MASTER

Activity cost analysis and cost-to-serve performance measurement

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Activity cost analysis and cost-to-serve performance measurement

by
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in partial fulfilment of the requirements for the degree of

Master of Science
in Operations Management and Logistics

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Management summary
A company’s profitability depends on selling price, cost of goods sold and the cost to serve its customers. In many companies the cost of goods sold are clearly described and there is lots of information and data available. On the contrary, the costs of serving a customer are often not clearly defined and therefore there is insufficient insight in the profitability of individual customers. In this report it is explained how the visibility can be increased and what can be done with this additional information.

The cost to serve a customer can be determined by using three general steps: identification of costs, estimation of the tariffs & allocation of the costs to the customers. The first step will identify the activities necessary to serve a customer, the costs related to these activities and the cost drivers of these activities. In the second step the fixed and variable costs will be identified by using regression and describing the relation between the activity costs and activity levels. After the fixed and variable costs are identified a tariff can be determined. Lastly the third step uses the tariff determined for allocation of activity costs to customers according to the cost driver.

On a high level the total customer costs $Y_c$ can be calculated by summing all the activity tariffs $a_i$ multiplied with the cost driver levels $x_{ic}$ of this customer for every activity $i$:

$$Y_c = \sum_{i \in I} a_i x_{ic}$$

The activity tariff $a_i$ can be calculated by using fixed ($F_i$) and variable ($V_i$) costs and the total activity level $X_i$:

$$a_i = F_i + v_i$$

With variable cost tariff $v_i = \frac{V_i}{X_i}$

The fixed and variable activity costs can be estimated with a simple linear regression with the total activity costs for period $p$ ($A_{ip}$) as dependent variable. This regression can also be used for forecasting:

$$A_{ip} = \hat{F_i} X_{ip} + \hat{v_i} X_{ip} + \epsilon_{ip}$$

With $\hat{F_i}$ and $\hat{v_i}$ being the estimations for respectively the fixed costs and the variable cost tariff for activity $i$. Besides $\epsilon_{ip}$ is the cost estimation error for activity $i$ in period $p$. These equations are valid with restriction that the total (activity) costs should be equal to the costs allocated to the customers. Besides the total activity level should be lower than the operational capacity available in order to prevent scheduling and performance issues.

Compared to other cost accounting methods the use of regression techniques is an additional feature in order to incorporate both fixed and variable cost. Most methods are using fixed tariffs, so they implicitly assume that all costs are variable. In order to fulfill the additional business requirements it is necessary to make a distinction between fixed and variable costs, which makes that the model can be used over multiple periods and the outcomes are still matching current financial reporting. Besides it provides more information about the cost structure that can be used for forecasting without doing an in-depth analysis in all activities and sub activities. Overall it can be said that by using regression techniques a more structural model can be developed that increases visibility over the processes, makes the model easily applicable over multiple periods and therefore reduces the workload, while meeting all the requirements set.
Application at Philips

This report is the outcome of a master thesis project carried out for Philips Business Group Automotive. The Business Group Automotive Lighting is organized in two businesses: OEM and Aftermarket. The focus of this project is Aftermarket EMEA with Wholesalers, Retailers, Online and OES as main customer groups. The goal of this project is to develop an easy applicable model that is able to create insight in:

1. The cost structure of serving customers
2. Distribution of costs among customers
3. Profitability of a customer & the costs related to serving a customer

Besides the demand for additional visibility there are two additional business requirements: the outcomes should match with current financial reporting in order to increase recognition and the analysis should be repeatable on a quarterly basis.

The profitability of a customer is determined by deducting all costs from the gross sales value. In figure A the Customer profitability model (Christopher, 2011) is given. In this project the focus will be on the distribution service costs. The distribution service costs are divided over the activities order administration, distribution and transportation. In order to determine the profitability of customer productions costs, sales costs, marketing costs and terms of trade need to be considered (figure B). Since it possible to allocate the costs according to the cost drivers it is possible to determine the costs of serving an individual customer and the profitability of this customer. Once the costs and profitability of an individual customer is known, it is possible to evaluate both the internal and external performance by looking into respectively the costs and the profitability of this customer. Besides the evaluation of individual customers it is also possible to evaluate customer groups by summarizing the values of individual customers.

In activity based costing all costs will be allocated to the cost object according to a certain cost driver by using a tariff. The activity tariff for cost allocation to the customers can be determined by dividing all activity costs by the total cost driver volume. There are three methods in order to estimate this tariff:
1. **Average/fixed tariff:** This method will derive a fixed tariff which will be applied in all periods. Since a single tariff will be determined for all periods it is assumed that all costs are variable and that the changes in volume represent proportional change in costs. For instance if the total activity level increases by 10%, the activity costs will as well increase by 10%.

