



MSc in Business Administration

Distribution network design:
The case of Hella GmbH & Co. KGaA

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Abstract

This thesis researches the application of different quantitative models to solve warehouse location problems in distribution network design. To find out which quantitative approaches are preferred by decision-makers at the case company, a focus group regarding strengths and weaknesses of optimization and simulation models is conducted. Based on the result of the focus group a two-step model approach is preferred by the decision-makers, where an optimization model is followed up by a simulation model.

The center of gravity approach is the chosen optimization model for this research. The outcome gives an indication on where the new possible warehouse location should be located based on the location of the customers and their demands. A static, deterministic and discrete-time simulation approach is chosen to build an as-is model as close to reality as possible and then run the simulation for the new warehouse location by changing the input parameters of the model accordingly.

This two-step model approach decided upon by the participants of the focus group allows for the combination of strengths and the mitigation of weaknesses of the separate approaches.

Overall, the outcome of this research can be used for future decisions in distribution network design at the case company, as well as in other cases, to improve existing distribution networks.

Keywords: *Distribution network design, supply chain management, warehouse location, simulation, optimization*

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This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature of any degree. This thesis is the result of my own investigations, except where otherwise stated. Other sources are acknowledged by giving explicit references. A bibliography is appended.

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Abbreviations

AM	Aftermarket
CEP	Courier Express Parcel
COG	Center of gravity
DIFM	Do it for me
DIY	Do it yourself
EMEA	Europe Middle East Asia
ES	External supplier
EXW	Ex Works
FCA	Free Carrier
FTL	Full truckload
GE	Business division Electronics
GH	Business division Aftermarket and Special Applications
GL	Business division Lighting
HD	Hella Distribution GmbH
HHU	Hella Hungary / Hella Hungary
HCZ	Hella CZ, s.r.o. / Hella Czech
HPL	Hella Poland / Hella Poland
HIT	Hella S.p.A. / Hella Italy
HES	Manufacturas y Accesorios Electricos S.A. / Hella Spain
HDK	Hella A/S / Hella Denmark
HNL	Hella Benelux BV / Hella Netherlands
HLGB	Hella Ltd. / Hella Great Britain
HFR	Hella S.A.S. / Hella France
HKG	Hella GmbH & Co. KGaA / Hella Germany
IAM	Independent Aftermarket
JV	Joint venture
LTL	Less than truckload
PC	Production company
SC	Sales company
SA	Special Applications
WD	Wholesale Distribution
WLP	Warehouse Location Problem
WP	Garage equipment

1 Introduction

In recent years logistics has become one of the main pillars of businesses. Without logistics and the distribution of goods and services, customers would not receive their goods at the right time, at the right place, in the right quantity and in the right quality (Arnold, Isermann, Kuhn, Tempelmeier, & Furmans, 2008).

To stay competitive in nowadays global business world, companies have to currently improve their businesses. Logistics have always been looked at as a service that does not bring any additional value to the customer and only production processes have been looked at to improve the overall processes and costs. However, by improving logistics processes not only the cost of getting to the final product can be decreased, but also the service levels being offered to the customer can be increased. By doing so competitiveness can be improved and the overall business strengthened (Sandberg, Kihlén, & Abrahamsson, 2011).

The main aspect of this research is distribution network design. When looking for a new warehouse location, qualitative methods and quantitative models are commonly used approaches (Klose & Drexl, 2005). However, a decision on a method or model must be taken in every single case, taking the specifics of the situation into account. Therefore, the question regarding this choice is one that is often asked in distribution network design. The focus for this research is put on two commonly used quantitative warehouse location models: optimization and simulation. A focus group is conducted with the viewpoint of finding out the strengths and weaknesses of those quantitative models. Following up on that, a decision is taken regarding the models used in this research and a new warehouse location is decided upon to identify possible changes in logistic costs and customer service level. To solve the commonly asked question, the research of the quantitative models is carried out at the case company Hella GmbH & Co. KGaA (hereinafter called “Hella”). There are two research questions set for this thesis.

“Which strengths and weaknesses do decision-makers see in optimization and simulation in terms of warehouse location problems?”

“How can optimization and simulation as quantitative models be used to design Hella’s distribution network in France?”

The first question is supposed to identify the preference of the decision-makers towards the chosen quantitative approaches with the aim to know more about the future use of

those approaches in a business setting at the case company. The second question aims at identifying the best possible distribution structure for Hella in France by using the quantitative models to solve the warehouse location problem while fulfilling the customers' service level and keeping end-to-end costs low.

First of all, the following literature review takes a look into supply chain management and warehouse location models. Efficient and responsive supply chains are displayed and the role of distribution in the supply chain is shown. Different types and concepts of shipments are differentiated and designing distribution networks is presented as one of the key tasks in supply chain management. Furthermore, a selection of qualitative methods and quantitative models of warehouse location are going to be introduced and distinguished.

Since this thesis is a one company case study, the case company Hella GmbH & Co. KGaA is presented. This includes the overall business, the corporate logistics department and the business division Aftermarket and Special Applications. Afterwards, Hella's business in France is introduced, by looking at the supply chain, customers and logistics costs.

The next chapter introduces the focus group, which is chosen as the basis for research on the strengths and weaknesses of optimization and simulation by the decision-makers. This chapter is the foundation for the decision upon specific optimization and simulation models for the analysis. The analysis part of the thesis starts with an overview of the analysis approach. Based on the outcomes of the focus group the specific quantitative optimization and simulation approaches for further research are chosen. Then the costs for inbound and outbound transports as well as the warehousing costs are analyzed to be able to use optimization and simulation approaches on the distribution network for Hella in France. The service level offered to the customer is another criterion taken into consideration before executing the warehouse location models for Hella.

Following is a discussion on the research and aspects that were not included in this thesis but should be taken into consideration when taking this thesis as a basis for an actual management decision.

The research ends with a conclusion and recommendations, which not only give recommendations for Hella on how to get closer to the best possible distribution structure, but also bring this research into connection with other literature and show how it takes another look at the two models presented than a lot of the other literature did so far.

2 Literature review

This literature review is supposed to give an overview over the topics that are researched for the purpose of this thesis. There are two main subjects that are researched to be able to analyze and design the distribution network for Hella in France. On the one hand supply chain management is looked at with further research on efficient and responsive supply chains, the role of distribution in supply chain management and the design of distribution networks. Also, different shipment types and concepts are introduced. On the other hand, warehouse location models are looked at. Qualitative methods and quantitative models are categorized and chosen examples for optimization and simulation models presented.

2.1 Supply Chain Management

“A supply chain consists of all parties involved, directly or indirectly, in fulfilling a customer request. The supply chain includes not only the manufacturer and suppliers, but also transporters, warehouses, retailers, and even customers themselves.” (Chopra, 2010) Satisfying customer needs is one of the main purposes of any supply chain, while generating profit for itself in the process. Not only the movement of goods from suppliers to manufacturers and products from manufacturers to customers, but also information and fund flows are part of the supply chain. An exemplary supply chain may consist of supplier, manufacturer, distributor, retailer and customer. However, not each of those stages must be present in a supply chain (Chopra, 2003, 2010).

Looking at a general supply chain two types of transports can be identified like seen in Figure 1. The first one is inbound transports, which transport the goods from the supplier to the manufacturer. Those transports bring materials into the company. The second one is outbound transports, which transport the finished goods from the manufacturer to the customer. Outbound transports bring materials out of the company (Scheer, 1994).



Figure 1 Inbound and outbound transports

According to Chopra (2010), when deciding upon a supply chain, the three main phases are: supply chain design, planning and operation. In the first phase, which is called supply chain design phase, companies decide upon their supply chain structure for the next several years. Outsourcing of parts of the supply chain is an example of one of those

2 Literature review

strategical decisions in the supply chain design phase. The second phase, supply chain planning, has a horizon of about one year. Planning actions include for example decisions on which plants are going to be supplied from which supplier within the supply chain, which was designed in the first phase. The last phase, supply chain operation, has a weekly or even daily horizon and includes decisions made by companies regarding individual customer orders.

Two of the main process views of supply chains are the cycle view and the push/pull view. The cycle view, as seen in Figure 2, is mostly used in the supply chain operation phase, since the supply chain is divided into a series of cycles, which are located at the interfaces within the supply chain (Chopra, 2010).

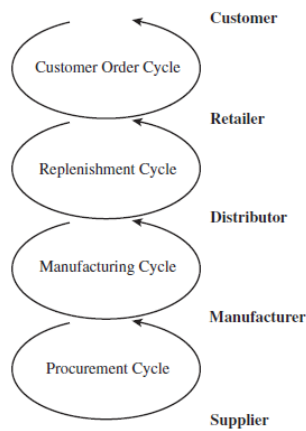


Figure 2 Cycle view of a supply chain

The push/pull view however, shown in Figure 3, is considered when strategic decisions have to be made, since it differentiates between the initiation of processes in response to a customer order (pull) or in anticipation of a customer order (push) (Chopra, 2010). Often the push/pull boundary is represented by a warehouse, which can be seen as the decoupling point, since it decouples the customer order from the production process by storing finished goods (Kundu, McKay, & de Pennington, 2008).

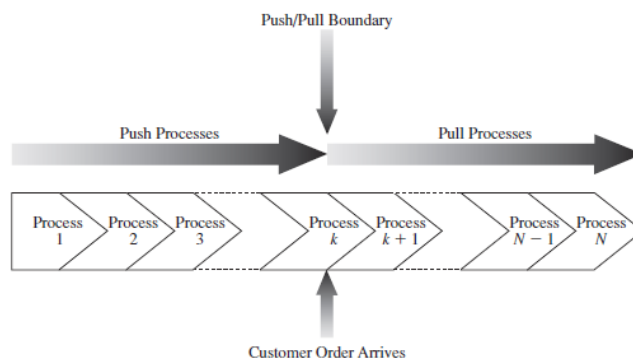


Figure 3 Push/pull view of a supply chain

2.1.1 Efficient and responsive supply chains

Figure 4 shows part of a decision-making framework for companies when considering their supply chain. The first step is looking at the competitive strategy of the company to be able to allow strategic fit with the supply chain strategy. This strategy will be decided upon regarding the needs of the customer and the necessary efficiency or responsiveness that results from that. Efficiency of the supply chain structure is looking at the supply chain cost and responsiveness is represented by customer service levels. The three main logistical drivers, that influence the decision on supply chain structure, are facilities, inventory and transportation (Chopra, 2010).

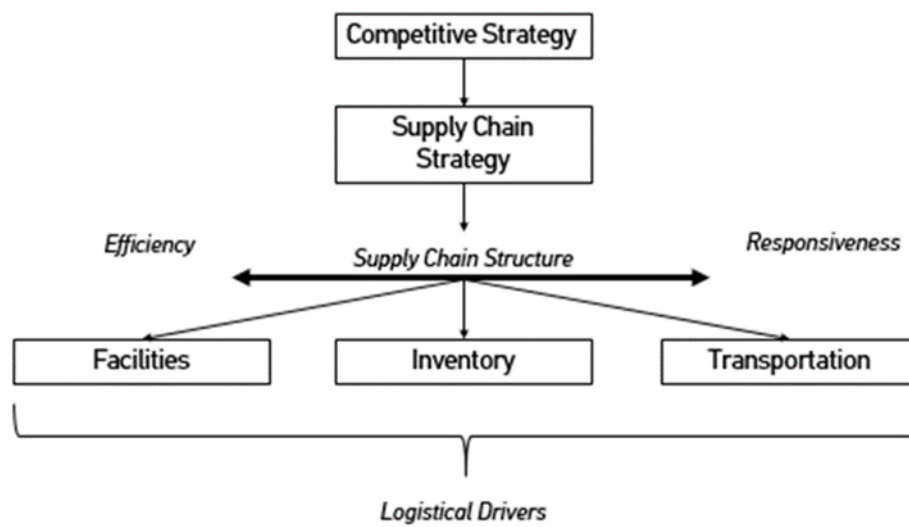


Figure 4 Supply chain decision-making framework

Facilities are production and warehousing sites along the supply chain, which either store, assemble or fabricate products. By increasing the number of warehouses responsiveness increases and higher service levels can be offered, but facility costs will increase as well. Reducing the number of warehouses can increase efficiency by decreasing facility costs (Chopra, 2010).

Inventory consists of raw materials, work in progress and finished goods within the whole supply chain. Efficiency and responsiveness can be heavily impacted by choices regarding inventory (Chopra, 2010). Efficiency can be reached by having a central warehouse which eliminates keeping the same goods in stock at different warehouse locations. By focusing on regional warehouses responsiveness can be increased, since the stock is closer to the customer and a higher service level can be offered.

Transportation is the movement of those inventories from one stage of the supply chain to the next one. A high level of responsiveness can be reached by using parcel

services, which satisfy higher service levels by offering next or even same-day deliveries. However, this increase in responsiveness brings an increase in cost as well (Chopra, 2010). Efficiency can be increased by using full truckloads to reduce the transportation costs, however, at the same time responsiveness might decrease.

To be able to decide upon a supply chain strategy the needs of the customer have to be analyzed. A supply chain can either be efficient by supplying demand at the lowest possible cost or responsive by responding quickly to customer demand (Chopra, 2010). Further characteristics for efficient and responsive supply chains can be seen in Table 1 below.

	Efficient supply chains	Responsive supply chains
Primary goal	Supply demand at the lowest cost	Respond quickly to demand
Inventory strategy	Minimize inventory to lower cost	Maintain buffer inventory to deal with demand/supply uncertainty
Lead-time strategy	Reduce, but not at the expense of costs	Reduce aggressively, even if the costs are significant
Supplier strategy	Select based on cost and quality	Select based on speed, flexibility, reliability and quality

Table 1 Characteristics for efficient and responsive supply chains

2.1.2 Role of distribution in the supply chain

Distribution network design as the first step of deciding upon a supply chain can be divided into two phases. The first phase visualizes the broad structure of the supply chain network. In this phase the decision on how many stages the supply chain will have and what role each of them is going to have is taken. The second phase goes into further detail by defining specific locations, capabilities, capacities and the allocation of demands (Chopra, 2010).

Moving and storing processes from the supplier stage to the customer stage of any supply chain can be referred to as distribution. It is present between the interfaces of the supply chain. Suppliers move raw materials and components to manufacturers on the next stage of the supply chain as well as manufacturers moving finished products to the end consumer. Since distribution affects not only the supply chain costs, but also has direct impact on the customer value, it is seen as a key driver of a firm's overall profitability (Chopra, 2003, 2010).

There are several distribution transport opportunities when thinking about moving products from the supplier stage to the customer stage in a distribution network. When looking at the transports in designing distribution networks, there has to be differentiated between different types and concepts of shipments. Each shipment type, as seen in

Figure 5 (FreightCenter, 2018), has specific characteristics regarding shipment size, duration and cost. According to the shipment type, the forwarder offers rate sheets, which show the price for a shipment regarding specific characteristics. The shipment types being looked at for further use in the course of this research are: full truckload (FTL), less than truckload (LTL), courier express parcel (CEP).

Full truckload

An FTL transport is characterized by a full truck filled up with goods combined with a loading unit so they can be handled as one transport unit. The most widely spread pallets to build up loading units are the Euro-pallet (800 mm x 1200 mm) and the Industry-pallet (1000 mm x 1200 mm). In the rates of forwarders for FTL transports in the most cases more importance is given to volume over weight. Additionally, with increasing distance the price increases as well (Arnold et al., 2008).

Less than truckload

According to Arnold et al. (2008), LTL shipments are characterized by goods combined by a loading unit, which makes it able to transport it as one transport unit. Those shipments do not entirely fill up a truck and can have a weight of up to 3,000 kg. In the rates of forwarders for LTL transport mostly more importance is given to weight over volume. Additionally, increasing distance also increases the price.

Courier express parcel

CEP shipments are characterized by a relatively low dimensions and weight (of about up to 30 kg). Due to those restrictions regarding the dimensions and the weight, the forwarder can standardize the handling of those shipments, which makes it able to offer a reliable service in a short period of time (Arnold et al., 2008). By doing that, shipments can be delivered with 24 h / 48 h service, same or next day delivery. In the rates of forwarders for national CEP shipment most importance is given to weight of the shipment, however, even though with national shipments no distances are considered in most cases, international CEP shipments are mostly going to be more expensive than national ones, due to higher distances than national ones.

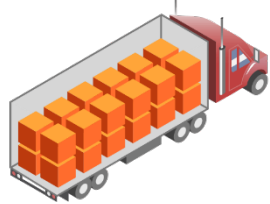


FTL	LTL	CEP
		
E.g. Schenker, Kühne + Nagel, Hartmann, Hellmann		E.g. FedEx, UPS, DHL

Figure 5 Overview of shipment types

The shipment concept shows how the transport is carried out by the forwarder. The shipment concepts introduced include direct shipment, drop shipment and cross-docking, as shown in Figure 6.

Direct shipment

A direct shipment is defined by the goods delivered from the supplier or owner of the goods directly to the customer. At the same time not only the material flow, but also the information flow is traveling from supplier to customer and vice versa (Bichler, Krohn, Philippi, & Schneidereit, 2017).

Drop shipment

A drop shipment is characterized by dropping one of the supply chain stages regarding material flow to reduce lead times and transport cost. However, the information flow including invoicing and payment still runs over all stages of the supply chain (Bichler et al., 2017).

Cross-docking

Cross-docking is the process of matching incoming freights directly with shipments on outbound trucks without storage in between the inbound and outbound process. Therefore, materials coming from different locations with the same consignee can be send together to reduce transportation costs and increase truck utilization (Bichler et al., 2017). By forwarders this technique is used mainly for LTL and CEP shipments to increase the utilization of the trucks by using hubs.

