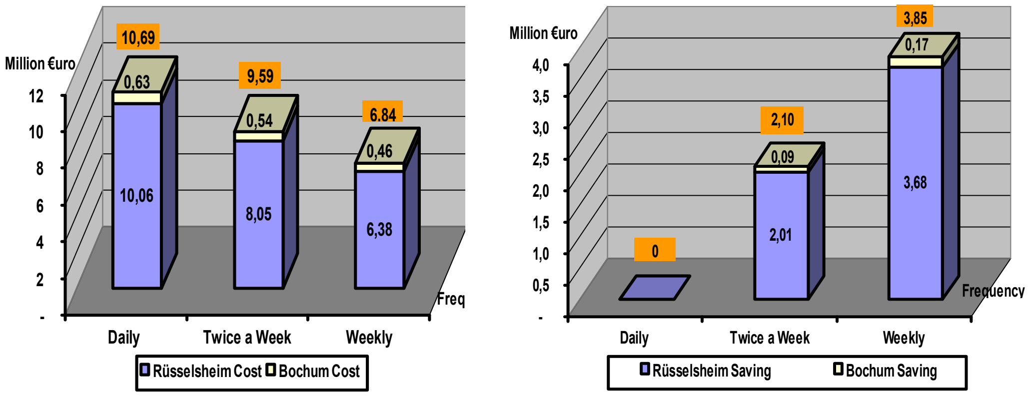

Figure 6-20 Annual Pick-Pack-Ship Cost and Saving Potency Chart

The PPS cost saving values (percentage) for each warehouse is shown in the figure 6-21. As shown, the maximum value of Germany PPS cost saving which falls in the value of 36.0% is mainly governed by Ruesselsheim saving of 36.6%. As already explained before, this phenomenon happens because Ruesselsheim warehouse is the first priority of root supply of all spare parts movement in Germany.

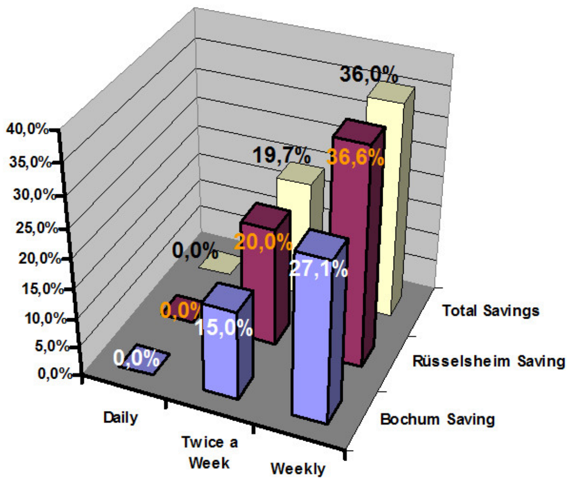

Figure 6-21 Annual Pick-Pack-Ship Cost and Saving Potency Chart

6.2.2.2 One Sourcing Warehouse System

After finish with the discussion of the two sourcing warehouse system PPS cost behavior to the delivery frequency alternatives, the discussion of one sourcing warehouse system as an implementation of warehouse consolidation concept will be presented in this section.

The try-out of one sourcing warehouse concept in the PPS cost reduction context is actually done to open the possibility of merging large number of different order lines supplied from different warehouses into smaller number of order lines which is supplied from only one sourcing warehouse in a case the originated different sourcing warehouses share the same stock. However, the fact that two different sourcing warehouses are assumed to supply different parts eliminates the possibility of reducing the number of order lines. However this concept is still applied due to its advantages to the transportation cost saving effort.

One sourcing warehouse system of PPS cost performance is displayed by table 6-3. A PPS cost performance comparison between one sourcing warehouse system which utilizes Ruesselsheim warehouse or Bochum warehouse and the existing system of two sourcing warehouse is clearly showed. As also done before, the preceding results of historical data analysis is also attached as a comparison.