2. **Fixed and variable costs estimation:** the second method will estimate the fixed and variable costs for an overall activity level. Consequently costs levels will be divided by the activity level. When analyzing the tariff estimation for each activity in the cost-to-serve analysis it can be shown that the goodness of fit of tariff estimation method 2 is significantly better than tariff estimates in method 1. In order to validate the model the last period was taken out of the sample for analysis in order to predict the outcomes based on the other methods. When analyzing the validation results, it can be seen that the estimation accuracy of the first method has decreased in some cases. This makes that the second method performs in both in the verification as well as in the validation better than the other method evaluated.

**Cost impact analysis of activity changes**

When analyzing the activity costs and the customer performance it can be seen that there is room for improvement regarding the internal activities. It is chosen to analyze the cost impact of one change in activities in detail. This model for evaluation of the cost impact of changing activities can also be used to evaluate to cost belief of changes in other activities. The change that will be analyzed in terms of cost is a change in the distribution structure. The main question of this hypothetical exercise is: What is the costs impact if the number of warehouses used for distribution is reduced from three to one?

Given that some the costs and volume of some activities might be changing, it is possible to develop some common sense scenarios for each of these activities. In order to model uncertainty for the subjective non-additive probabilities of events (scenarios), belief functions can be created by applying the Dempster-Shafer theory of beliefs (Ayyub & Klir, 2006). The Dempster-Shafer theory can better map uncertainties in application domains such as business decisions, besides people tend to make judgements about uncertainties in terms of beliefs.

When combining the scenario beliefs with the cost estimation for each scenario it is possible to develop a cost belief function. The costs belief function displays the cost impact given the scenarios and their uncertainty scaled to the current situation. Once the impact for the activities is analyzed and the costs allocation can be done according to the cost-to-serve model as discussed before, in order to analyze the costs impact for each of the three regions. Figure C gives the average costs impact for customers groups currently being served from the central distribution center (CDC), regional distribution center 1 (RDC1) and regional distribution center 2 (RDC2).

As can be seen in figure C the upper bound of the 95% confidence interval of the costs estimation in the new situation is lower than the costs in the current situation for both RDC1 and RDC2. On the other hand there is no significant costs impact for the customers currently being served from the CDC.
Preface

This report is the result of my graduation project that has been conducted in completion of the master Operations Management & Logistics at Eindhoven University of Technology. The project has been carried out at Philips Lighting Business Group Automotive. I am very grateful that I had the possibility to do research within this inspiring company and would like to thank all the people that have made this project successful.

First of all I want to thank Mr. Reindorp and Mr. Broekmeulen. Dear both, throughout the period of our cooperation I am grateful for both the positive and negative feedback and comments. Secondly I want to thank Cynthia Koens: as a company supervisor you introduced me to the organization. I am thankful for that and I am convinced that it helped me during this thesis project and it will help me in the future. Lastly I want to thank everyone else involved in this project for providing me information, feedback, comments and support. Due to the involvement of all of you, I was able to develop myself for both in from a professional perspective as well as from a scientific perspective.

The end of this graduation project is also the end of my student life. Throughout the years of my studies it was taught how to develop my knowledge and my capabilities. I faced many challenges and finally overcame all of them. However none of that would have been possible without the support of my parents, brothers and friends. Their support and feedback got me where I am today and where I will be in the future.

Thank you all!

Wouter Kuijvenhoven

May, 2015
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1. Introduction

Companies are routinely seeking for opportunities to decrease costs and improve profitability. A company’s profitability depends on selling price, cost of goods sold and the cost to serve its customers (Guerreiro, Bio, & Merschmann, 2008). Where the cost of goods sold relates to the product purchased by the customer, the cost-to-serve is related to all other services offered to a customer (e.g. placing order and delivery of goods) and the costs of acquiring a customer and maintaining customer relations (e.g. sales and marketing costs). In many companies the cost of goods sold are clearly described and there is lots of information and data available. On the contrary, the costs of serving a customer are often not clearly defined and therefore there is insufficient insight in the profitability of individual customers.