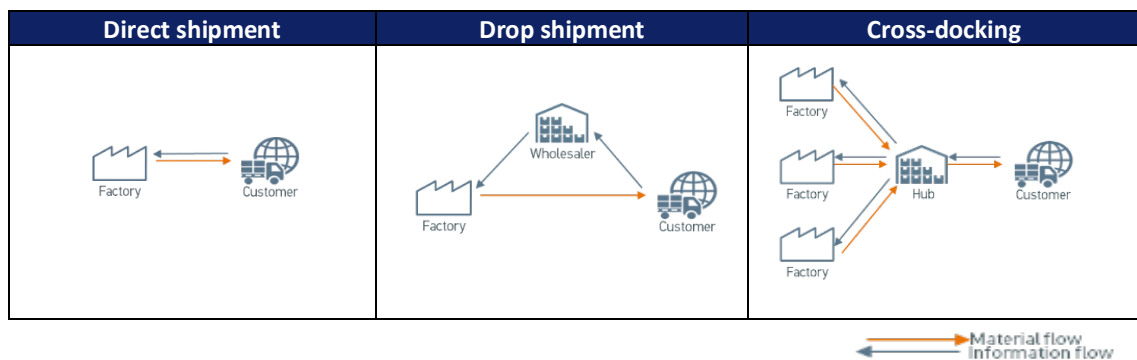


Figure 6 Overview of shipment concepts

2.2 Warehouse location models

With location decisions in distribution systems, which represent the second step in designing distribution networks, there are two subproblems to be solved optimally. The first one is the location problem, which considers the location where warehouses or hubs should be located within the network. The second one is the allocation problem, which contemplates the catchment area of the to-be located sites (Klose, 2013). For the choosing

and evaluation of location alternatives, there are qualitative method-based and quantitative model-based procedures that can be looked at when thinking about the location of warehouses, regarding different types of criteria taken into consideration. By assuming that with the change of the location of warehouses revenues will not be affected, the problem of choosing a location can be limited to the determination of the lowest cost location (Dangelmaier, 1999). According to this, the target of choosing warehouse location is the minimization of relevant costs with regard to the necessary service level of the customer and the available resources (Ballou, 1995). Figure 7 shows an excerpt of possible methods and models in distribution network design (Klose & Drexl, 2005; Law, Kelton, & Kelton, 1991).¹

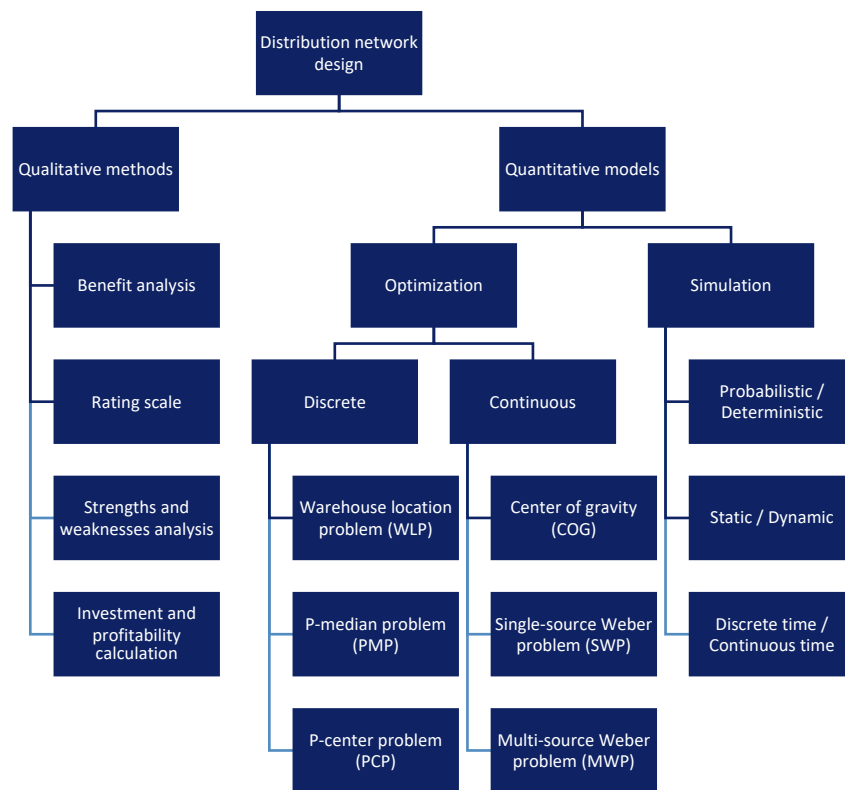


Figure 7 Overview of methods and models in distribution network design

¹ For further research regarding optimization approaches only the WLP and COG are introduced in more detail

2.2.1 Qualitative methods

The aim of qualitative methods of location optimization is choosing a location by using individual criteria specific to a company's special requirements. Most of the times non-quantifiable and non-monetary criteria are given a great importance in those methods, since the illustration in quantitative models is mostly insufficient. The assessment is taking place by using a list of criteria, which contains so-called location factors. Location factors in those cases can be the specific circumstances and conditions of locations that the company is able to use (Domschke & Drexl, 1996). These are descriptors, which describe and characterize the industrial location (Kettner, Schmidt, & Greim, 1984). According to Freyer (2007), the following Table 2 represents hard and soft location factors.

Hard location factors	Soft location factors
<ul style="list-style-type: none"> – Infrastructure – Work force – Taxes and duties – Cost structure – Public regulations – Spaces 	<ul style="list-style-type: none"> – Image – Attractiveness – Residential value – Recreational value – Cultural and sports offerings – Recreational areas – Social climate – Educational offers – Environmental quality

Table 2 Hard and soft location factors

The choice of the relevant location factors for each case is determining the profile of requirements for a location and is limiting the range of possible ones. The classification of global, regional and local location factors can be helpful, since the information procurement process can be stopped if already global factors are not fulfilled by a certain location (Kettner et al., 1984). A preferably complete capture and description of possible alternatives is decisive for the quality of the overall location decision outcome (Dangelmaier, 1999). When deciding upon location factors, the dimensions availability, quality and cost of usage should always be taken into consideration.

Since in most cases a number of different location factors are looked at, scoring models are a possibility to weigh certain location factors more heavily than others. One possibility to rate different location alternatives can be a benefit analysis. Strengths and weaknesses analysis is another method that can be of help (Kettner et al., 1984).

2.2.2 Quantitative models

Location planning is one of the main areas, where quantitative models are used in operations research. When using model-based procedures in location planning, it can be differentiated between the techniques of optimization and simulation.

Generally, simulation is the targeted experimentation on models (Heinzel & Brandt, 1999). With the help of a simulation, the different alternatives of distribution structures can be analyzed and evaluated by modification of the model parameters. This way a series of different system constellations can be tested regarding the achievable results in relation to service level and cost (Coyle, Bardi, & Langley, 1996). An optimal solution regarding the objective function can not be obtained (Schildt, 1994). However, simulations can be very helpful, when the goal is to estimate the influence of deviations, problems with quality and reliability, and other disturbances in the system (Hoppe & Conzen, 2002). Simulations demand an extensive database, to be able to reproduce the connections and interactions within the model as close to reality as possible.

In contrast, location optimization targets the determination of an optimal distribution structure, by solving the underlying model with the usage of mathematically-formal procedures. In the following, selected methods of location optimization are looked at further. The quantitative models can be classified on the basis of different criteria and characteristics (Ballou, 1995). A common way is the subdivision of the models based on the possible location of the warehouse into discrete and continuous ones. In discrete models the locations are only possible in the nodes of a network. Therefore, this model demands a network that includes distance data. In contrary to that, within continuous models the possible locations can be located at any point in the plain. Since the amount of the possible locations stays unlimited, an equivalence of the locations is assumed, and topographical constraints are disregarded. Prerequisite for the usage of one of those approaches is to know at least about the points and amount of demands, as well as the transportation costs. Often in the actual application of a quantitative procedure in a business setting, the necessary database is not available in the required quality or extent, which, as well as the unrealistic modelling, shows the problematics of the application. The room for interpretation of outcomes based on this data is accordingly big (Freichel, 2002).

2.2.2.1 Optimization

To further get into the topic of optimizations, the beforementioned subdivision by the possible locations of the warehouse is used. Therefore, discrete and continuous optimization models are distinguished further by presenting some of the most commonly used ones in warehouse location.

Discrete models

The scope for solutions by using discrete approaches is limited to a finite amount of potential new warehouse locations. Those approaches are based on a network with distance data, in whose nodes the warehouses could be located. Since in reality there is also only a finite amount of reasonable warehouse locations, and transports are handled using networks (mostly road networks), this constraint seems to be uncritical. Often mixed integer optimization models are applied (Ballou, 1995). In practice this leads to hard to solve optimization tasks with extremely long computing times, so that frequently heuristics or problem specific algorithms need to be used to solve those problems. One of the big advantages of discrete approaches is, that location dependent fixed costs and partly even non-linear cost functions can be taken into account. Furthermore, multiple supply chain stages and the capacities of the facilities can be illustrated in those models.

The objective function of the capacitated, one-stage warehouse location problem (WLP) is as follows:

$$\text{Min } C = \sum_{i=1}^I \sum_{j=1}^J c_{ij} \times x_{ij} + \sum_{i=1}^I F_i \times y_i$$

where

Min C =	minimal cost
i = 1,...,I	index of the potential warehouse locations
j = 1,...,J	index of the demand points
c _{ij} =	transportation costs of one unit of the good from i to j
x _{ij} =	amount of goods transported from i to j
F _i =	fixed cost at location i
y _i =	$\begin{cases} 1 & \text{if location i is used} \\ 0 & \text{if not} \end{cases}$

Concerning the objective functions of warehouse location problems it can generally be differentiated between minsum location problems, which minimize the average distances and the minmax location problems, which minimize the maximum distance (Klose & Drexl, 2005). Latter are mainly used for location planning of public domain buildings like fire departments. Minsum problems are of higher relevance in the private sector, since here the aspect of transportation costs has a higher impact.

Continuous models

As mentioned before when using continuous models every point in the plain is a potential warehouse location (no spherical view). The result of the optimization is a coordinate pair for every location in the plain. The assumed homogeneity of the locations results in the fact that the use of location specific costs is not possible, which can be seen as a serious deficiency of those models. Since there is no infrastructure network underlying, the inclusion of route specific transport costs is not possible, and an appropriate metric for distance measuring needs to be chosen. The distances between all of the points in the plain need to be determinable and should be able to approximate the reality. Furthermore, it is assumed that the transportation costs are proportional to the distance travelled and the amount of goods transported. Due to the restrictions mentioned, the scope of application for continuous models in an operational location planning is limited. However, in combination with strategical considerations the findings of those models can be looked at as helpful. They offer first information on possible “good” warehouse locations, especially when the information regarding suitable locations is limited.

In the following, one of the more well-known optimization methods, the center of gravity (COG) approach, is presented (Murphy & Wood, 2003). It is used when looking for a single location of a warehouse which is supplying multiple customers (Johnson & Wood, 1977). Furthermore, it is assumed that the transportation costs are the sole determining factor for the determination of the warehouse location (Ballou, 1995). A cartesian coordinate grid is put over the relevant area for consideration. Therefore, it is possible to assign x and y coordinate points to each of the demand points. By adding up the x and y coordinates weighted with the demand respectively, the gravity coordinates are determined. The demand is usually represented by the weight of goods transported to each customer within a certain period of time.

The following equations represent the latitude and longitude point of the possible new facility:

$$x^* = \frac{\sum_i d_i x_i}{\sum_i d_i}$$

$$y^* = \frac{\sum_i d_i y_i}{\sum_i d_i}$$

where

x^* =	actual latitude point for the optimal location
y^* =	actual longitude point for the optimal location
d_i =	demand of each location
x_i =	x coordinate of the demand point
y_i =	y coordinate of the demand point
$i = 1, \dots, I$	numerator

This is a minsum model, which minimizes the distance that goods travel and gives the optimal location coordinates (Krajewski, Ritzman, & Malhotra, 2007). The weighted center of gravity approach thereby gives the user the possibility to weigh the transport distances with the demand of each customer, so that the center of gravity moves closer to the higher demand. The target of the model is to determine the location for a warehouse with the minimal transportation costs, assuming that transportation costs are interdependent with travelled distance.

This approach delivers a possible location based on the center of gravity regarding the demand (center of mass, ton center). This warehouse location represents a permitted, however, not (cost-) optimal solution. The influence on the costs is established by the assumption, that the transportation costs represent the main part of the logistic costs in distribution (Coyle et al., 1996) and that they are dependent on the weights of transports. Such an insinuation simplifies the actual relations, since the distance between the warehouse location and the demand point as a factor influencing the transportation costs is blanked out. It becomes obvious that this method is a heuristic approach of location planning. However, centroid methods for location determination of central warehouses are used in operational practice due to their simple operation.

2.2.2.2 Simulation

Simulation as a quantitative model is well-known across industries, since poor planning can have a giant impact on the overall business. Therefore, simulation is chosen to evaluate operating performance before implementation and compare different operational alternatives (Chang & Makatsoris, 2001). There are three parts in simulation: develop a simulation model, design a simulation experiment, and perform simulation analysis (Maria, 1997).

The first part in using a simulation as a quantitative model for distribution network design is building up the model. The steps in this involved in developing a simulation model according to Maria (1997) are the following:

- 1) Identify the problem
- 2) Formulate the problem
- 3) Collect and process real system data
- 4) Formulate and develop a model
- 5) Validate the model
- 6) Document model for future use

Modeling is building up an abstract representation of the system of interest. Elements within the model can be broken down to simpler forms, to ease the modeling process. However, it is important to make sure that the model represents the as-is situation closely, to make sure that the outcomes of the following simulation runs by using the model are close to the real system. A simulation model based very loosely on the actual processes can lead to unrealistic outcomes.

In general, a model for simulation purposes is a conceptual process model, which is enriched with mathematical formulas. The possible mathematical model classifications according to Averill, Law and David Kelton (1991) have three dimensions, as seen in Figure 8 below.

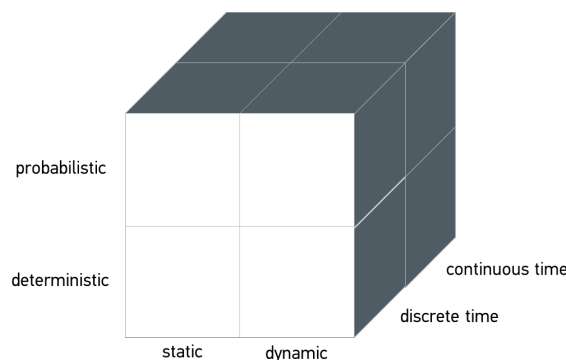


Figure 8 Classification of different types of models

Static vs. dynamic

Dynamic simulation models assign time an important role, by assuming that the system evolves over time. In *static* simulation models time is not an element.

Discrete time vs. continuous time

In *discrete* simulation models change can occur at separate points in time, which means that the system change is directly connected to time. *Continuous* simulation models, however, the change can occur constantly.

Probabilistic vs. deterministic

In *probabilistic* simulation models one or more random parameters are included, which increases uncertainty and means fixed inputs yielding different outputs. Therefore, one model needs more than one run. *Deterministic* simulation models are characterized by fixed inputs yielding fixed outputs, due to no randomness and uncertainty. This means, that a deterministic simulation model only needs one run.

Table 3 below shows possible uses for simulation models according to their type regarding deterministic/stochastic and static/dynamic characteristics (Law et al., 1991).

	Deterministic	Probabilistic
Static	Financial scenarios	„Monte Carlo“ simulation
Dynamic	Deterministic forecasting over time	Queueing and inventory models

Table 3 Possible uses for different simulation models

The second part is the design of a simulation experiment, which is represented by operating the model of the real system. The steps involved in designing a simulation experiment according to Maria (1997) are the following:

- 7) Select appropriate experimental design
- 8) Establish experimental conditions for runs
- 9) Perform simulation runs

The input parameters of the model can be reconfigured and experimentation can take place. In a real system, experimenting with input parameters or reconfiguring them is often impossible, impractical or too expensive. Therefore, by being able to experiment with the simulation model, costs can be saved, and the real system secured. By working with the model and studying it, the behavior of the actual system can be inferred for certain operations.

To eliminate unforeseen bottlenecks and to reduce the possibility of not meeting specifications, simulations are used before implementing any changes to the real system. For instance, in designing distribution networks simulation can be helpful to answer

questions like: How many supply chain stages are necessary for the currently existing customer base? Which customers are going to be delivered from which warehouse? Which service level can be offered to the customers? How will costs develop if the warehouse location is shifted from X to Y?

Figure 9 shows the simulation study schematic according to Maria (1997), which shows that the process of building a simulation model is an iterative process, since the system under study becomes the altered system. That system then becomes the system under study and the iterative process starts again.

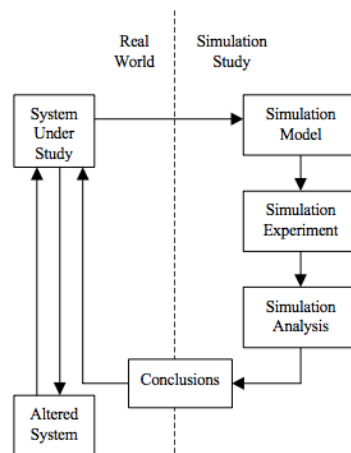


Figure 9 Simulation study schematic

The third part is the simulation analysis and the steps involved in performing simulation analysis according to Maria (1997) are the following:

- 10) Interpret and present results
- 11) Recommend further course of action

Most complex simulation models are built using simulation software. There has to be differentiated between the two types simulation languages (e.g. Arena) and application-oriented simulators (e.g. AutoMod). On the one hand, simulation languages offer more flexibility, but programming expertise might be necessary. On the other hand, application-oriented simulators are easy to learn, however, an animation that looks correct does not guarantee a valid model.