Table 6-2 Pick-Pack-Ship Cost Comparison

Dataset	Delivery Frequency	1 Warehouse System (RUE)	1 Warehouse System (BOC)	Existing System
Simulation Dataset	Daily	10.456.877,84	10.709.866,82	10.694.568,68
	Twice a Week	8.397.505,68	8.600.671,14	8.587.667,64
	Weekly	6.690.747,36	6.852.620,28	6.841.471,74
Dataset	Delivery Frequency	1 Warehouse System (RUE)	1 Warehouse System (BOC)	Existing System
Historical Dataset	Daily	12.290.384,00	12.587.732,00	12.570.284,96
	Twice a Week	11.268.502,48	11.541.127,54	11.524.863,70
	Weekly	10.231.125,92	10.478.653,16	10.463.525,06
Dataset	Delivery Frequency	1 Warehouse System (RUE)	1 Warehouse System (BOC)	Existing System
Deviation	Daily	-1.833.506,16	-1.877.865,18	-1.875.716,28
	Twice a Week	-2.870.996,80	-2.940.456,40	-2.937.196,06
	Weekly	-3.540.378,56	-3.626.032,88	-3.622.053,32

The PPS cost in response of different delivery frequency scenario chart and in response of two different distribution system setups is displayed by the figure 6-22. As indicated at the historical data analysis, by appointing Bochum warehouse as the only consolidated sourcing warehouse will give the most expensive PPS cost due to its expensive PPS constant, in opposite appointing Ruesselsheim warehouse as the consolidation warehouse will give the cheapest PPS cost also due to its PPS constant.

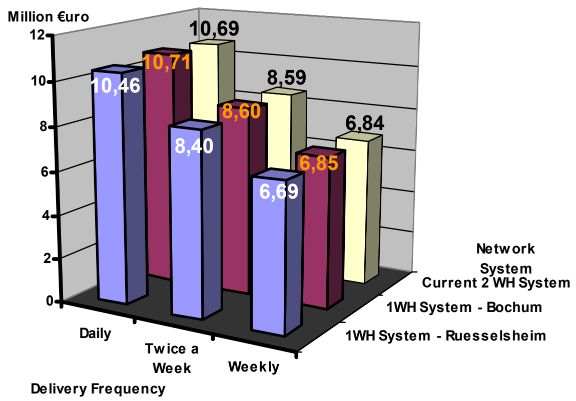

Figure 6-22 Annual PPS Cost - Delivery Frequency – Network System

Figure 6-23 shows the PPS cost amount of saving (%) relatively to the current system PPS cost level. Just like indicated by the historical data analysis, the maximum saving value of 37.3% appears by utilizing Ruesselsheim sourcing warehouse as the only sourcing warehouse within a weekly delivery period scenario. Again, corresponding to the PPS cost constant, in the minimum saving level bound point of view, the utilization of Bochum warehouse as the only sourcing warehouse within the current delivery frequency scenario leads to a deficit of PPS costing charge of 0.1%.

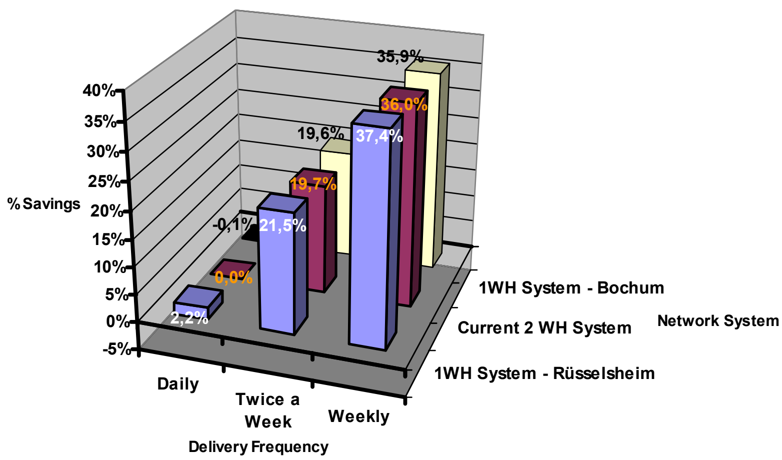

Figure 6-23 Annual PPS Cost Savings - Delivery Frequency – Network System Chart

6.3.2 Transportation Cost

Transportation cost as the backbone element of distribution cost parameter will again be analyzed by the application of simulation study. As already done in the historical data analysis, the important building parameters which influence the value of the end transportation cost will be presented here, just like the exact structure of explanation that already have been used. Here, the effect of using random dataset generated from the historical data is presented. Like before, some deviations will appear due to the uncertainty value which is added to the random dataset causes the end result will not be exactly the same as the historical data analysis. However the tendency of the system's behavior should be convergent

6.3.2.1 Current Distribution Network System

In discussing transportation cost, the first step that should be done is again defining the basic transportation cost parameter. As done before the amount of annual load meter will be the first parameter to be defined. As shown by the figure 6-20, the load meter dataset generated by simulation program is presented. The total annual load meter generated by the simulation is rather has the equal value to the historical dataset. With a negligible deviation of less than 0.0009%, the generated simulation dataset reflects the historical dataset well.

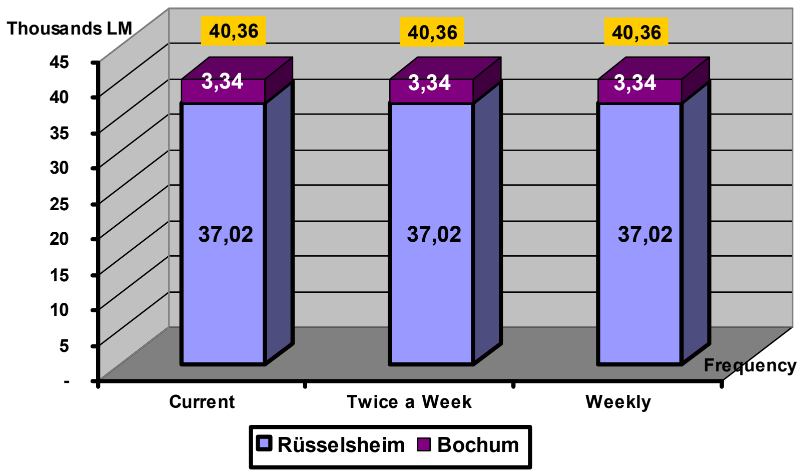

Figure 6-24 Generated Annual Load Meters Requirement Data

Jumping into the combination of the number of full trucks value and less trucks value which build the end number of total trucks requirement, table 6-1 shows the composition of the annual trucks requirement of the simulation result data set. As done before, not only the simulation result dataset which is presented but also the historical analysis result dataset also presented in the table. As can be seen, considerable deviations are existing especially at the less than truck load composition. Deviations of LTL ranging from 8.33% to -5.21% exist due to the randomness factor which is generated by the simulation. However the total trucks requirement number does not have deviation values more than 1%.

Table 6-3 Trucks Requirement Composition Result Dataset Comparison

	Simulation Dataset			Historical Dataset			Deviation		
	FTL	LTL	Total	FTL	LTL	Total	FTL	LTL	Total
Current	1.526	6.086	7.612	1.529	6.639	8.168	0,20%	8,33%	6,81%
Twice a Week	2.174	2.491	4.665	2.177	2.484	4.661	0,14%	-0,28%	-0,09%
Weekly	2.452	1.313	3.765	2.489	1.248	3.737	1,49%	-5,21%	-0,75%

To get a better picture of the system performance, figure 6-21 shows the simulation results of annual truck requirement performance of the simulated existing system distribution network at the defined delivery frequency scenarios. By the indicated picture, the fact that the dataset result generated from simulation has the same tendency as the historical data analysis is being forwarded. The only significant difference between the simulation result and the result expelled from the historical data analysis is only the composition of LTL number stated in the table before.

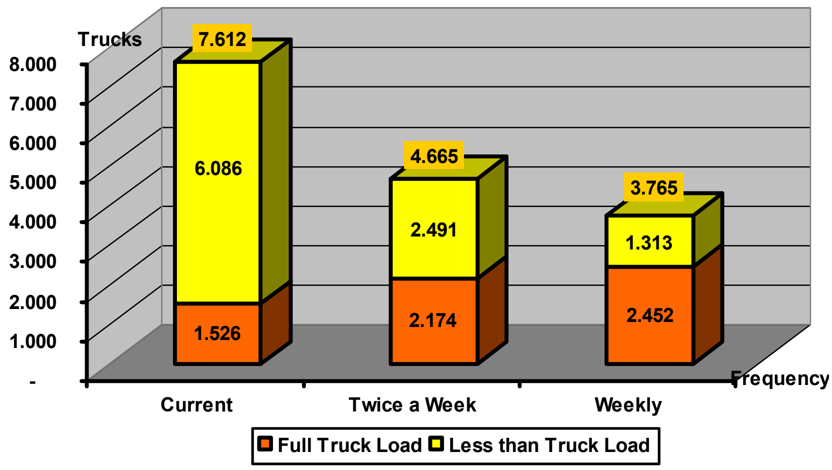

Figure 6-25 Simulated Annual Total Trucks Requirement

Having the annual trucks requirement defined, the next step is to calculate the trucks requirement savings which can be derived easily from the annual trucks requirement value. Again, the comparison between the trucks savings result which is gained from the historical data analysis and the simulation study is presented in Table 6-2. As shown, there some deviation exist which results from the random uncertainty factor added in the simulation dataset generation.