It is very obvious, that using simulation as a quantitative model is a way more detailed approach than an optimization model. In order to be able to perform all steps necessary for a simulation, more input data is necessary. Also, more processes need to be carried out during the simulation experiment part of the model. In the end the outcome has to be set in perspective by analyzing the simulation outcomes and comparing them to the as-is situation and possible other simulation run outcomes (Maria, 1997).

3 Case company: Hella GmbH & Co. KGaA

Hella GmbH & Co. KGaA is a German automotive part supplier headquartered in Lippstadt, North Rhine-Westphalia. With more than 40,000 employees in about 35 countries, 125 locations worldwide and sales of about 6.6 € billion in the fiscal year 2016/2017, Hella belongs to the top 100 largest industrial companies in Germany and is also one of the top 40 automotive suppliers in the world (Hella GmbH & Co. KGaA, 2018b).

The structure of Hella, as shown in Table 4 (Hella GmbH & Co. KGaA, 2018a), corresponds to the business activities. The company is thus divided into the business segments Automotive, which comprises the business divisions Lighting (GL) and Electronics (GE), as well as the Aftermarket and Special Applications segments, which comprise the Business Division Aftermarket and Special Applications (GH).

Business Segment	Automotive		Aftermarket	Special Applications
Business Division	Lighting (GL)	Electronics (GE)	Aftermarket and Special Applications (GH)	
Sales (in €)	~ 2.8 bill.	~ 2.2 bill.	~ 1.6 bill.	
Product examples	<ul style="list-style-type: none"> – Full-LED Headlamps – Glare-free beam light 	<ul style="list-style-type: none"> – Energy management – Automated driving 	<ul style="list-style-type: none"> – Spare parts / workshop equipment – Lighting technology for special original equipment 	

Table 4 Business segment and division setup

3.1 Department: Corporate Logistics Material Flow

The department Corporate Logistics Material Flow comprises the central material flow logistics functions for all business divisions. In this department strategical decisions regarding material movements are taken and standards formulated, which are then rolled out to the actual logistics operations in the business divisions.

The department is sub-divided into Corporate Logistics Intralogistics and Corporate Logistics Extralogistics. The research is going to take place for the latter. The sub-divisions of this department are Network Design, Packaging Engineering & Container and External Transport, as seen in Figure 10.

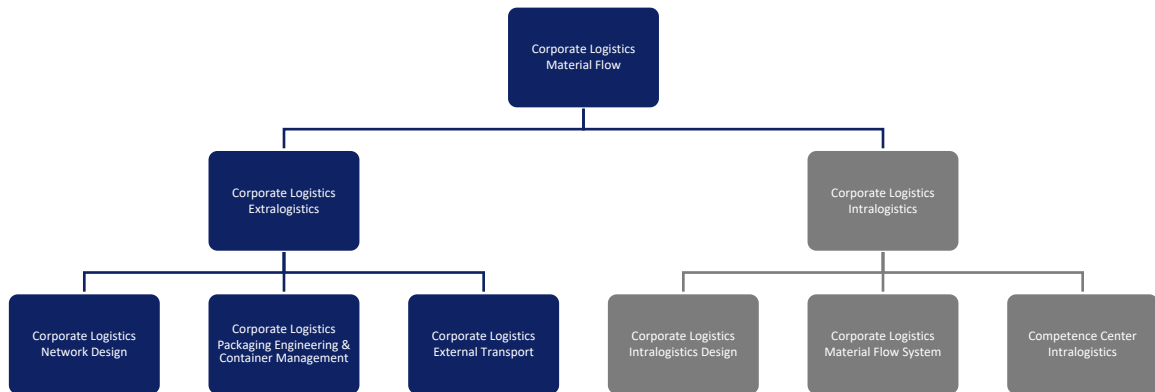


Figure 10 Corporate Logistics Material Flow organization chart

3.2 Business division: Aftermarket and Special Applications

The Aftermarket and Special Applications business division is build up by two different business segments. The Aftermarket segment combines the independent aftermarket, garage equipment business and wholesale activities. In the Special Applications segment lighting and electronics products for special vehicles are manufactured and sold (e.g. construction and agricultural machinery, buses, motor homes and marine). The current setup of the business division, as well as customers and products, can be seen in Figure 11 below (Hella GmbH & Co. KGaA, 2018a).

	AFTERMARKET (AM)			SPECIAL APPLICATIONS (SA)
Business Division	Independent Aftermarket (IAM)	Wholesale (WD)	Garage Equipment (WP)	Special Original Equipment (SOE)
Customers	Wholesale	Garages	Garages	Small-series manufacturer, airports
Products	<ul style="list-style-type: none"> Parts Tools Services 	<ul style="list-style-type: none"> Car parts Accessories Concepts 	<ul style="list-style-type: none"> Garage equipment Diagnostics 	<ul style="list-style-type: none"> Lighting Electronics

Figure 11 Business division Aftermarket and Special Applications setup

Taking a more detailed look into the sales figures of the business division GH, it gets obvious that the main business focus is Europe with an 80 % share of total sales, as shown in Figure 12. Therefore, the Aftermarket and Special Applications business is seen as a regional one with Europe as the main focus (Hella GmbH & Co. KGaA, 2018b).

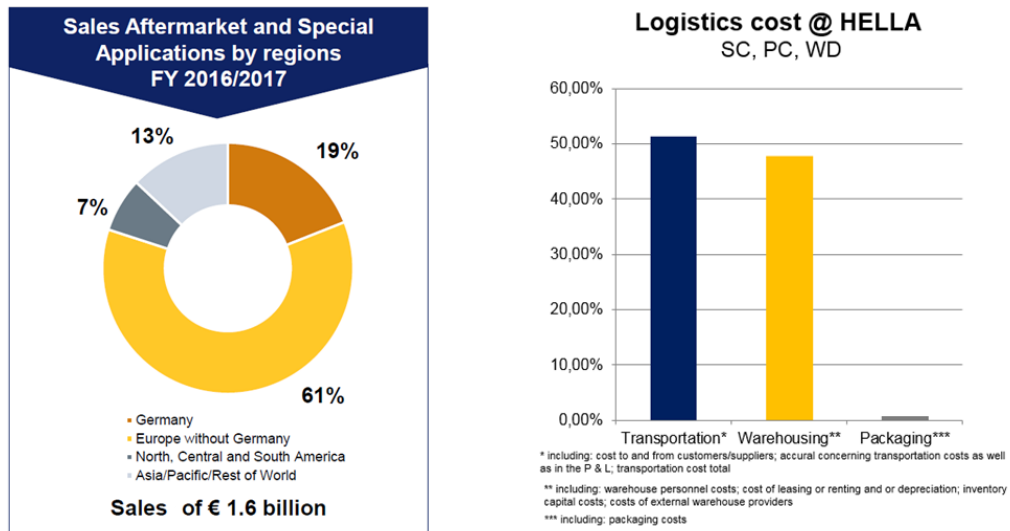


Figure 12 Sales Aftermarket and Special Applications by regions and logistics cost

Overall at Hella, the logistics costs in the supply chain are split up like seen in Figure 12. Transportation costs have the highest share of logistics cost with about 51 %. Warehousing costs follow with a 48 % share and packaging costs have the lowest share with only about 1 % of total logistics cost (Hella GmbH & Co. KGaA, 2017).

3.3 Hella in France

Hella S.A.S. in Le Blanc-Mesnil, in close proximity to Paris, is a subsidiary of Hella GmbH & Co. KGaA. HFR belongs to the business division Aftermarket and Special Applications of Hella and acts as Hella's sales company in France. They offer more than 40,000 articles in about 17 product groups to their customers.

Logistics costs

Taking a closer look at the logistics costs as a percentage of sales, as seen in Figure 13, one can see that Hella France (HFR) is the sales company with the highest logistics costs in Europe as percentage of sales. HFR comes up with a 5.73 % share of transportation costs, a 2.74 % share of warehousing costs and a 0.18 % share of packaging costs of total sales (Hella GmbH & Co. KGaA, 2017). Therefore, HFR as Hella's sales company in France will be the case study for this thesis. At this point it is also certain, that the transportation costs are the main aspect for possible cost savings, since compared to the other sales companies of Hella in other countries, which range from 0.23 % to 4.62 % transportation costs of total sales, the cost is noticeably higher. However, the warehousing costs of HFR are at an acceptable level compared to the other sales companies (1.43 % to 4.68 %). The packaging costs with a cut of only 0.18 % of total sales are not going to be considered further during this research.

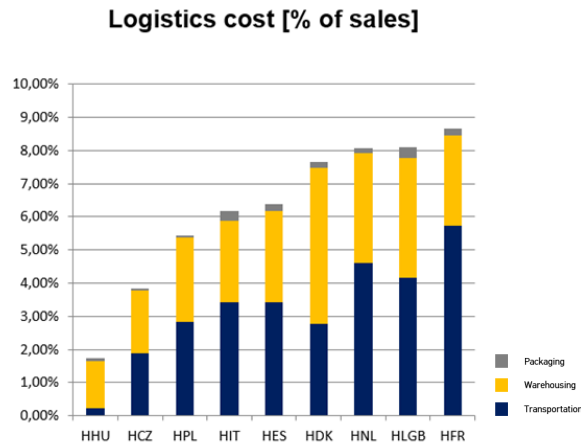


Figure 13 General overview of logistics costs at Hella FY 2016/17

Looking further into the costs for transportation, the costs can be split up into inbound and outbound costs. The inbound costs for HFR in the FY 16/17 were at 373,000 €, compared to the outbound costs at 1,143,380 €. Therefore, the inbound-outbound-ratio is 1:3. This shows, that the higher transportation costs at Hella France are arising for the outbound transports.

Customers

HFR has a customer base of about 2,300 customers, which they are supplying with products for the independent aftermarket as well as special original equipment. A customer is also referred to as a sold-to-party, since the invoicing goes to the customers address. Those 2,300 customers have about 3,100 ship-to-parties, which are the actual physical delivery locations. Therefore, the sold-to-party and the ship-to-party can be different locations, but also the exact same location. An example represents Oscaro, a French automotive part supplier, which is one customer with two ship-to-parties. The invoice is always sent to the same location, however, the goods are sent to both of Oscaro's locations. The customers are clustered according to their logistics criteria like distribution and order behavior amongst others. The result of this process are nine customer clusters for IAM and three customer clusters for SOE (see Appendix 1).

Adding to the customer clusters, the amount of same and next day deliveries, sales, sales share, number of customers, top customers and top product categories are shown. As visible in Appendix 1, same and next day deliveries make up a large split of the overall used shipping conditions with Hella's French customers (in average 44.23 % for IAM and 8.00 % for SOE customers).

Supply chain

To be able to analyze the situation for HFR in more detail, Hella's supply chain for the business in France has to be looked at as shown in Figure 14. Currently the setup in France

consists of the sales company with the main warehouse in Le Blanc-Mesnil and branch warehouses in Lyon and Marseille. HFR is used as the decoupling point, which can also be described as the boundary between push and pull processes. Figure 14 shows the current supply chain setup of HFR as well as the spread of ship-to-parties across France. In regions with blue ship-to-party clusters there are between zero and ten parties, in yellow ones between 11 and 100, and red ones host more than 100 ship-to parties. The numbers within the clusters represent the exact amount of ship-to-parties in that region.

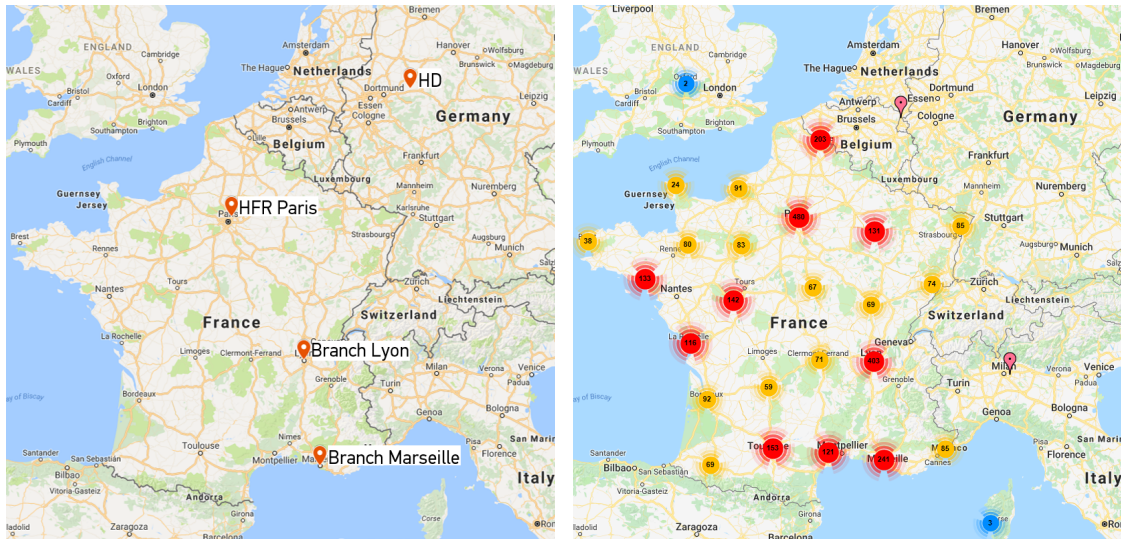


Figure 14 Map of the current supply chain setup HFR and ship-to-party distribution

Hella's current supply chain is shown in Figure 15 below. Hella's production companies (PC), joint ventures (JV) and external suppliers (ES) deliver goods to Hella Distribution GmbH (HD) in Erwitte, which is the central warehouse for Hella in Germany. From HD the goods are transported to the sales company HFR in France, which are then supplying their customers directly or via their branches in Lyon and Marseille. It is important to note that not every customer gets delivered by using each stage of the supply chain.



Figure 15 Hella supply chain HFR

4 Focus Group: Selecting the right models

The research started by conducting a focus group at Hella GmbH & Co. KGaA, which was supposed to identify the preference regarding the two different warehouse location model approaches presented earlier based on their strengths and weaknesses.

The focus group study was preferred over a survey, because up to now there was no focus on this topic within the company. Therefore, the employees did not have any detailed know-how on either of the approaches and would not have known what exactly to expect from each of the approaches. The usage of a survey would not have offered the participants to request further information on how to understand the questions. Closed questions would have therefore limited the possible outcomes of the survey, since there might have been a comprehension problem. Also, answers to open questions might have deviated due to missing understanding of the questions asked and the outcomes might have ended up unusable. Furthermore, the focus group was preferred over one-on-one interviews since it provided interaction between the participants and that brings it closer to reality, where together a decision must be taken about future network design topics. Also, the focus group was chosen since it gives the participants a chance to ask questions for clarification.

The first part of the research is a focus group study on the topic of the preference of the decision-makers regarding optimization and simulation approaches in distribution network design. First off, the methodology of focus group studies in general is introduced. Then, the preparations of the focus group study at Hella taking the methodology into consideration, including questions, time-frame and participants, is presented. There were five questions prepared for the focus group study to be able to analyze the preference of the decision-makers. However, during the focus group study a sixth question, as a follow-up to the ones before was asked, to summarize the results coming out of the focus group study and strengthen the overall opinion of the participants.

4.1 Focus group methodology

According to Bryman and Bell (2015) a focus group consists of a small number of participants in a group interview setting with the emphasis of questioning being set on a fairly tight topic. In general group interviews work with several people to discuss a certain topic and focused interviews work with people that have been known to have an involvement with the topic being discussed. Therefore, a focus group combines aspects of both group and focused interviews. The person who runs the focus group is called the

4 Focus Group

moderator or facilitator and guides the session without being too intrusive. A main aspect of focus groups is that the interviewees can challenge each others' views which leads to more realistic accounts of what the participants actually think (Bryman & Bell, 2015).

When conducting a focus group, it is important to record and afterwards transcribe it. Of high importance in case of a focus group is who said what, since several persons are going to be heard on the focus group recording. Therefore, the transcribing focus groups can be more effort than transcribing a one-on-one interview. Another aspect that needs to be looked at is, if there are any opinion leaders in the group which might dominate the discussion. The moderator should always try to get everyone to participate and voice their opinion (Bryman & Bell, 2015).

The amount of focus groups is associated to the theoretical saturation criterion which says that as soon as the moderator can anticipate in a fairly accurate fashion what the following focus group is going to say, saturation is reached (Bryman & Bell, 2015). The size of groups is somewhere in between six and ten (Morgan, 1998; Tremblay, Hevner, & Berndt, 2010). However, Blackburn and Stokes (2000) found in their research, that it gets more difficult to manage a focus group if there are more than eight participants.

The level of involvement of the moderator is another aspect of specific importance to a focus group. The general understanding of involvement is, that the moderator should not structure the focus group too much or be too intrusive. The discussions within a focus group setting can deviate, however re-focusing the groups' attention is seen as an important moderator task. Overall, there is no rule of how free-flowing or structured a focus group should be, since it depends on the topic and the already existing knowledge about it (Bryman & Bell, 2015).

When selecting the participants for a focus group, there has to be made a decision between randomly sampling participants or using natural groups, which means participants that already know each other. Some researchers see natural groups of participants skeptical due to possible assumptions, which might be taken for granted by the group and therefore some topics might not be brought up during the focus group. However, natural groups have an advantage in the exploration of collective and shared understandings and meanings (Bryman & Bell, 2015)

Possible limitations of focus groups are missing control over the development of the discussion and how far the group itself might be able to take it over. Another aspect is the data generated by a focus group, which in general is more difficult to organize, transcribe and analyze. Furthermore, cautious participants might not voice their opinions

enough and therefore give opinion leaders a chance to gain control over the whole group (Bryman & Bell, 2015).

4.2 Focus group preparation

For the purpose of this research a focus group was conducted by using a natural group of six Hella employees. The topic to research was the preference the two different models of warehouse location selection. Since two opposite models were chosen as possible approaches to a warehouse location problem, the preference of the decision-makers was researched to analyze which one outweighs the other. The questions for the focus group were chosen from different areas, which made it able to draw conclusions on the preference of the decision-makers.

The participants were chosen from several hierarchy levels and also outside the material flow departments, to increase the generalizability of the outcomes within Hella. Table 5 gives an overview of the participants of the focus group and their occupation within Hella.

Participant	Occupation
Participant A	Director Corporate Logistics Material Flow
Participant B	Vice President Order Fulfilment EMEA
Participant C	Head of Order Fulfilment Realization and Performance
Participant D	Head of Corporate Logistics Extralogistics
Participant E	Head of Corporate Logistics Network Design
Participant F	Project Manager Corporate Logistics Network Design

Table 5 Focus group participant overview

Another aspect that was taken into consideration, when choosing the participants for the focus group, was the operative and strategic side of decisions. The ratio of employees working in operative and strategical positions is about 1:1. For the outcome of the focus group this means, that it is not only a strategical decision, but that the possibility of it being accepted by an operative day-to-day business manager is given. Therefore, not only the strategical aspects, but also operative aspects are taken into account during this focus group study.

The time frame of the focus group was set to 60 minutes with the possibility to go up to 120 minutes in case it was needed. The presentation at the beginning of the focus group took about 15 minutes and the discussion followed up on that with about 45 minutes.

The focus group started off by a presentation of the two warehouse location models chosen for this thesis: optimization and simulation. General aspects of each model were presented to get a uniform understanding of what each of those terms mean. This

4 Focus Group

was necessary, since both terms are used on a daily basis in a business setting without sticking to a single common understanding for each.

The first question “What do you see as strengths and weaknesses of each model?” was chosen to make sure of the understanding of the terms optimization and simulation and also to make the differences and similarities of the models and the main points of each clear to the participants. Therefore, this question offered all participants to start off into the focus group with the same general understanding of the models, by sharing opinions about strengths and weaknesses.

“How realistic is the outcome of the models for you?” was the second question asked during the focus group. The purpose of this question was to offer an insight into the participants opinions about the models and their outcomes. By using this question, the basic opinion of the participants about the models could be understood. This question also showed if any of the outcomes came as a surprise to the participants, or if they were expected.

The next question “How close to reality are those models?” meant to find out about the participants opinions about the models being close to reality or mostly textbook knowledge. A possible follow up question for this section of the focus group would have been “What would be your choice?” to get to know which models the participants would rate closer to reality. The follow-up question at the end of the focus group includes this aspect of asking for a possible alternative.

The fourth question was “How clear is the way of getting to the results?”. This question was chosen to show if the participants understood the way of getting to the outcomes. If participants did not understand the way of getting to the results it would have also given an indication if there is even a necessity or want of the decision-maker to understand the outcomes.

“Would you present the outcomes of the models at an executive board meeting?” was the fifth question of the focus group and was supposed to indicate the participants’ trust into the models, since the data presented at an executive board meeting is supposed to be of high quality only and needs to be understood by the executive board members to make decisions based on it.

The last question of the focus group was “For future situations in distribution design, in which you are looking for a new warehouse location, what would be your idea of using the presented models, or do you have alternatives?”. This question was not a planned question to be asked during the focus group. However, it was asked due to several

answers of questions before leaning towards the possibility of a two-step model. Therefore, this follow-up question was asked to identify if this tendency was understood correctly by the moderator and in that case to strengthen the outcomes of the focus group.

4.3 Focus group outcomes

After the recording of the focus group was transcribed, the outcomes were analyzed according to the target of finding out about the preference of the decision-makers concerning the warehouse location models.

Question 1: “What do you see as strengths and weaknesses of each model?”

The results regarding question one coming out of the focus group can be seen in Table 6 below. As can be seen from the results of the focus group regarding the first question about strengths and weaknesses, the participants see more weaknesses than strengths in both warehouse location models. The main topics chosen as strengths and weaknesses belong to the categories infrastructure, input/parameters, monetary values and time frame. On the one hand, the main selling points for an optimization are the easiness of getting and using the data necessary and the short time frame to carry out the optimization. However, the participants of the focus group rated an optimization only as a first indication in the search for a new warehouse location.

On the other hand, the main selling point for a simulation is the quantifiable result which can be represented in Euros and therefore directly give an indication of end-to-end cost.

Overall, the participants see a simulation as a more in-depth model compared to an optimization, since more detailed data is used. However, a simulation comes with more risks regarding data quality and time frame.

4 Focus Group

	Strengths	Weaknesses
Optimization	<ul style="list-style-type: none"> – Does not take so long – Gives a quick first indication 	<ul style="list-style-type: none"> – Independent from given infrastructure (just based on geography) – It does not recognize where the hubs of the forwarders are – No monetary value, only best possible location for the criteria defined – Hard to act on the result – No end-to-end view of the supply chain
Simulation	<ul style="list-style-type: none"> – Quantified result (monetary value) 	<ul style="list-style-type: none"> – A lot of work to choose the right parameters, take assumptions – Hard to make sure that input parameters are valid – Big amount of data, tables need to be combined – Very time consuming – Final effect of parameters must be decided upon already during the process – Dependency on local support, local interest might differ from general interest – Different data sources, combining them does not always work

Table 6 Outcome question one

Question 2: “How realistic is the outcome of the models for you?”

When it comes to rating the models with regard to how realistic they are, the first aspect mentioned by the participants is that both approaches only take a look into the past and not into the future. This can be a problem in case customer requirements change or new products would be introduced which then would make the outcome of the models not be accurate enough and divergent of the actual material flows (Note: depends on data base available, the data used for the case study are historical values). Furthermore, according to the participants it definitely depends on the database how realistic the approaches are, since it is necessary to verify that the data used is the correct one. The participants rated the outcome of the simulation higher in being realistic, due to outcomes which can actually be seen as the solution afterwards, since the different simulations were the pre-defined potential locations.

Overall, as shown in Table 7 below, the intention of both approaches is understood completely different by the participants, with the optimization just giving a first indication on the mathematical/statistical best possible location taking one criteria into account and the simulation as the basis for a management decision.

Optimization	Simulation
<ul style="list-style-type: none"> – Only past values, no future development considered <ul style="list-style-type: none"> - Change of customer requirements - Introduction of new products – Just gives a first indication on best possible location 	<ul style="list-style-type: none"> – Only past values, no future development considered <ul style="list-style-type: none"> - Change of customer requirements - Introduction of new products – Depends on the database – Verification of used data is necessary – Outcomes can actually be seen as the solution afterward – Basis for a management decision

Table 7 Outcome question two

Question 3: “How close to reality are those models?”

On the one hand, according to the participants, a simulation is closer to reality if the parameters and the data put into the model are prepared properly. However, this also means that the simulation only shows the best we know with our data. So, in case the data is not sufficiently accurate or processed then the outcomes might be further from reality than expected.

On the other hand, an optimization is only looked at as a statistical result and therefore just as a first indication to know where to go further and from there on build up different scenarios. This opinion has been reinforced by the participants seeing the outcomes of an optimization as not feasible due to the consideration of only one criteria. More reasons mentioned by the decisions-makers regarding an optimization being far from reality include that there is no infrastructure looked at and only air distances are taken into consideration.

Overall, the decision-makers see a simulation as closer to reality with the restriction that the input data has to be prepared properly. An optimization was again just seen as a first step to give an indication on the further warehouse location process. The results can be seen in Table 8 below.

Optimization	Simulation
<ul style="list-style-type: none"> – Only a first indication to know where to go further and from there on build up scenarios – Just a statistical result – Outcomes might not be feasible, nothing else except one criteria considered – No infrastructure looked at – Only air distances looked at 	<ul style="list-style-type: none"> – Close to reality if parameters and input are prepared properly – Shows the best we know with our data

Table 8 Outcome question three

Question 4: “How clear is the way of getting to the results?”

On the one hand, an optimization is a clear and easy to understand approach with an obvious logic and the sharpness is higher than in a simulation since only one criteria is looked at and not that many assumptions are made.

On the other hand, with a simulation one has to understand which parameters are inside the model, like criteria and chosen locations, to be able to understand a simulation as a whole. Therefore, for non-experts it might be hard to identify the aspect that has the highest impact on the whole model. By adding more factors into a simulation, the whole model might change and one never knows instantly which of the parameters led to the change in that result. Also, since the outcome of the simulation approach is stated in a monetary value, it shows that a lot of assumptions have been made about the clustering of distances and demands.

Overall, as seen in Table 9 below, the clarity of the way to get to the results is easier to understand with an optimization approach, since only one criteria is looked at. A simulation needs a far more in-depth analysis to be understood also by non-experts.

Optimization	Simulation
<ul style="list-style-type: none"> – Clear and easy to understand approach with an obvious logic – Sharpness is higher, since only one criteria is looked at 	<ul style="list-style-type: none"> – Parameters have to be understood – Hard to understand for non-experts which parameter has the highest influence – One new factor can change the whole model without an explanation – Outcome is in Euros, lot of clustering of distances and weights

Table 9 Outcome question four

Question 5: “Would you present the outcomes of the models at an executive board meeting?”

The participants all immediately agreed that they would present the outcomes of the models at an executive board meeting. Preferably the participants would present both at the same time with the simulation building up on the outcome of the optimization. Reasons for that are that the optimization gives a first indication about the possible new warehouse location and the simulation then will make it easier to convince the executive board members to make a decision based on it.

Another aspect mentioned was that the optimization approach in the future could also be used as a validation for the location chosen by using a simulation approach, since it should be somewhere close. In case it would be considerably apart from each other, one should be able to explain the deviation. The results can be seen in Table 10 below.

Optimization	Simulation
<ul style="list-style-type: none"> – Should be the first step – Can be used as a validation for the location chosen by using a simulation approach 	<ul style="list-style-type: none"> – Should be the second step – Needs more preparation to present – Decision-makers will feel more comfortable to make a decision based upon a simulation

Table 10 Outcome question five

Question 6: “For future decisions in distribution design, where you are looking for a new warehouse location, what would be your idea of using the presented models, or do you have alternatives?”

This follow-up question was not planned in preparation of the focus group. However, during the focus group it got more and more obvious that the participants do not prefer one of the models over the other, but rather want to combine them into a two-step model. The participants agreed on always doing an optimization first to get a rough picture of where the location might be. The second step would then be to do a simulation based on that to be able to look at the end-to-end costs.

4.4 Main findings relevant to further research

During the focus group it got more and more clear that the participants do not prefer one approach over the other but rather want to use both in future distribution network design decisions. The follow-up question asked by the moderator shows clearly that a two-step model is preferred over the usage of just one model. The reason of the focus group was to identify the preference of decision-makers regarding optimization and simulation models. The participants accept both models on their own and showed up their strengths and weaknesses, however, the participants decided that there could be added value by combining both models. Strengths and weaknesses mentioned by the participants, as well as other comments during the focus group, show that each of the models is appreciated for its purpose. The optimization approach is seen as a “quick first indication” whereas the simulation approach is seen as a “basis for a management decision”. Looking at the input necessary for each of those approaches, the participants instantly decided that the simulation is an “in-depth approach” that needs a lot of preparation. However, combining it with the optimization approach, which is seen as a “clear and easy understandable” approach, which does not need a lot of input data, the two-step model integrates the best of both of them.

First of all, the optimization gives an indication regarding the possible warehouse location based on raw data. Then, the simulation can be done based on the outcome of the optimization, so that the start into the simulation approach is made easier.

Overall, the focus group showed, that location models do not have to be looked at as separate, but can be combined, to reduce weaknesses of each and therefore increase the overall strengths of the models.

5 Analysis: Designing the distribution network for the case company

The outcome of the focus group showed that the decision-makers prefer to make future warehouse location decisions based on a two-step model approach. First step of the model is to use an optimization and then do a simulation based on the outcome of the optimization.

In general, when designing distribution networks there are two steps to take. The first one is to visualize the broad structure of the supply chain, by looking at how many supply chain stages are necessary and what their roles are going to be. The second one is the location decision, which is subdivided into location and allocation, and defines the specifics of each location.

For the first step the decision is based on the customer clusters (see Appendix 1), which show that 44.23 % of Hella's IAM and 8.00 % of Hella's SOE customers demand same/next day deliveries. On this basis it is necessary that there is at least one supply chain stage kept in France, so that the customer service level demands can be met. Since, the costs arising with the current supply chain setup with two supply chain stages in France are high in comparison to other sales companies, the optimization and simulation approach is going to be focused on a supply chain setup with one stage in France.

The optimization approach chosen for this one company case study is the weighted center of gravity approach. This approach is a continuous model, which is preferred over a discrete one in this case due to the possibility of the potential warehouse location being located anywhere in the plain and not only in the nodes of the existing network. Choosing a continuous model (COG) over a discrete one (WLP) increases the amount of potential warehouse locations. An advantage of the WLP would be, that fixed costs of the warehouse could be taken into consideration. However, at Hella this data is not available. Therefore, the decision is to use the center of gravity model.

Since this research is taking place in the first phase of supply chain design, the level of abstraction is higher than in the following phases. The simulation approach chosen is a static, deterministic and discrete-time one. A static approach was preferred over a dynamic one, since the database provided by Hella and used in this research does not allow any differentiation regarding time and the system will not evolve over time. A deterministic simulation model is chosen instead of a probabilistic one, since with the level of abstraction chosen, a detailed view on the processes is not possible. Mainly the supply chain stages are going to be looked at and the processes happening within the supply chain stages are looked at as some kind of black box. Therefore, randomness and

uncertainty within those processes will not be part of this simulation model. Adding to the decision made earlier with regard to a static rather than a dynamic simulation model, also a discrete time simulation model is preferred over a continuous time one, due to the beforementioned reasons. The two-step model approach can be seen in Figure 16 below.



Figure 16 Two-step model for analysis

5.1 Optimization

The optimization represents the first step of the two-step model. For the purpose of this research the weighted COG approach was chosen, which is used to locate the COG based on actual demand. This happens by taking the coordinates of the customers' ship-to-parties and the associated demands into consideration. In the center of gravity approach the ship-to-parties are looked at. The cost for outbound transports from HFR to their customers in FY 16/17 was about 77 % compared to only about 23 % of costs in inbound transports, therefore only outbound transports are considered for the COG model since those have the higher impact on the overall transport costs, which offers a higher possibility for savings. To bring the whole COG calculation closer to reality, it is done for both, weights and volumes of the demands, to be able to compare the two possible warehouse locations. Then the criterion with the higher impact on the transport costs for outbound transports is identified and the COG based on this criterion is chosen. To illustrate the way the COG optimization works, the calculation for the top ten ship-to-parties according to weights is carried out as an example.

The first step in the process is to convert the ship-to-party addresses into latitude and longitude points and then identify the weights of the goods each customer received in the chosen time period. The addresses of the ship-to-parties have to be converted to latitude and longitude points so that the mathematical programming can move the location of the possible new warehouse on what is referred to often as a grid. An excerpt of the weight per ship-to-party for FY 16/17 can be seen in Table 11 below, it shows the top ten ship-to-parties according to weights of demands.

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Ship-to-party	ZIP	Weight (in t)	Share of total outbound (in %)
OSCARO	95100	246	8.68
LOGIC SYSTEM	13127	170	6.03
OSCARO	95800	95	3.35
AGCO S.A.	60000	47	1.66
ESAT	72700	38	1.36
CBM	72000	31	1.09
PARTNER'S	41260	30	1.06
GARNIER LOG.	44540	29	1.01
AZ NEGOCE	92230	28	0.99
MISTER AUTO	69960	25	0.88
Total		739	26.12

Table 11 Volumes per customer for top ten customers

The ship-to-party address, in this case ZIP code, is converted into latitude and longitude points with the help of Google Maps. Then, the calculation (see chapter 2.2.2.1) is done as follows: every latitude and longitude point is multiplied with the corresponding weight of the ship-to-party. Resulting out of this are the overall products of weight and latitude (35,013,421 trad) and the overall product of weight and longitude (1,946,527 trad) as seen in Table 12.

Ship-to-party	ZIP	d_i (in t)	x_i (in rad)	$d_i \times x_i$ (in t / in rad)	y_i (in rad)	$d_i \times y_i$ (in t / in rad)
OSCARO	95100	246	48.9472096	12,016.70	2.2466847	551.56
LOGIC SYS.	13127	170	43.4496688	7,407.10	5.2579968	896.36
OSCARO	95800	95	49.0356169	4,645.56	2.0603250	195.19
AGCO S.A.	60000	47	49.4295386	2,325.30	2.0807122	97.88
ESAT	72700	38	47.9688930	1,839.15	0.1593629	6.11
CBM	72000	31	48.0061100	1,482.25	0.1995560	6.16
PARTNER	41260	30	47.6125789	1,428.66	1.3551089	40.66
GARNIER	44540	29	47.5249380	1,360.30	-1.1843969	-33.90
AZ NEGO.	92230	28	48.9255250	1,367.02	2.2932749	64.07
MISTER A.	69960	25	45.6704717	1,141.34	4.8984123	122.41
Total		739		35,013.42		1,946.53

Table 12 Top ten customers calculation

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Each of those is divided by the overall demand (i.e. weight; 739 t) of the top ten ship-to-parties to receive the latitude and longitude point of the new possible location (COG 1):

$$x^* = 35,013.42 \text{ trad} / 739 \text{ t}$$

$$x^* = 47.4091046 \text{ rad}$$

$$y^* = 1,946.53 \text{ trad} / 739 \text{ t}$$

$$y^* = 2.6356498 \text{ rad}$$

This point (47.4091046, 2.6356498) is located in the region Centre Val de Loire in close proximity to Bourges in France.