Table 6-4 Trucks Requirement Savings Result Dataset Comparison

	Simulation Dataset		Historical Dataset		Deviation	
	Quantity	Percentage	Quantity	Percentage	Quantity	Percentage
Current	-	0,0%	-	0,0%	-	-
Twice a Week	2.947	38,7%	3.507	42,9%	560	4,22%
Weekly	3.847	50,5%	4.431	54,2%	584	3,71%

Figure 6-22 embodies the trucks requirement savings value of the simulated existing system in a chart. As shown by the figure, gradually a truck use saving of 38.7% and 50.5% can be achieved by applying each temporal consolidation strategy of twice a week delivery frequency and weekly delivery frequency replenishment. These values actually lower than the values shown at the historical data analysis; however a lower bound value of the trucks use saving can be adopted from this simulation results.

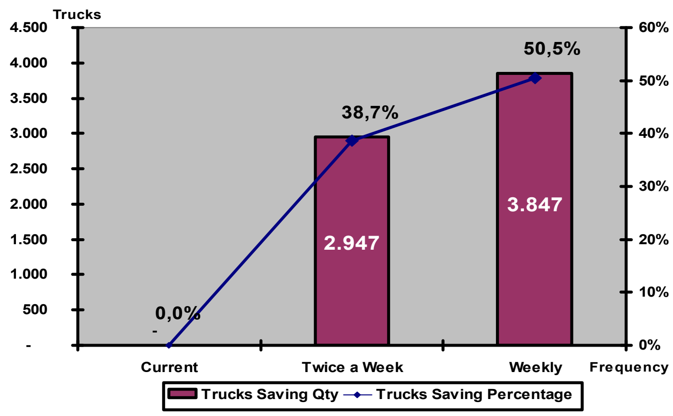

Figure 6-26 Simulated Annual Total Trucks Savings

From the discussion of the trucks use saving potency, the transportation cost value as an implementation of the transportation effort cost is the next topic. As already implied by the historical data analysis, current costing method does not consider the truck utilization factor. Therefore, the total truck use savings potency investigation which has been done is useless since the only measuring parameter is the total volume transported not how effective the value of the volume being transported.

As can be seen from the figure 6-13, the annual transportation cost value falls under the exact number as the one appears at the historical data analysis due to the similarity of load meter level. Eventhough the simulated dataset results imply less LTL number, the current costing method does not charge less for less transportation cost. The application of benchmark costing method for the existing system will be presented at the end of the one sourcing warehouse study section.

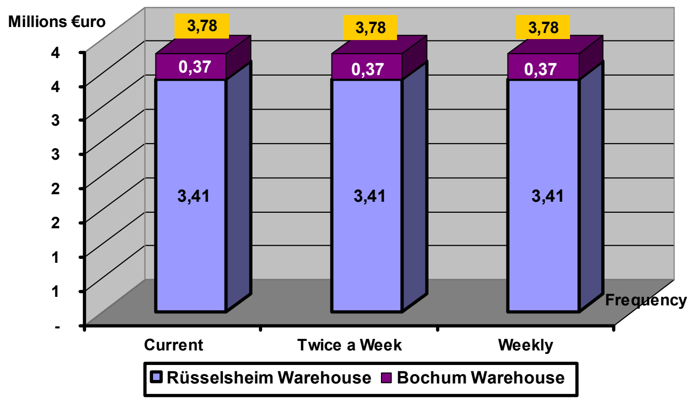

Figure 6-27 Simulated Annual Transportation Cost Expenses

6.3.2.1.1 One Sourcing Warehouse System

One sourcing warehouse as an implementation of warehouse consolidation shipment concept has not created big impact for the PPS Cost since the type of parts which are supplied by both warehouses is assumed to be unique. However, the warehouse consolidation is expected to reduce the transportation effort significantly. Therefore, the impact of the application of warehouse consolidation to the transportation cost will be discussed here.