This approach is followed up by using the COG formulas with the coordinates of all ship-to-parties of HFR as well as the *weights* of the goods. By doing that, the following output is created (COG 2):

$$x_1 = 47.1847992 \text{ rad}$$

$$y_1 = 2.6218145 \text{ rad}$$

This point (47.1847992, 2.6218145) is located in the region Centre-Val de Loire in close proximity to Bourges in France.

Following up on that, the same calculation approach is used when calculating the COG with *volumes* of the goods. The following output is created taking volumes into consideration (COG 3):

$$x_2 = 47.4137191 \text{ rad}$$

$$y_2 = 2.5374556 \text{ rad}$$

This point (47.4137191, 2.5374556) is also located in the region Centre-Val de Loire in close proximity to Bourges in France. However, this COG 3 based on the volumes is located about 30 km north of the COG 2 which is taking the weights of the deliveries into consideration.

There are some reasons for the three locations to be in the same area, as shown in Figure 17. The first reason is, that the possible warehouse locations are in central France, which makes sense taking into consideration that the French customers are spread all over France. Furthermore, the top ten customers are spread all over France and with about 26 % of the overall inbound volume according to weights, they have a pretty big influence on the overall outcome.

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Since the outbound processes of HFR consist of CEP and LTL transports, the main aspect is weights due to forwarders putting more importance on weights in rate sheets for those types of shipments. The COG 2 based on weights of the demands is therefore closer to reality, since the weights directly influence the cost of transportation. However, the distance between both points is only about 30 km and therefore Bourges is chosen as a new possible location for a warehouse.



Figure 17 Map of COG

5.2 Simulation

The simulation represents the second step of the two-step model. The first scenario of the simulation is based on the as-is setup of the distribution network of France, to make sure that the simulation model is accurate. The second scenario is based on the possible new location, which is defined by the center of gravity optimization approach.

The overall simulation model is characterized by inbound transports, warehousing and outbound transports. For the inbound transports, all costs created by transports to HFR from production companies, joint-ventures and external suppliers are taken into consideration. Warehousing consists of the costs caused by handling the products, Hella's warehouses in France and the logistics employees. The part of the outbound transports is concerned with the costs incurred by the delivery of the goods from HFR to the customer.

Table 13 shows an overview of the inputs, processes and outputs of the simulation model. The input data also represents the parameters which can be changed to run the simulation for other cases.

Simulation model		
Input	Process	Output
<ul style="list-style-type: none"> – Warehouse location – Shipment data inbound and outbound (weight, volume, packaging, commercial terms and shipment type/concept used) – Costs for inbound transports (depending on shipment type and rate sheets) – Costs for warehousing (depending on handling, warehouse and personnel costs) – Cost for outbound transports (depending on shipment type and rate sheets) – Customer requirements 	<ul style="list-style-type: none"> – Calculate inbound costs – Calculate warehousing costs – Calculate outbound costs – Service level consideration 	<ul style="list-style-type: none"> – Costs for inbound transports – Costs for warehousing – Costs for outbound transports – Indication on service level

Table 13 Simulation inputs, processes and outputs based on as-is situation

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5.2.1 As-is situation

To be able to do a simulation on basis of a new distribution structure setup, the as-is situation is modeled as close to reality as possible to be able to make sure that the simulation outcome is realistic. The following Figure 18 shows the as-is situation regarding the distribution structure for Hella in France. First of all, the inbound transports are looked at, which supply HFR in Paris with goods from HD as well as other sources. Then the warehousing costs, including warehouse and office personnel, are analyzed. Following up on that, the outbound transports, which supply Hella's 3,100 ship-to-parties, as well as the replenishment of the branch warehouses are looked at in detail.

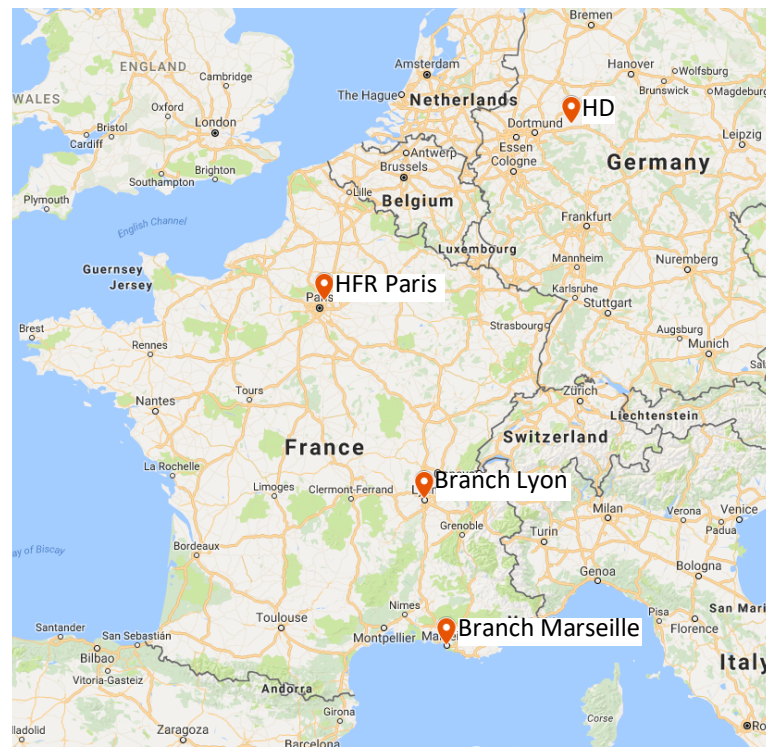


Figure 18 Map of current supply chain setup

5.2.1.1 Inbound

The inbound streams are all the transports from production companies, joint-ventures and external suppliers to HFR in France. There are 33 active suppliers for HFR, out of which 17 are companies owned by the Hella Group. Those 17 companies make up a 99.52 % split of the total inbound volume for Hella in France (see Table 14). Due to the minimal volume of the external suppliers, those material flows are not considered further. Due to the main shipment type for inbound transports at HFR being FTL shipments, the focus is

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put on the volume of the goods, since the forwarders put more importance on volumes when it comes to rate sheets.²

Company	Volume (in m ²)	Share of total inbound (in %)
Hella Group	17,068	99.52
External	82	0.48
Total	17,150	100.00

Table 14 Inbound volume split Hella and External

The top nine companies are going to be analyzed further, since the other eight supplying companies have a volume that is too low to influence the overall cost drastically (see Appendix 2). The volume considered for the inbound transports is therefore 17,064 m² (99.50 %) as shown in Table 15.

Company	Country	Volume (in m ²)	Share of total inbound (in %)
Hella GmbH & Co. KGaA	Germany	9,231	53.83
Behr Hella Service GmbH	Germany	5,264	30.70
Hella Pagid GmbH	Germany	813	4.74
Hella Gutmann Solutions GmbH	Germany	592	3.46
Hella Fahrzeugteile Austria GmbH	Austria	452	2.64
Hella Lighting Finland Oy	Romania	312	1.82
Hella BHAP Automotive	China	240	1.40
HKG Nellingen	Germany	116	0.68
Hella-New Zealand Limited	New Zealand	39	0.23
Total		17,082	99.50

Table 15 HFR suppliers

The biggest percentage of inbound volume comes from Hella GmbH & Co. KGaA, which means that those materials are delivered from the central warehouse in Germany directly, Hella Distribution GmbH in Erwitte. However, not only those goods are supplied from HD but also the goods of Behr Hella Service GmbH, Hella Pagid GmbH and Hella Gutmann Solutions GmbH, since those companies of the Hella Group store their materials at HD as well. Also, Hella's factory in Finland was closed, so all those products are now produced in Romania and shipped to France from HD. Furthermore, HKG Nellingen and Hella Fahrzeugteile Austria GmbH are supplying HFR via a cross-dock at HD. Therefore, only Hella BHAP Automotive and Hella New Zealand Limited are not going to be supplied from HD out of the top nine Hella France suppliers (see Table 16).

Delivery from	Volume (in m ²)	Share of total inbound (in %)
HD	16,784	97.87
Hella BHAP Automotive	240	1.40
Hella New Zealand Limited	39	0.23
Total	17,064	99.50

Table 16 HFR supply sources

² For outbound transports, like in the center of gravity approach, the main aspect is still put on weight of the goods due to the forwarders putting more importance on weight when it comes to freight rates.

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The next step in analyzing the inbound volumes of HFR is to look at the different delivery scenarios that are existing. Table 17 shows the four main delivery scenarios when looking at the inbound processes.³


















Delivery scenario	Supply chain stage					Information
1	 PC/JV/ES	 HD/HKG	 SC	 Branch	 Customer	
2	 PC/JV/ES	 HD	 SC	 Branch	 Customer	Cross-docking HD
3	 PC/JV/ES		 SC	 Branch	 Customer	Drop shipment HD
4	 PC/JV/ES	 HD/HKG			 Customer	Drop shipment SC
<div> <div>Push</div> <div>→ →</div> <div> </div> <div>← ←</div> <div>Pull</div> </div>						

Table 17 Delivery scenarios HFR

Since this research takes place in the first phase of choosing a supply chain, which is called network design phase, there has to be differentiated between push and pull processes within the delivery scenarios. The push processes are the ones leading towards the goods being delivered to the sales company, which represents the main warehouse in France. Those processes are being controlled by forecasting the demand of the goods by using historical data and possible future trends. The transport processes from the sales company to the branch warehouses and the customers are pull processes. This means, that the goods are only sent out if a customer order is existing. Therefore, the sales company, HFR in Paris, is the decoupling point of the supply chain. The suppliers chosen for analysis can be assigned to the four delivery scenarios mentioned above as follows:

- 1) The first delivery scenario is the most common one and uses all the available supply chain stages. Suppliers that are using this delivery scenario are the following:
 - Hella GmbH & Co. KGaA
 - Behr Hella Service GmbH
 - Hella Pagid GmbH
 - Hella Gutmann Solutions GmbH
 - Hella Lighting Finland Oy

³ The distribution over a branch always represents an optional supply chain stage.

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- 2) The second scenario is represented by cross-docking the goods at HD and then sending them on to the sales company in France. Suppliers using this scenario are (Note: there is no ownership taken by HKG for the goods cross-docked at HD):
 - Hella Fahrzeugteile Austria GmbH
 - HKG Nellingen
- 3) The third scenario is a drop shipment of the HD, which means that goods are sent from the supplier directly to the sales company and therefore do not need to be handled at HD. Those suppliers are:
 - Hella BHAP Automotive
 - Hella New Zealand Limited
- 4) The last scenario is a drop shipment of the SC, which means that goods are sent from the supplier to HD and from there the goods are sent directly to the customer without shipping them to the sales company first. The suppliers using this approach are not looked at further in this research, since those costs are not changing by re-locating the warehouse in France. The delivery is still happening from HD in Erwitte to the end customer.

The inbound transports from HD to HFR take place with full truck loads (FTL) at least once a day (so-called 3R⁴ transports). With an average utilization of the trucks at about 70 %, a truck fits a volume of about 54 m³.⁵ Therefore, with a total inbound volume at HFR coming from HD of 16,784 m³ a total sum of about 319 trucks was used in FY 16/17 to transport that volume from Germany to France. The cost point for those trucks comes down to 286,000 €.

Figure 19 shows the inbound transports at HFR. The inbound transports coming from Hella BHAP Automotive and Hella New Zealand Limited are transported from China and New Zealand via air-cargo. The costs for those transports in the FY 16/17 were 87,000 €. Since with air-cargo the biggest influence on the overall cost of the transports is the airfreight itself as the main run, there will be no drastically higher costs when shipping the goods to another place in France, since the pre-run and post-run via trucks do not make up a large split of the overall costs (Corporate logistics extralogistics

⁴ Regular reliable replenishment

⁵ Assumption made by HCC-LOMN

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department, personal communication, June 5, 2018). Therefore, the total cost for the inbound transports for the as-is situation is 373,000 €.

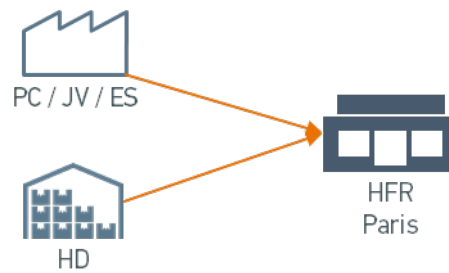


Figure 19 As-is inbound transport overview

5.2.1.2 Warehousing

The current setup in France hosts three warehouses with a total of about 5,000 m² warehouse and 1,250 m² office space. The main warehouse and the sales company are located in the proximity of Paris and the other branch warehouses are located in Lyon and Marseille. The warehouses have road access only and air shipments are being transported via truck from the airport to the warehouse. HFR has a total of about 80 employees split over all departments. There is a total of 22 logistics employees split over the three locations, whereby each branch has two employees. The sales company including the main warehouse has 18 logistics employees under contract which split up like follows:

- Warehouse: 15 employees
- Administration: 2 employees
- Logistics manager: 1 employee

The costs and expenses for the FY 16/17 can be seen in Table 18 below split up according to the cost-incurring warehouse. The first cost types belong to personnel costs and they include the salary, sick and vacation pay and social benefits like medical. The other cost types belong to operating expenses. The first one is external services including consulting, security and cleaning services. Maintenance includes the service of vehicles and buildings. Rents and leasing include the leasing for the branch warehouses in Lyon and Marseille. Since the warehouse in Paris is already in Hella's ownership, there are no leasing fees to pay. Travel expenses is the next category including car rental, mileage and entertainment. Other costs consist of gas, car insurance, phone bills, office supplies, trainings and utilities. Furthermore, the costs for warehouse equipment and forklifts belong to this cost type.

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Cost type	Paris (in €)	Lyon (in €)	Marseille (in €)	Sum (in €)
Personnel	540,419	57,867	51,438	649,724
Social benefits	241,909	28,725	23,330	293,964
Subtotal personnel cost	782,328	86,592	74,768	943,688
External Service	84,268	3,731	4,874	92,873
Maintenance	30,291	1,270	1,903	33,464
Rents and leasing	-	52,500	42,729	95,229
Travel expenses	2,524	211	197	2,932
Others	23,142	24,819	19,261	67,222
Subtotal operating expenses	140,225	82,531	68,964	291,720
Total	922,553	169,123	143,732	1,235,408

Table 18 Expenses per warehouse in FY 16/17

Overall, in FY 16/17 the personnel cost for Hella in France came up to 943,688 € and the operating expenses came up to a total of 291,720 €. Therefore, the cost of warehousing for Hella's business in France comes up to 1,235,408 €.

5.2.1.3 Outbound

The outbound transports are all the transports going from HFR to the ship-to-parties, as well as the replenishment of the branch warehouses. At HFR the outbound transports are more complex than the inbound transports, since the number of ship-to-parties is higher than the number of suppliers.

Since for the outbound processes the weight of the goods has a higher influence on the cost of transportation due to the rate sheets of forwarders for CEP and LTL transports, the outbound transports are looked at with regard to the weight of the goods. There are two forwarders used for Hella's business in France, Schenker for LTL shipments and TNT National Express for CEP shipments. The rates for the CEP shipments are fixed on a national level depending on the weight of the freight. At HFR packages with a weight of up to 70 kg are sent out as CEP shipments. Regarding the rate sheets for LTL shipments from Schenker, the weight and distance influences the rate of the shipments. Rates are quoted from the location of the current warehouse in Le Blanc-Mesnil, to all other locations in France per loading meter and pallet (see Appendix 3 and Appendix 4).

Since the rate sheets are based on the location of the current warehouse they are not applicable for the possible new warehouse location. Therefore, to guarantee comparability for the further use of this rate sheet within this research, the rates are formed into six groups according to distance from the starting point (see Appendix 5 and 6). Then, the average is taken of each specific rate for the departments in this group. Thereby, since Paris is located far in the north of France, and the prices for long distances

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going into the south of France are available, the groups can be used from other points in France to be able to have an approximation of the transport costs. A map of the groups formed, and an excerpt of the average rates calculated for group one through six are shown in Table 19.

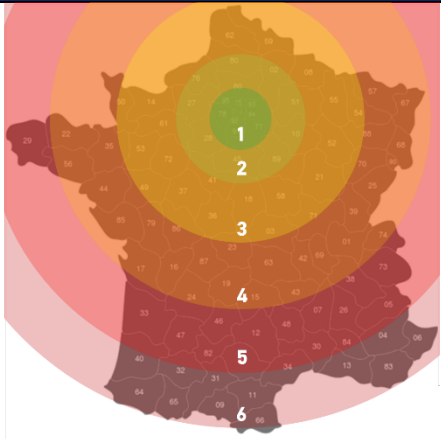
Map of rate sheet groups	Group	1 pallet	2 pallets	3 pallets	4 pallets
	1	89.10 €	95.70 €	100.10 €	104.50 €
	2	106.54 €	114.24 €	121.71 €	128.78 €
	3	121.41 €	130.14 €	139.36 €	149.26 €
	4	133.85 €	145.00 €	159.54 €	175.33 €
	5	153.85 €	171.31 €	195.65 €	223.37 €
	6	166.35 €	188.86 €	220.00 €	266.38 €

Table 19 Map of rate sheet groups Paris and average cost overview

The weight of the outbound shipments for FY 16/17 overall was at 2.827 t. However, this weight includes shipments using Incoterms, that do not give the responsibility for the transport to Hella. Shipments using the Incoterms EXW and FCA are excluded, since the responsibility for the transports is at the buyer.⁶ Furthermore, returns are excluded, because they are paid for by the buyer. The applicable transport weight is 1,499 t and is split as shown in Table 20.

Forwarder	Paris (in t)	Lyon (in t)	Marseille (in t)	Sum (in t)
TNT National Express	278	29	45	352
Schenker	1,147	-	-	1,147
Total	1,425	29	45	1,499

Table 20 Applicable transport weight by warehouse

On the one hand, Paris is using LTL and CEP transports to deliver to their customers and replenish the branch warehouses. On the other hand, the branch warehouse in Lyon and Marseille only deliver to Hella's customers via CEP shipments. The reason for just Paris using LTL shipments is, that it is Hella's main warehouse in France and therefore stores most of the goods. Also, Paris as the most northern location of Hella in France is in this case the best location to consolidate shipments for customers and therefore be able to use LTL shipments rather than CEP ones. The warehouses in Lyon and Marseille mostly supply Hella's customers in southern France with CEP shipments. LTL shipments going to bigger customers in the south are mostly transported from the main warehouse to the

⁶ Incoterms are commercial terms regulating the risk and cost transfer during shipments.

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customer directly. Furthermore, the transports from the main warehouse in Paris to the branch warehouses in Lyon and Marseille have to be looked at. For the replenishment of those warehouses LTL shipments are chosen. Those shipments transport on average one pallet to each of the warehouses. The frequency for replenishment is once a week for Lyon and twice a week for Marseille. The costs for those transports according to the actual LTL rate sheets are at 24,648 €.

The outbound transports for the as-is scenario can be seen in Figure 20 below. Overall, the costs for outbound transports to customers is at 1,144,396 € and for replenishment of the warehouses the cost is at 24,648 €. Therefore, the overall cost for outbound transports is 1,169,044 €.

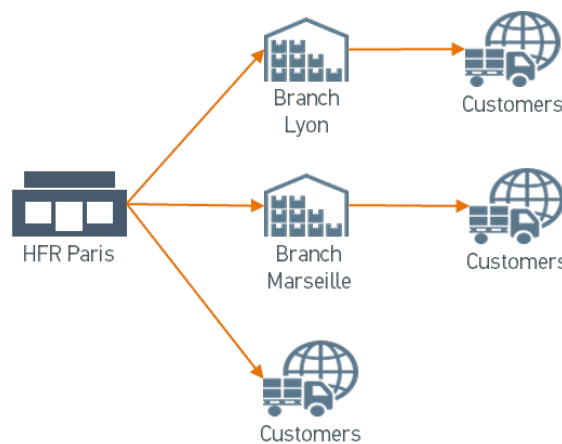


Figure 20 As-is outbound transport overview

To make sure that the chosen rate sheet grouping is accurate, the as-is situation is calculated by using the rate sheet with six groups, and then compared to the actual as-is cost in FY 16/17. Since the cost for the CEP shipments are the same on a national level, there is no change of costs when re-locating the warehouse. However, the distance is a factor for the freight rates for LTL shipments. The comparison of the actual and calculated outbound transportation cost can be seen in Table 21 below. The difference of only 2.24 % is an indicator for the accuracy of the grouped rate sheets.

Forwarder	Paris – actual (in €)	Paris – calculated (in €)	Difference (in %)
TNT National Express	500,684	500,684	-
Schenker	642,696	668,360	+3.99
Total	1,143,380	1,169,044	+2.24

Table 21 Comparison grouped rate sheet cost to actual rate sheet cost

5.2.1.4 Conclusion

Table 22 below gives an overview over all cost types that occur in the current distribution network in France. The basis for the inbound transports are 99.50 % of the actual inbound

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volume HFR had in the FY 16/17. Warehousing costs and outbound transports are based on the actual weights that were transported in the FY 16/17. Inbound transports represent the smallest share of the overall cost and warehousing and outbound transports have about the same influence on the overall cost in the current supply chain setup.

Cost type	Cost (in €)	Share of total cost (in %)
Inbound transports	373,000	13.43
Warehousing	1,235,408	44.48
Outbound transports	1,169,044	42.09
Total	2,777,452	100.00

Table 22 As-is cost

More than 40 % of the IAM and 8 % of the SOE customers demand a same or next day delivery. To be able to identify the service level being offered to those customers with the as-is supply chain setup, the possible area to be covered in one day has to be identified. Therefore, a driving visualization is chosen to show which parts of France can be delivered withing the given time frame by taking the laws and regulations for truck transports into consideration. One day of transportation according to laws of the European Union equals a maximum of ten hours of driving.⁷ The average speed for trucks is estimated at 70 km/h. Figure 21 below shows the driving visualization with those aspects as a basis from Paris. The customers in the far south of France cannot be delivered with same and next day deliveries due to the high distance.

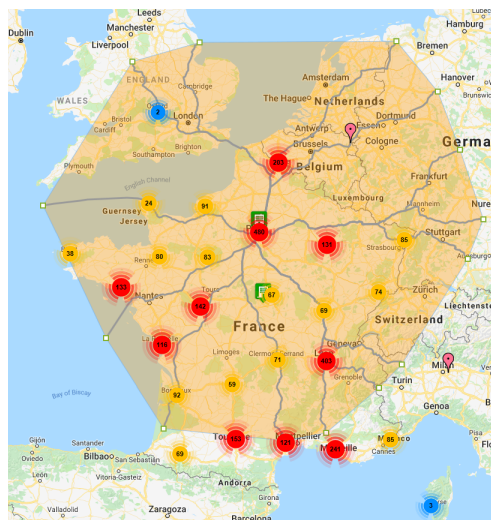


Figure 21 Driving simulation from Paris

In simulation it is important to make sure that the model based on the as-is situation is as close to reality as possible. For the inbound transports 99.50 % of the actual inbound volume are taken into consideration. There is no data available about the other 0.50 %

⁷ According to regulation EG 561/2006

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which is mostly delivered by external suppliers, therefore no difference between actual and as-is model cost can be identified. However, putting the 0.50 % in relation to the 99.50 %, which come up to a cost of 373,000 €, the cost for the leftover inbound transports cannot be decisive. The warehousing costs in the as-is model represent the actual cost, therefore the accuracy in this part of the model is given. For the outbound transports the rate sheets were grouped to be able to replicate the rate sheet structure to the new warehouse location in the next step. The as-is model cost is about 2.24 % higher than the actual cost in FY 16/17 (see Table 23). However, overall the difference in cost between the as-is model and the actual situation is at 0.93 %. Therefore, the accuracy in the simulation model is given and the usage of this model on the to-be situation is possible.

Cost type	Cost (in €) -actual	Cost (in €) – as-is model	Difference (in %)
Inbound transports	373,000	373,000	-
Warehousing	1,235,408	1,235,408	-
Outbound transports	1,143,380	1,169,044	+2.24
Total	2,751,788	2,777,452	+0.93

Table 23 Comparison as-is model to actual cost

5.2.2 Simulation based on Center of Gravity

The simulation for the purpose of this research is conducted on the basis of the outcome of the center of gravity optimization model. As a basis for the COG the weights of the goods are chosen for the cost calculation of outbound transports from HFR.

As in the simulation for the as-is situation, the inbound transports are looked at first. The impact of the new warehouse location on the transport cost from HD and other sources is analyzed. Then the warehousing costs, including warehouse and office personnel, are analyzed according to the reduction of number of warehouses from three to one. Following up on that, the outbound transports, which supply Hella's 3,100 ship-to-parties, are looked at in detail to see if there is an improvement in transport costs and service level due to the new possible warehouse location being at the center of gravity of Hella's customers in France (see Figure 22).



Figure 22 Map of future supply chain setup

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To run the simulation model on the to-be situation, the input parameters have to be changed accordingly. The change of the input parameters can be seen in Table 24 below.

Parameter	As-is model	To-be model
Warehouse location	– Paris, Lyon, Marseille	– Bourges
Shipment data	– Inbound: HD, Hella BHAP and Hella New Zealand – Outbound: HFR to customers, HFR to branches, branches to customers	– Inbound: HD, Hella BHAP and Hella New Zealand – Outbound: HFR to customers
Costs for inbound transports	– From HD: 319 trucks to HFR Paris (600 km) – From Hella BHAP / Hella New Zealand: Fix cost of 87.000 €	– From HD: 319 trucks to HFR Bourges (850 km) – From Hella BHAP / Hella New Zealand: Fix cost of 87.000 €
Costs for warehousing	– Handling of shipments in three warehouses – 22 employees	– Handling of shipments in one warehouse – 18 employees
Costs for outbound transports	– LTL: Schenker rate sheets (grouped with Paris as starting point) – CEP: TNT rate sheets	– LTL: Schenker rate sheets (grouped with Bourges as starting point) – CEP: TNT rate sheets
Customer requirements	– Service level requirements demanded by customer	– Service level requirements demanded by customer

Table 24 Change of input parameters from as-is model to to-be model

5.2.2.1 Inbound

To be able to simulate the new warehouse location in Bourges, the change in transportation cost in the inbound transports is calculated. The cost for the transports in the FY 16/17 was 373,000 €, which splits in 286,000 € for the transports from HD to HFR and 87,000 € for the transports via air-cargo from Hella BHAP Automotive and Hella New Zealand Limited. As mentioned before the cost for the transports via air-cargo is not changing drastically due to the change of the warehouse location from Paris to Bourges, since the main run comes up with the largest split of the transport cost. The post-run does not have enough influence on the overall transport cost, and therefore the cost estimated stays the same. However, the increase of the transport costs for FTL transports from HD in Germany to France has to be calculated. The current distance between HD and HFR in Paris is at about 600 km. The future distance between HD and Bourges is at about 850 km. Therefore, the increase in distance is at about 250 km. According to the Purchasing Services department (personal communication, 15.05.2018), the change in costs for the same amount of 319 trucks and an increase of distance of 250 km can be estimated at about 105,000 €. Therefore, the overall cost of inbound transportation is at 478,000 €.

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One point that has to be mentioned when looking at the increase in transport cost of about 105,000 € each year is that the attractiveness of the region for the forwarder is not looked at. The attractiveness of the region is for example specified by the expected possibility for the forwarder to organize round-trips to prevent empty runs. Looking at the region of Paris it is most likely a more attractive region for a forwarder than the region of Bourges, which is about 250 km south of Paris, because more businesses and therefore transports are happening in that region. In case the region of the new warehouse location is less attractive to the forwarder, it could lead to a further cost increase for the inbound transports. Other factors influencing the attractiveness of the region can be traffic connections and street conditions. An overview of the to-be inbound transports can be seen in Figure 23.

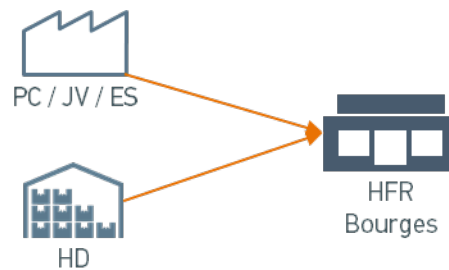


Figure 23 To-be inbound transports overview

5.2.2.2 Warehousing cost

A new warehouse and office building are rented in the region of Bourges to supply the customers from the new warehouse location identified in the optimization. The space necessary is the same as in the current distribution setup with 5,000 m² warehouse and 1,250 m² office space. The cost for renting office space in Bourges is at 6 €/m² and at 3 €/m² for renting warehouse space (Real estate governance department, personal communication, May 28, 2018). Therefore, the overall renting cost is at about 22,500 € a month. The basis for the costs generated by the new warehouse in Bourges are taken from the cost of the current main warehouse in Paris. Since the branch warehouses would no longer be necessary, the associated costs (e.g. personnel, rent and maintenance) are cancelled out. Considering the warehouses in Lyon and Marseille have a relatively small size (each less than 50 m² of goods), the handling for those goods at the new warehouse location does almost cause no extra work and therefore no employees from the branch warehouses are taken over into the new warehouse in Bourges. However, the costs for renting a new warehouse in the region of Bourges with about 270,000 € a year are taken

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into consideration. Overall, the costs of the new distribution network concerning warehousing is at 1,192,553 €, as seen in Table 25 below.

Cost type	Paris / Lyon / Marseille (in €)	Bourges (in €)
Personnel	649,724	540,419
Social benefits	293,964	241,909
Subtotal personnel cost	943,688	782,328
External Service	92,873	84,268
Maintenance	33,464	30,291
Rents and leasing	95,229	270,000
Travel expenses	2,932	2,524
Others	67,222	23,142
Subtotal operating expenses	291,720	410,225
Total	1,235,408	1,192,553

Table 25 Expenses for future warehouse in Bourges

5.2.2.3 Outbound

The next step is to calculate the change in transportation cost for the outbound transports using the grouped rate sheets.

To be able to apply the grouped rate sheets based on the as-is scenario, the circles built up are moved towards the new warehouse location in Bourges. Then, the departments are assigned to their rate sheet group, which gives information about the freight rates. The map of the rate sheet groups and the freight rates can be seen in Table 26 below. Also, rate sheet group number six is no longer needed, since the new warehouse location is closer to the centre of France and therefore the maximum distance is reduced.

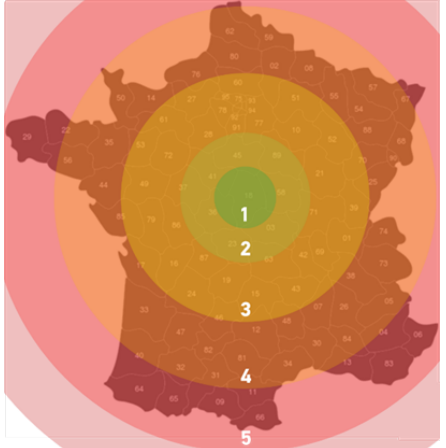
Map of rate sheet groups	Group	1 pallet	2 pallets	3 pallets	4 pallets
	1	89.10 €	95.70 €	100.10 €	104.50 €
	2	106.54 €	114.24 €	121.71 €	128.78 €
	3	121.41 €	130.14 €	139.36 €	149.26 €
	4	133.85 €	145.00 €	159.54 €	175.33 €
	5	153.85 €	171.31 €	195.65 €	223.37 €
	6	-	-	-	-

Table 26 Map of rate sheet groups Bourges and average cost overview

By re-locating the main warehouse from Paris to Bourges, and eliminating the second supply chain stage in France, the CEP transports which in the current setup are send out from the branches, now have to be send out from the main warehouse in Bourges. However, for CEP transports no new rate sheets are needed since the prices for CEP are

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the same all over France, just depending on the weight and not the distance. Therefore, the sum of transportation costs for CEP transports with TNT National Express stays the same, even though the CEP shipments from the branches are now delivered from Bourges. Therefore, the complexity of the outbound transports of HFR is reduced, as seen in Figure 24.



Figure 24 To-be outbound transports overview

The weight data for the outbound transports is the same as in the as-is scenario, however, the goods that were shipped via CEP from the branch warehouses are now also being shipped from Bourges, as seen in Table 27. Also, the shipments from HFR in Paris to the branch warehouses no longer have to be considered.

Forwarder	Bourges (in t)	Bourges (in €)
TNT National Express	352	616,730
Schenker	1,147	500,684
Total	1,499	1,117,414

Table 27 Applicable transport weight from branches

For the amount of 1,149 t transported by Schenker using LTL transports come up to a overall cost of 616,730 €. The cost for CEP shipments, with a combined weight of 352 t stays at 500,684 €. The overall shipment cost for outbound transports is therefore 1,117,414 €.

5.2.2.4 One-time cash effect

The simulation looks at the whole distribution scenario in an already implemented and smoothly running way. However, a one-time cash effect will occur when changing the distribution structure of Hella in France. This cash effect is not a part of the simulation, but it will still be looked at to make sure that the decision is made based on the overall costs. An overview is given in Table 28 below.

The first aspect of the one-time cash effect are the moving costs, which include re-locating the main warehouse from Paris to Bourges and also integrating the two branches in Lyon and Marseille into the new main warehouse in Bourges (e.g. inventory, shelves). Assuming a stock with a volume of about 8,100 m² in Paris and transportation cost for the route Paris to Bourges of 422 € per truck (according to the rate sheets), the overall moving cost for 150 trucks will be at about 63,300 €. The transportation of the

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stock from Lyon and Marseille can be handled by using a truck for each of the locations, since the volume of the stock at each location is less than 50 m³. Those transports will come up at a cost of about 943 € according to Hella's current rate sheets.

The second aspect is the sale of the old building, which is currently owned by Hella and paid off completely. The expected revenue for the sale of the current warehouse building is at approximately 1,900,000 € (Real estate governance department, personal communication, May 28, 2018).

The third aspect is travel costs related to the project. The assumption here is, that six persons will go on five business trips to get a deeper understanding of the situation in France and to coordinate the project.⁸ Each business trip consists of costs for flight, accommodation and other expenses which comes up to 500 € a person. Therefore, the overall travel costs related to this project will be 15,000 €.

The last aspect is redundancy payments. Those payments have to be made due to the new location for the main warehouse in France. Most probably none of the employees are willing to move with the warehouse to keep their job. Therefore, redundancy payments have to be done and new employees need to be hired. Redundancy payments come up at about 974,940 € for all 22 employees of Hella in France.⁹

Cost type	Cost (in €)
Moving cost	64,243
Sale of old building	-1,900,000
Travel cost	15,000
Redundancy payments	974,940
Total	-845,817

Table 28 One-time cash effect

5.2.2.5 Conclusion

Table 29 below gives an overview over all cost types that occur in the future distribution network in France. The basis for the inbound transports is 99.50 % of the actual inbound volume HFR had in the FY 16/17. Warehousing costs are based on the costs that occurred at the main warehouse in Paris, since the activities carried out in the branch warehouses are minor and will be able to be done by the personnel which is currently working in the main warehouse. There is not a high demand for extra handling or other activities. Adding to that are the expected cost of renting the new warehouse. The outbound transports are

⁸ Assumption made by HCC-LOMN

⁹ Assumption made by HCC-LOMN

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based on the actual weights that occurred in the FY 16/17, with the cost being calculated by using the grouped rate sheets with Bourges as the starting point.