As done before, the composition of the LTL and the FTL trucks numbers of the simulated system of one sourcing warehouse network are presented by the table 6-3 below. By the indication shown by the table, the numbers of FTL and LTL which build the total number of trucks requirement are clearly stated. The historical dataset result achieved before is also being presented in the table to get a clear comparison of the result which is gained by the simulation method and the historical data analysis method.

Table 6-5 Trucks Requirement Composition Result Dataset Comparison

	Simulation Dataset			Historical Dataset			Deviation		
	FTL	LTL	Total	FTL	LTL	Total	FTL	LTL	Total
Current	1.701	3.066	4.767	1.700	3.423	5.123	-0,06%	10,43%	6,95%
Twice a Week	2.389	1.260	3.649	2.398	1.245	3.643	0,38%	-1,20%	-0,16%
Weekly	2.649	695	3.344	2.676	624	3.300	1,01%	-11,38%	-1,33%

Taking the historical dataset as a basis, the historical dataset analysis result shows greater improvement number better than the simulation method. As shown, at the historical dataset the total truck number decreases from 5.123 to 3.300 totaled 1.823 points which accounts for 35.6%. On the other hand at the simulation study result, the total trucks requirement reduction of 29.9% appears. This lower reduction value of the simulation study is caused by the initial dataset condition set up. As shown, at the historical dataset, the current number of existing system of total trucks requirement falls on the number of 5,123 while on the simulation data study the initial total trucks requirement number falls on the number of 4,767 due to different shuffle of dataset. Nevertheless the trucks number requirement of the consolidated weekly system is rather fall at the same point. The truck requirement numbers are 3,344 trucks for the simulation system and 3,300 trucks for the historical data analysis. This phenomenon shows that the consolidated system has a convergence of system performance values regardless what the initial conditions are.

Having the number of the total number of trucks defined along with the deviation gained compared to the results of historical data analysis, building a representation of the annual total trucks requirement of the simulated one sourcing warehouse system is demanded. For comparison purpose, an extra dataset result of the simulated existing two sourcing warehouses system is embedded. Therefore figure 6-24 is being forwarded to get graphical insight of how do these two systems will perform in different delivery frequency scenarios setup.

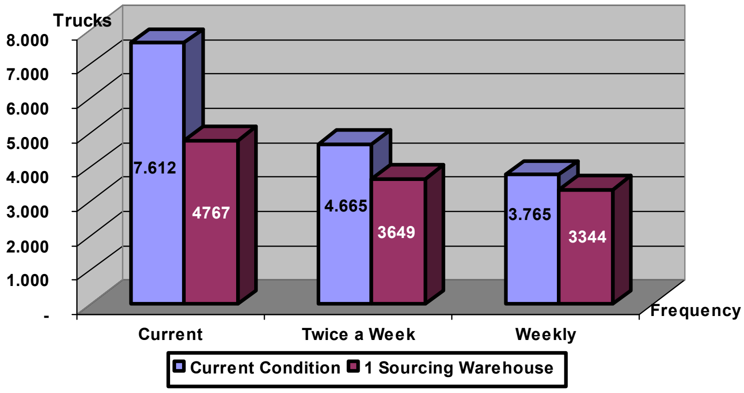

Figure 6-28 Simulated Annual Total Trucks Requirement

Stepping in to the topic of savings, the amount of potential savings which can be gained by the application of a new system is always a topic of interest. Therefore as already done before, a simple data conversion for switching the total trucks requirement number into savings numbers is also done. Table 6-4 shows the saving numbers which can be gained by switching the existing system of two sourcing warehouses into one sourcing warehouse system. The simulation results dataset is presented again along with the results dataset gained from historical data analysis for comparison. As discussed before, due to the initial condition setups the saving quantity that can be gained from simulation study method is lower than the one produced by historical data set. A massive trucks requirement number saving of 89.5% can be gained by the application of warehouse consolidation in the weekly delivery frequency setup to the existing ongoing system.