Overall, as mentioned for the as-is scenario as well, the inbound transports have the smallest share of the overall cost and warehousing and the outbound transports have about the same share.

Cost type	Cost (in €)	Share of total cost (in %)
Inbound transports	478,000	17.14
Warehousing	1,192,553	42.78
Outbound transports	1,117,414	40.08
Total	2,787,967	100.00

Table 29 To-be cost

The following Figure 25 shows the driving simulation to give an indication on which customers can be delivered regarding same and next day deliveries. With Bourges as the starting point same and next day deliveries are available to all French customers, which offers a high service level.

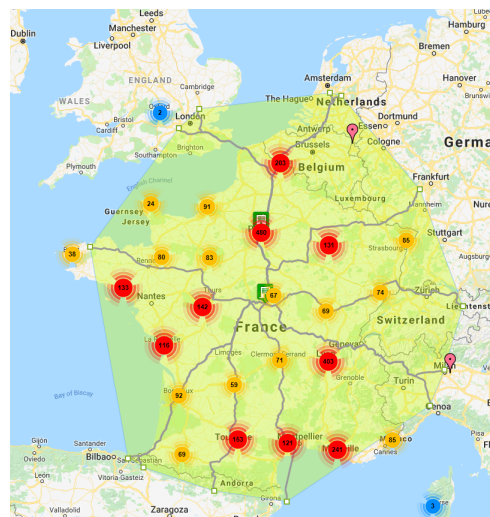


Figure 25 Driving simulation from Bourges

5.3 Scenario comparison

Now that the as-is scenario with the main warehouse being located in Paris, and the two branch warehouses being located in Lyon and Marseille, and the to-be scenario with the only warehouse being in Bourges are analyzed, both of them are compared regarding efficiency and responsiveness to be able to make recommendations based on that.

5.3.1 Costs

As shown in Table 30 below, the overall costs a year when comparing the as-is to the to-be situation of the distribution network show an increase of about 0.38 %. This shows, that by changing Hella's setup in France from two to one supply chain stage and from three to only one warehouse the overall cost is about the same.

Cost type	As-is (in €)	To-be (in €)	Change (in €)	Change (in %)
Inbound transports	373,000	478,000	+ 105,000	+ 28.15
Warehousing	1,235,408	1,192,553	- 42,855	- 3.46
Outbound transports	1,169,044	1,117,414	-51,630	-4.41
Total	2,777,452	2,787,967	+ 10,515	+ 0.38

Table 30 Scenario cost comparison

Taking a look at the one-time cash effect above, it can be seen that there are costs of about 1,054,183 € to be expected. Nonetheless, the sale of the current warehouse building in France would be able to cover for those costs and even leave a plus of 845,817 €.

However, even though the cost for the distribution network of Hella in France stay about the same, the fact that the maximum distance to Hella's customers from the main warehouse is decreased is a positive aspect looking at possible future business growth. With growing business Hella can profit from lower freight rates due to smaller distances (see Figure 26). Furthermore, taking out one supply chain stage, by eliminating the branch warehouses, reduces the complexity in Hella's distribution network in France.

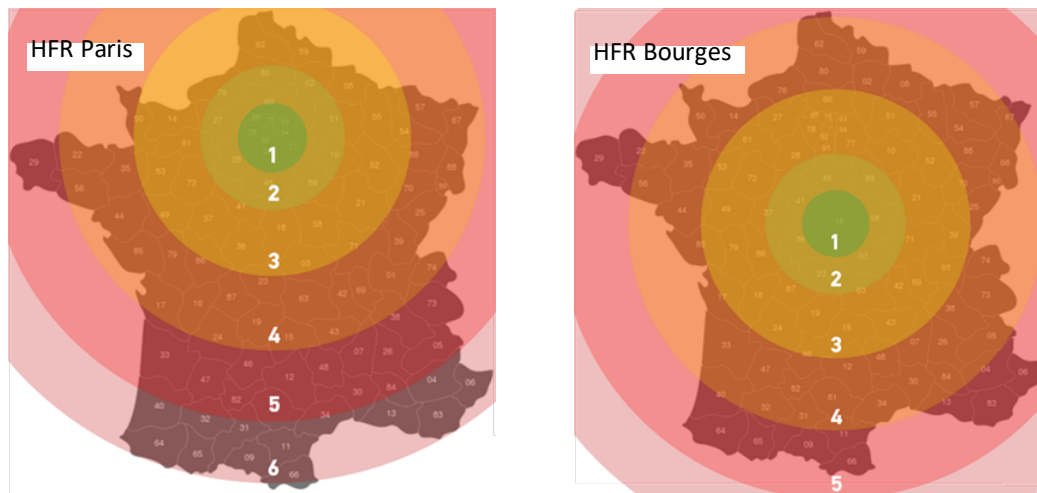


Figure 26 Transport cost comparison according to rate sheets

5.3.2 Service level to the customers

To be able to serve their customers, Hella has to be able to fulfill their service level requirements. Since many of the customer clusters have a high amount of same and next day deliveries it is important that Hella can fulfil those requirements. Therefore, the warehouse has to be located in proximity to the customers so that they can be reached within one day of transportation.

As visible in the combined driving visualization in Figure 27, almost all customers that can be reached from Paris can also be reached from Bourges. Furthermore, there are three big groups of customers located in the south of France, with more than 500 ship-to-parties. In the driving visualization with Paris as the basis, those ship-to-parties can not be reached within one day, which means that same and next day deliveries are not possible, since the goods are first transported to the main warehouse in Paris and then transported on to the branch warehouses in the next step. However, taking Bourges as the basis for the driving visualization, one can see that all of those ship-to-parties in the south of France can be reached in the set time limits.

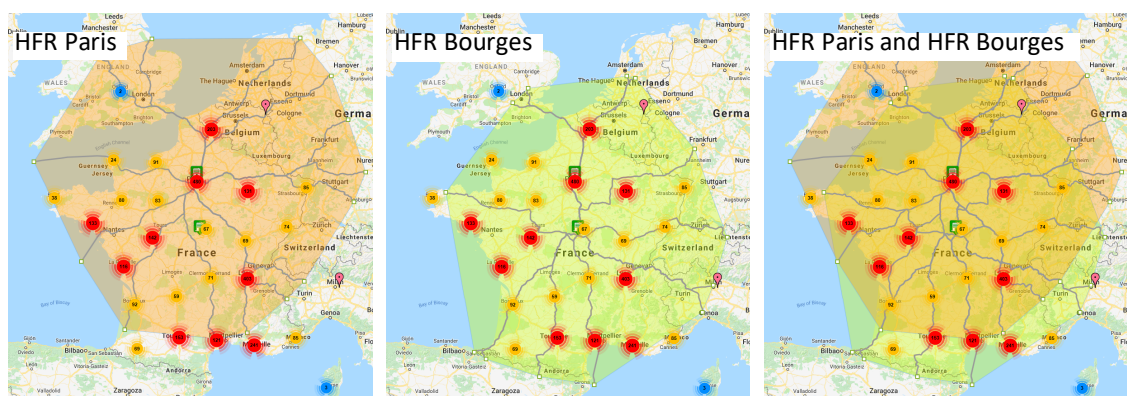


Figure 27 Driving visualization from Paris and Bourges

When looking at Hella's supply chain in France and at the different scenarios regarding distribution network design, it is important to take efficiency and responsiveness of the supply chain into consideration, since facilities, inventory and transportation influence those supply chain structure characteristics.

Facilities

Reducing the amount of facilities generally comes with a decrease in responsiveness and an increase in efficiency. However, moving from three warehouses to only one main warehouse in France does not reduce the responsiveness of Hella. As visible in the driving visualization in Figure 23, Hella will still be able to be responsive to their customers' needs and will even be better in satisfying those needs by being able to cater better to the

customers in the south regarding same and next day deliveries. Nonetheless, the efficiency only decreases about 0.38 % due to increased cost in the overall supply chain.

Inventory

The inventory will in the to-be state of the distribution network only be kept in one place rather than three places across France. Responsiveness in this case does not change for Hella's customers, however, the efficiency increases due to the possibility of combining the stocks of all three warehouses and therefore being able to reduce safety stocks which were kept in each warehouse.

Transportation

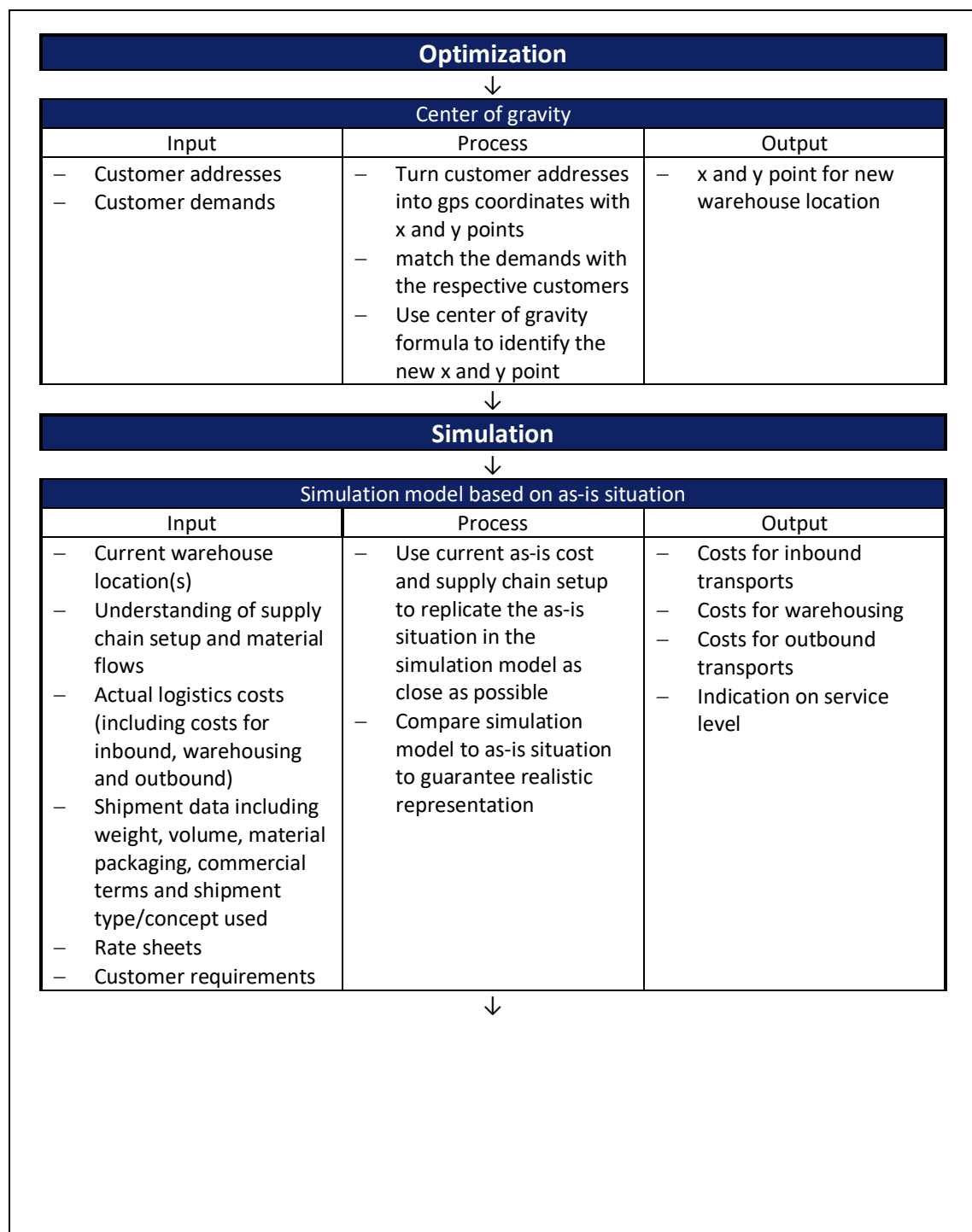
Transportation is another logistical driver with impact on the supply chain structure. By continuing the usage of CEP and LTL shipments to the customers, the responsiveness is kept up for Hella's distribution structure in France. However, eliminating transports between HFR in Paris and the branch warehouses in Lyon and Marseille as well as reducing transport distances to customers in France the efficiency can be kept at about the same level even though the transport costs from HD to HFR will increase.

Hella does not really have a strict supply chain strategy only taking responsiveness or efficiency into consideration, but rather is trying to find the right balance between both. The primary goal for Hella's supply chain is therefore to fulfil customer needs by keeping end-to-end supply cost low. This combines Hella's efforts in trying to respond as quickly as possible to demand taking the efficiency of the supply chain in consideration. Therefore, customer needs are only met if they come at an acceptable price. This theory stretches over all parts of the supply chain structure like inventory, lead-time and supplier strategy.

Overall, by re-locating the main warehouse from Paris to Bourges, Hella is able to increase responsiveness towards their customers while decreasing cost efficiency only to a negligible extent.

5.4 The two-step model

To be able to use the created two-step model on other cases at Hella, as well as on other cases in general, the approach used, including data input necessary, processes carried out and the output created, is presented in Figure 28. Based on the output of the two-step model, the as-is and to-be situation based on the center of gravity are compared and differences in costs and service level are identified. Then, the two scenarios are compared to come to a decision regarding the distribution network design.



5 Analysis

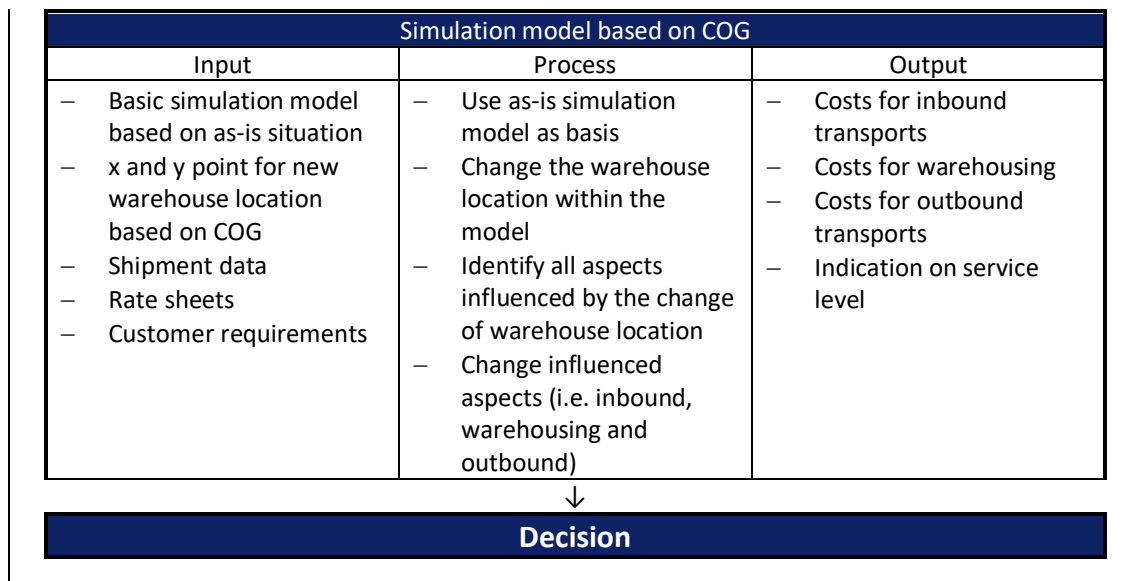


Figure 28 Two-step model including inputs, processes and outputs

6 Discussion

This part of the thesis is supposed to give a voice to speculations and assumptions made during the research process, as well as showing up weaknesses that may result from those.

First of all, in the beginning of this research it was mentioned that packaging costs are not going to be looked at in further detail, since they only make up about 0.18 % of the sales of Hella in France. However, if delivery scenarios are changing due to new warehouse locations and a reduction in overall warehouses in France it also needs to be checked that the packaging services necessary before delivering to the customer (e.g. labeling) can be done at the new warehouse location.

Another aspect is that a possible change in delivery scenarios for some of the customer clusters has not been looked at in the course of this research. There might be a possibility to deliver to some of the customer clusters directly from HD in Erwitte and no longer over HFR. Especially SOE customers in France with high demands would be a possible suspect for a future look at those possibilities. This change would amongst others have an impact on the inventory in the warehouses, necessary warehouse space and the utilization of the trucks.

Furthermore, in the inbound deliveries the main aspect was put on the 99.5 % of the volumes and some of the smaller external suppliers have been neglected due to small volumes. However, when looking at the execution of the warehouse relocation, all inbound deliveries should be looked at and also the 0.5 % that have been neglected so far should be analyzed to make sure that the new distribution structure will be successful. Also, the airfreight which was considered from suppliers in China and New Zealand would have to be looked at in more detail to be able to identify the cost increase for the possible longer post-run.

When taking a look at the optimization and simulation approaches, the region chosen was Bourges in France. In case of a re-location of Hella's main warehouse in France, the forwarder hubs in the region have to be looked at. The location of forwarder hubs influences the cut-off times for customer orders as well as the price paid for the transports.

Also, during this research the focus was set on material flows only. When looking at a supply chain it is important to not only look at material but also at information flows. This is necessary to make sure that the supply chain planned regarding material flows can also be carried out by using the current information systems in place, or the ability to improve the systems, and the occurring costs, need to be looked at.