Table 6-6 Annual Trucks Requirement Saving Comparison Dataset

	Simulation Dataset		Historical Dataset		Deviation	
	Quantity	Percentage	Quantity	Percentage	Quantity	Percentage
Current	2.845	59,7%	3.045	59,4%	200	-0,24%
Twice a Week	3.963	83,1%	4.525	88,3%	562	5,19%
Weekly	4.268	89,5%	4.868	95,0%	600	5,49%

Figure 6-25 exists as a representation of the savings calculation result presented by the table 6-4 before. As graphically shown, the one sourcing warehouse system will gain more trucks requirement number saving better than the existing system which utilizes one sourcing warehouse. A massive maximum number of 4,268 of trucks requirement reduction which accounts for 89.5% savings can be gained by the consolidated warehouse system.

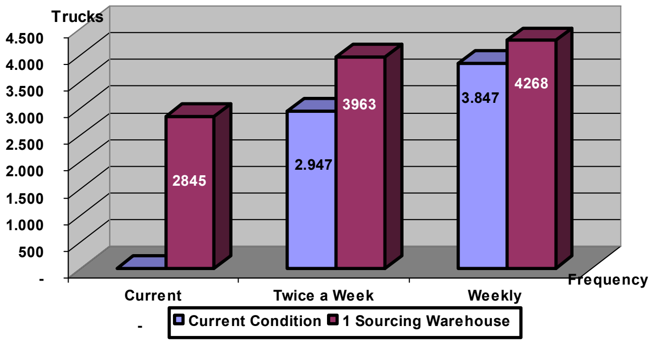

Figure 6-29 Simulated Annual Total Trucks Savings

Having the trucks requirement saving number defined, the total transportation cost reduction is something to be expected. As discussed many times, in fact the massive trucks use saving which can be gained by the proposed systems is somehow not supported by the existing costing method. By applying the existing costing method the number of transportation cost which has to be paid is somehow constant regardless the trucks use saving potency exist. Therefore the one who will take the main benefits of the application of the proposed system is definitely the third party logistic transportation company because they will receive the same amount of money for the massive decreasing transportation expenses.

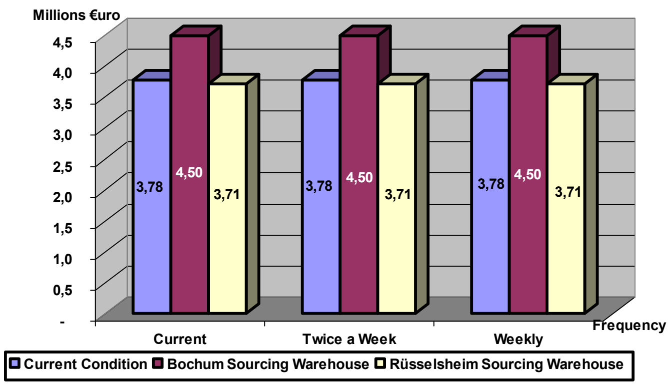

Figure 6-30 Simulated Annual Transportation Cost Expenses

Acknowledging the unusual interaction between the big numbers truck savings potency and the constant number of transportation cost value, as done before, a benchmark transportation costing method which incorporated the truck utilization parameter and the traveling distance into the charge definition is applied. A detailed transportation cost numbers which reflects how each costing method impacts the transportation cost number in different consolidation strategy applied is listed at the table 6-5. By the table, a comparison of the simulation result dataset and the historical analysis results dataset exist to get a better insight of the total transportation cost behavior to each charging method.

Table 6-7 Annual Transportation Cost Comparison Dataset

Result Dataset	Delivery Frequency	Current Costing Method			Benchmark Costing Method		
		Existing System	1 Warehouse System (BOC)	1 Warehouse System (RUE)	Existing System	1 Warehouse System (BOC)	1 Warehouse System (RUE)
Simulation	Current	3.778.007,74	4.499.852,76	3.712.882,99	2.099.980,12	1.831.157,73	1.744.847,94
	Twice a Week	3.778.007,97	4.499.852,76	3.712.882,99	1.740.695,29	1.505.338,00	1.421.682,29
	Weekly	3.778.007,96	4.499.852,76	3.712.882,99	1.484.973,46	1.487.982,38	1.389.438,45
Historical	Current	3.778.034,65	4.499.884,46	3.712.909,15	2.443.083,94	1.858.937,22	1.920.853,82
	Twice a Week	3.778.034,65	4.499.884,46	3.712.909,15	1.739.038,96	1.504.190,43	1.420.540,17
	Weekly	3.778.034,65	4.499.884,46	3.712.909,15	1.484.973,46	1.485.576,23	1.385.732,35
Difference	Current	0,00%	0,00%	0,00%	14,04%	1,49%	9,16%
	Twice a Week	0,00%	0,00%	0,00%	-0,10%	-0,08%	-0,08%
	Weekly	0,00%	0,00%	0,00%	0,00%	-0,16%	-0,27%