6 Discussion

The one-time cash effect taken into consideration when using the simulation approach based on the center of gravity were taken from experiences from past projects. Therefore, this cash effect can only be taken as an indication and each of the cost types has to be checked in detail before actually switching the distribution network design.

The last point for discussion is the possibility of choosing a service provider to run the warehouse rather than Hella employees. This possibility has not been looked at further during this research, however, it might be possible to have higher cost savings by outsourcing the warehousing activities to a service provider.

However, despite the points mentioned in this discussion, the two-step model consisting of an optimization and a simulation model is trusted by the decision-makers at Hella.

7 Conclusion and recommendations

The overall topic for the research at Hella GmbH & Co. KGaA was concerned with distribution network design and how to use qualitative methods and quantitative models in a business setting. Optimization and simulation models were chosen for analysis during this research. Optimization approaches are characterized by solving the underlying model using mathematically-formal procedures, whereas simulations are characterized by experimentation on models by changing parameters.

A focus group with six employees was conducted to identify the preference of the decision-makers regarding optimization and simulation models in warehouse location. The outcome of the focus group showed that neither of the approaches is preferred over the other one, but rather both approaches should be build-up on each other to reduce weaknesses and increase the overall strength of the new build two-step model.

For the purpose of this research the weighted center of gravity approach and a static and deterministic simulation are chosen due to the database available at the case company and the classification of warehouse location into the first phase of supply chain design. By applying the optimization model, the center of gravity based on the inbound volumes of Hella in France is identified. Then, by using a simulation model, the as-is situation is simulated, to make sure that the model is accurate enough. Then the warehouse amount and location are switched, which leads to a change in freight rates as well as costs for warehouse space. After the to-be situation was analyzed the as-is and to-be situations were compared, to identify that there is a slight cost increase of about 0.38 % by re-location the warehouse. However, since the new warehouse location is closer to the centre of France as the old one, the logistical requirements of the customers regarding same/next day deliveries can be handled better. Therefore, the responsiveness of Hella in France increases while keeping the efficiency at about the same level.

Connecting this research to other research shows that until now mostly warehouse location models have been looked at separately. It is just recently that more research has gone into the combination of e.g. optimization and simulation approaches. Therefore, this research provides another aspect to this growing field of research, since it shows that in a business setting combined approaches are preferred over choosing a single method or model, because it makes the overall outcome more reliable. Also, by choosing dynamic and probabilistic simulation models, the supply chain planning and operation phase of supply chain design can be visualized.

7 Conclusions and recommendations

For future distribution network design decisions at Hella, the proposed two-step model should be used, to be able to have a quick indication first by using the weighted center of gravity approach, and then have the overall end-to-end costs of the supply chain by analyzing it in-depth by using a simulation model. By doing that, the first indication can be seen as kind of a barrier. If the outcome of the weighted COG is close to the actual warehouse location at the current state, further research might be unnecessary. Therefore, using an optimization approach first to get a quick indication of the situation can also help Hella to go easy on their resources.

Overall, this research provides an interesting perspective on the usage of warehouse location methods and models in a business, by taking the persons who in the end take the decision into consideration.

Appendices

Appendix 1 – Customer clusters

Customer Cluster	IAM				
	Wholesaler				5 Importer
	1 Commercial buying groups w/o log. structure	2 Buying groups with log. structure	3 Independent platforms	4 Traditional WD with log. structure	
Explanation customer groups	> delivery to members, small WDs with regional focus ex ID recharge	Business with WD through buying groups with log. platform: Ex AAG, ADF, AAP	Regional hub independent from platform, regional distributor 2 main networks in France: Apprax and GFI Apprax has 5 members, GFI was founded by districash	national & intern. WD, business to members with platform, bigger structures of AAG, AD Temot and AAP	Car importers: VAG, Mercedes, Japanese and Korean, MAN
Sales in EUR (FY14/17)	2,226,064	5,436,800	1,083,125	15,524,548	951,031
Sales Share per cluster IAM	6%	14%	3%	44%	3%
Sales Share per cluster SOE					
Number of Customers	263	9	7	175	9
Number of Ship to Parties	434	47	19	1310	129
Top Customers	Adherents Agra 0.5 m€ ID Recharge Ind. 0.3 m€ Alliance Group Auto Fr. 0.3 m€ Adherents 0.2 m€	Cora 2.9 m€ Alliance Group Auto Fr. 1.2 m€ Plateforme Agra 0.3 m€ Brenstar 0.3 m€	PAP 0.4 m€ ADIPA 0.2 m€ DASIR 0.2 m€	Alliance Group Auto 4.6 m€ Fr. CBM 1.0 m€ IDLP 0.6 m€ SOEXIMEX 0.6 m€	Volkswagen 0.6 m€ MAN Truck 0.1 m€ Mercedes Benz 0.1 m€
Top 5 product categories (m€)	Cooling products 333,929 Universal 299,244 Workshop equipment 225,205 Air-conditioning 224,911 Brakes 148,571	Headlights 2,400,779 Cooling products 453,132 Rear lights and indicators 471,722 Air-conditioning 287,225 Electronic parts 260,555	Headlights 354,836 Rear lights and indicators 175,183 Universal 131,538 Air-conditioning 124,328 Cooling products 95,085	Headlights 3,309,771 Cooling products 2,722,117 Universal 1,501,071 Air-conditioning 1,269,788 Workshop equipment 1,170,905	Universal 840,107 SOE Headlights 64,175 SOE government equip. 24,302 SOE marker lights 13,742 Cooling products 6,563
	1,231,863	4,073,413	880,970	9,973,592	946,909
Shipping condition (used)	same/next day 70%	same/next day 4%	same/next day 14%	same/next day 39%	same/next day 7%

Customer Cluster	IAM			
	Fast Fitter			9 E-commerce
	6 Fast Fit National Platform	7 Fast Fit Workshops/Outlet	8 Fast Fit Diagnostics (HGS)	
Explanation customer groups	Nora Auto, Leclerc Auto, Tyre specialists, Roady, etc. and tyre specialists moving to parts (seuromaster)	Same as Fast Fit National Platform, but mainly franchises and independent affiliates	Same players including glass specialists	Oscaro, Mister Auto, Yakarouler and other specialists, probably development with Ebay
Sales in EUR (FY14/17)	1,095,691	726,422	1,495,042	6,653,757
Sales Share per cluster IAM	3%	2%	4%	19%
Sales Share per cluster SOE				
Number of Customers	1	9	6	3
Number of Ship to Parties	1	596	202	7
Top Customers	Logic System 1.0 m€	Nora Auto 0.4 m€ Group Feu Verts 0.2 m€ Contratrade 0.2 m€	Carglass 0.8 m€ France Pare Brise 0.6 m€	Oscaro 5.5 m€ Mister Auto 1.0 m€ Yakarouler 0.1 m€
Top 5 product categories (m€)	Brakes 923,525 Air-conditioning 59,518 Electronic parts 29,138 Cooling products 26,423 Universal 13,372	Brakes 289,221 Air-conditioning 275,833 Electronic parts 79,466 Cooling products 58,773 Headlights 34,927	Workshop equipment 1,716,452	Brakes 1,726,110 Universal 1,229,725 Cooling products 931,866 Headlights 815,069 Rear lights and indicators 690,802
	1,052,174	738,220	171,645	5,393,572
Shipping condition (used)	same/next day 26%	same/next day 70%	same/next day 68%	same/next day 100%

Customer Cluster	SOE		
	10 Big SOE	11 Mid SOE	12 Small SOE
Explanation customer groups	Top 10 SOE Customers	Top 11-20 SOE Customers	all other SOE Customers
Sales in EUR (FY14/17)	9,876,482	5,490,025	352,350
Sales Share per cluster IAM			
Sales Share per cluster SOE	63%	35%	2%
Number of Customers	23	118	115
Number of Ship to Parties	41	155	124
Top Customers	AF CO SA 1.9 m€ CLAAS Tractor SAS 1.8 m€ MANITOU ANCIENS 1.3 m€	SPRI - BU TECHNOLOGIE 0.27 m€ CATERPILLAR SWITZERLAND 0.27 m€ SNCF MOBILITES 0.23 m€ PREOCULTURE 0.21 m€	CABINES SILVA TAVARES 0.01 m€ VANS BARBOT SARL 0.01 m€ SAFE PARTS INTERNATIONAL 0.01 m€
Top 5 product categories (m€)	SOE Arbeitscheinw. PS-Prod. 2,400,451 SOE Frontbeleuchtung/ Zubeheer 2,310,502 SOE Heckleuchten 2,060,978 SOE Elektronik / Elektronik 436,208 SOE Andere 395,811	SOE Frontbeleuchtung/ Zubeheer 1,192,207 SOE Arbeitscheinw. PS-Prod. 649,161 SOE Heckleuchten 607,825 SOE Universal Produkte 485,045 SOE Markierungsleuchten 430,044	SOE Markierungsleuchten 39,584 SOE Innenleuchten 30,109 SOE Heckleuchten 37,968 SOE Behordengeräte 33,932 SOE Arbeitscheinw. PS-Prod. 32,447
	7,622,313	3,394,305	162,050
Shipping condition (used)	same/next day 4%	same/next day 4%	same/next day 10%

Appendix 2 – Inbound volumes of Hella Group owned suppliers

Company	Volume (in m²)	Share of total inbound (in %)
Hella GmbH & Co. KGaA	9,231.23	53.83
Behr Hella Service GmbH	5,264.97	30.70
Hella Pagid GmbH	813.53	4.74
Hella Gutmann Solutions GmbH	592.75	3.46
Hella Fahrzeugteile Austria GmbH	452.88	2.64
Hella Lighting Finland Oy	312.22	1.82
Hella BHAP Automotive	240.94	1.40
HKG Nellingen	116.95	0.68
Hella-New Zealand Limited	39.26	0.23
Subtotal	17,082.74	99.50
Hella Romania S.R.L.	1.52	0.01
Hella Fahrzeugkomponenten GmbH	0.90	0.01
Hella Limited	0.67	< 0.01
Hella Automotive Sales, Inc.	0.15	< 0.01
Hella Benelux B.V.	0.11	< 0.01
Hella Aglaia Mobile Vision GmbH	0.02	< 0.01
Hella S.P.A.	0.01	< 0.01
Hella Australia PTY LTD	< 0.01	< 0.01
Total	17,086.12	99.52

[illegible]

Appendix 4 – Rate sheet TNT Express National

Weight, up to	Express		12:00 Express		10:00 Express		9:00 Express		Express
	Regi onal	Nat i onal	Regi onal	Nat i onal	Regi onal	Nat i onal	Regi onal	Nat i onal	Cors i ca
0 to 0.5 kg	4,35	4,35	5,35	5,35	7,35	7,35	8,35	8,35	24,13
0.5 kg to 1 kg	4,45	4,45	5,45	5,45	7,45	7,45	8,45	8,45	24,77
2 kg	4,82	4,93	5,82	5,93	7,82	7,93	8,82	8,93	25,07
3 kg	5,05	5,16	6,05	6,16	8,05	8,16	9,05	9,16	24,94
4 kg	5,28	5,39	6,28	6,39	8,28	8,39	9,28	9,39	25,17
5 kg	5,51	5,62	6,51	6,62	8,51	8,62	9,51	9,62	25,40
6 kg	5,74	5,85	6,74	6,85	8,74	8,85	9,74	9,85	25,63
7 kg	5,97	6,08	6,97	7,08	8,97	9,08	9,97	10,08	25,86
8 kg	6,20	6,31	7,20	7,31	9,20	9,31	10,20	10,31	26,09
9 kg	6,43	6,54	7,43	7,54	9,43	9,54	10,43	10,54	26,32
10 kg	6,66	6,77	7,66	7,77	9,66	9,77	10,66	10,77	26,55
11 kg	6,89	7,00	7,89	8,00	9,89	10,00	10,89	11,00	26,78
12 kg	7,12	7,23	8,12	8,23	10,12	10,23	11,12	11,23	27,01
13 kg	7,35	7,46	8,35	8,46	10,35	10,46	11,35	11,46	27,24
14 kg	7,58	7,69	8,58	8,69	10,58	10,69	11,58	11,69	27,47
15 kg	7,81	7,92	8,81	8,92	10,81	10,92	11,81	11,92	27,70
16 kg	8,04	8,15	9,04	9,15	11,04	11,15	12,04	12,15	27,93
17 kg	8,27	8,38	9,27	9,38	11,27	11,38	12,27	12,38	28,16
18 kg	8,50	8,61	9,50	9,61	11,50	11,61	12,50	12,61	28,39
19 kg	8,73	8,84	9,73	9,84	11,73	11,84	12,73	12,84	28,62
20 kg	8,96	9,07	9,96	10,07	11,96	12,07	12,96	13,07	28,85
21 kg	9,19	9,30	10,19	10,30	12,19	12,30	13,19	13,30	29,08
22 kg	9,42	9,53	10,42	10,53	12,42	12,53	13,42	13,53	29,31
23 kg	9,65	9,76	10,65	10,76	12,65	12,76	13,65	13,76	29,54
24 kg	9,88	9,99	10,88	10,99	12,88	12,99	13,88	13,99	29,77
25 kg	10,11	10,22	11,11	11,22	13,11	13,22	14,11	14,22	30,00
26 kg	10,34	10,45	11,34	11,45	13,34	13,45	14,34	14,45	30,23
27 kg	10,57	10,68	11,57	11,68	13,57	13,68	14,57	14,68	30,46
28 kg	10,80	10,91	11,80	11,91	13,80	13,91	14,80	14,91	30,69
29 kg	11,03	11,14	12,03	12,14	14,03	14,14	15,03	15,14	30,92
30 kg	11,26	11,37	12,26	12,37	14,26	14,37	15,26	15,37	31,15
each kg extra	0,25	0,30	0,25	0,30	0,25	0,30	0,25	0,30	0,30

Appendix 5 – Grouped rate sheet LTL Paris

Group	ZIP code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	523	524	525	526	527	528	529	530	531	532	533	534	535	536	537	538	539	540	541	542	543	544	545	546	547	548	549	550	551	552	553	554	555	556	557	558	559	560	561	562	563	564	565	566	567	568	569	570	571	572	573	574	575	576	577	578	579	580	581	582	583	584	585	586	587	588	589	590	591	592	593	594	595	596	597	598	599	600	601	602	603	604	605	606	607	608	609	610	611	612	613	614	615	616	617	618	619	620	621	622	623	624	625	626	627	628	629	630	631	632	633	634	635	636	637	638	639	640	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665	666	667	668	669	670	671	672	673	674	675	676	677	678	679	680	681	682	683	684	685	686	687	688	689	690	691	692	693	694	695	696	697	698	699	700	701	702	703	704	705	706	707	708	709	710	711	712	713	714	715	716	717	718	719	720	721	722	723	724	725	726	727	728	729	730	731	732	733	734	735	736	737	738	739	740	741	742	743	744	745	746	747	748	749	750	751	752	753	754	755	756	757	758	759	760	761	762	763	764	765	766	767	768	769	770	771	772	773	774	775	776	777	778	779	780	781	782	783	784	785	786	787	788	789	790	791	792	793	794	795	796	797	798	799	800	801	802	803	804	805	806	807	808	809	810	811	812	813	814	815	816	817	818	819	820	821	822	823	824	825	826	827	828	829	830	831	832	833	834	835	836	837	838	839	840	841	842	843	844	845	846	847	848	849	850	851	852	853	854	855	856	857	858	859	860	861	862	863	864	865	866	867	868	869	870	871	872	873	874	875	876	877	878	879	880	881	882	883	884	885	886	887	888	889	890	891	892	893	894	895	896	897	898	899	900	901	902	903	904	905	906	907	908	909	910	911	912	913	914	915	916	917	918	919	920	921	922	923	924	925	926	927	928	929	930	931	932	933	934	935	936	937	938	939	940	941	942	943	944	945	946	947	948	949	950	951	952	953	954	955	956	957	958	959	960	961	962	963	964	965	966	967	968	969	970	971	972	973	974	975	976	977	978	979	980	981	982	983	984	985	986	987	988	989	990	991	992	993	994	995	996	997	998	999	1000	1001	1002	1003	1004	1005	1006	1007	1008	1009	1010	1011	1012	1013	1014	1015	1016	1017	1018	1019	1020	1021	1022	1023	1024	1025	1026	1027	1028	1029	1030	1031	1032	1033	1034	1035	1036	1037	1038	1039	1040	1041	1042	1043	1044	1045	1046	1047	1048	1049	1050	1051	1052	1053	1054	1055	1056	1057	1058	1059	1060	1061	1062	1063	1064	1065	1066	1067	1068	1069	1070	1071	1072	1073	1074	1075	1076	1077	1078	1079	1080	1081	1082	1083	1084	1085	1086	1087	1088	1089	1090	1091	1092	1093	1094	1095	1096	1097	1098	1099	1100	1101	1102	1103	1104	1105	1106	1107	1108	1109	1110	1111	1112	1113	1114	1115	1116	1117	1118	1119	1120	1121	1122	1123	1124	1125	1126	1127	1128	1129	1130	1131	1132	1133	1134	1135	1136	1137	1138	1139	1140	1141	1142	1143	1144	1145	1146	1147	1148	1149	1150	1151	1152	1153	1154	1155	1156	1157	1158	1159	1160	1161	1162	1163	1164	1165	1166	1167	1168	1169	1170	1171	1172	1173	1174	1175	1176	1177	1178	1179	1180	1181	1182	1183	1184	1185	1186	1187	1188	1189	1190	1191	1192	1193	1194	1195	1196	1197	1198	1199	1200	1201	1202	1203	1204	1205	1206	1207	1208	1209	1210	1211	1212	1213	1214	1215	1216	1217	1218	1219	1220	12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