Despite the fact that the benchmark costing method constants values are being taken from different type of field other than the spare part distribution field, the benchmark costing method indicates a decreasing total cost trend as the consolidation effects are getting stronger. Eventhough further study is needed to determine the exact costing constant number, this indication is important to show that the benchmark costing method template exists as a better and more reasonable charging method. The benchmark costing method is sensitive of the truck utilization factor and the distance parameter. Both parameters reflect the amount of transportation effort that has to be invested.

Back to the comparison of the system's behavior corresponding to the costing method alternatives topic, the graphical representation of the transportation cost behavior in the application of existing costing method and the benchmark costing method in different consolidation strategy alternatives is being forwarded by the figure 6-19 as the closing chart. As done in the historical data analysis, the tendency of each costing method is the one to be learned, not the comparison of the number.

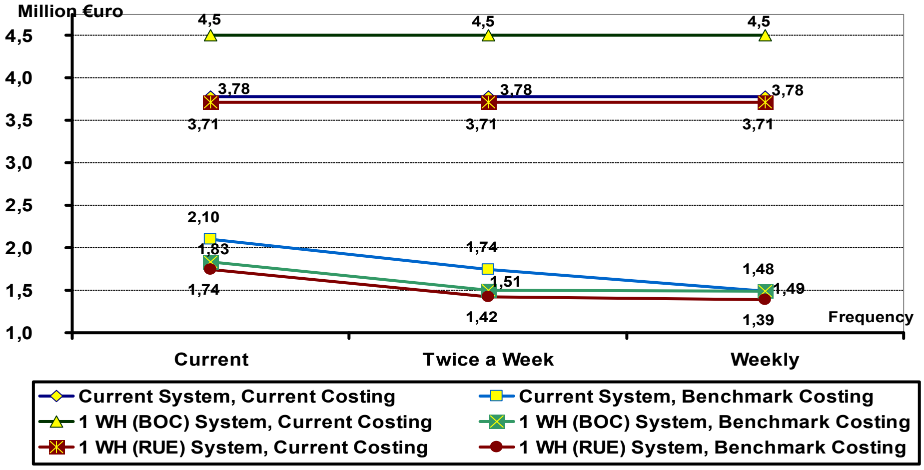

Figure 6-31 Annual Transportation Cost Comparison

References

Aldarrat, H. (2007). *Modeling and Controlling of an Integrated Distribution Supply Chain: Simulation Based Shipment Consolidation Heuristics* (Doctoral Dissertation Draft, Universität Duisburg-Essen, Fakultät für Ingenieurwissenschaften» Maschinenbau und Verfahrenstechnik» Institut für Produkt Engineering).

Aldarrat, H., & Noche, B. (2007). LDNST: A Prototype Supply Chain Simulation Tool for Evaluating the Supply Chain Distributing Strategies.

Banks, J. (1999). Introduction to simulation. In *Simulation Conference Proceedings, 1999 Winter* (Vol. 1, pp. 7-13). IEEE.

Banks, J., Carson, I., Nelson I., & Nicol, DM. (1999), *Discrete-Event System Simulation*. Prentice Hall.

Ballou, R. H. (2004). *Business Logistics/ Supply Chain Management: Planning, Organizing, and Controlling the Supply Chain*. Pearson Education.

Lapierre, S. D., Ruiz, A. B., & Soriano, P. (2004). Designing distribution networks: Formulations and solution heuristic. *Transportation Science*, *38*(2), 174-187.

Seila, A. F. (2004). Spreadsheet Simulation. In *Proceedings of the 36th conference on Winter simulation* (pp. 41-48). Winter Simulation Conference.

Shannon, R. E. (1998). Introduction to the Art and Science of Simulation. In *Proceedings of the 30th conference on Winter simulation* (pp. 7-14). IEEE Computer Society Press.