A main challenge for businesses is to meet customers’ expectations in terms of service, at a healthy margin (Braithwaite & Samakh, 1998). It is essential to meet a customers’ expectation, since satisfied customers are more likely to stay and to pay a good price. Besides, today’s markets are so competitive that current market prices reflect the norm of customers’ utility and expectations. Therefore realizing a premium in customer’s perception for customer service activities, gives a competitive advantage. The nature of the service commitment that a company makes to its customers is a part of its positioning in the market place. The profitability per customer depends on the cost to produce the products and the costs to serve the customer (Guerreiro, Bio, & Merschmann, 2008). This creates a dilemma in a company’s pricing policies and service activities. Therefore understanding the costs related of serving a customer form the basis of further positioning the firm in the market in terms of pricing policies and service activities towards customers.

Customer profitability is of key interest to a company, since profitability is not equally distributed over all customers. For instance, Freeman et al. (2000) stated that 50 percent of the best customers deliver about 95 percent of total turnover and about 100 percent of the profit. Others show us that 20% of the customers generate 225% of the profits, the middle 70% of the customer is around break-even point and 10% of the customers were losing 125% of the profits (Cooper & Kaplan, 1991). Lastly Storbacka (1997) showed that more than half of the customers are unprofitable. This means there is a large difference in profitability between individual customers and not all customers contribute towards the profitability of a business. Since a significant part of the customer base is not contributing to the profit of a company, more and more businesses want to look into the distribution of profitability among customers.

The impact of dealing with large and small customers or bulk and high service customers on customer profitability is considerable (Braithwaite & Samakh, 1998). The cost drivers as for instance volume and number of orders differ among these customers. Therefore, a deeper look into the details of the various cost activities and cost drivers is needed. The cost-to-serve method is a tool that looks into the details of the various cost pools and cost drivers related to serving a customer.

This research focusses therefore on improving the visibility of cost related to serving a customer. In section 1.1 a company description will be given, section 1.2 will describe the external company environment and section 1.3 will give and outline of the report.

1.1 Company

Royal Philips is a diversified technology company, focused on improving people’s lives through meaningful innovation in the areas Healthcare, Consumer Lifestyle and Lighting (Koninklijke Philips N.V., 2014b). Philips is a market leader in cardiac care, acute care, home healthcare, energy efficient lighting solutions, new lighting applications, male shaving & grooming and oral healthcare. Philips integrates technologies and design into people centric innovations, reflected by the company’s slogan “innovation and you”.

The company, headquartered in the Netherlands, posted annual sales of 23.3 billion euro’s in 2013 and employs about 115 thousand employees worldwide (Koninklijke Philips N.V., 2014a). Philips is organized in three main divisions: Healthcare, Consumer Lifestyle and Lighting, in order to deliver the brand promise of “innovation that matters to you”. Healthcare is focused on delivering the best technical products and solutions to help clinicians diagnose, treat and manage today’s most prevalent diseases, while creating the ideal experience for all patients. Consumer Lifestyle is responding to consumers’ aspirations with delivering (locally) relevant innovations that increases health and well-being of people, with products as for instance shaving, healthy cooking and oral care.

Philips Lighting is a leading provider of lighting solutions and applications in both professional and consumer markets. Philips Lighting pioneered in many of the breakthroughs in lighting in the past 123 years, creating lighting solutions that transform environments, create experiences and help shape identities. Philips Lighting employs 47 thousand employees worldwide.

Philips Lighting spans the entire value chain from light sources, luminaires, electronics and control to application-specific systems and services. This is done through the following businesses (Koninklijke Philips N.V., 2014a):

- **Light Sources & Electronics**: LED, eco-halogen, (compact) fluorescent, high-intensity discharge and incandescent light sources, plus electronic and electromagnetic gear, modules and drivers.
- **Consumer Luminaires**: functional, decorative lifestyle, scene-setting luminaires
- **Professional Lighting Solutions**: controls and luminaires for city beautification, road lighting, sports lighting, office lighting, shot/hospitality lighting & industry lighting
- **Automotive Lighting**: car headlights and signaling
- **Lumileds**: packaged LEDs

Figure 1.1 provides an overview of the revenue per business group within Philips Lighting.

The conventional lamps industry is highly consolidated, with GE and Osram as key competitors. The LED lighting industry is very dynamic, with new competition from Asia, the semiconductor industry and the building management sector. The luminaires market is fragmented, with competition varying per region and per market segment.

The business group Automotive Lighting is one of the world’s largest suppliers of lamps to the automotive industry and aftermarkets. With worldwide one in three cars equipped with Philips lamps, Philips is one of the largest players in this market. The business group Automotive Lighting has annual sales of approximately 800 million euros.
The market for automotive lighting is divided in the following regions: Asia & Pacific (1), EMEA (2), Latin America (3) and North America (4).

As of September 23, 2014 Philips announced major transitions by splitting off its lighting business (Koninklijke Philips N.V., 2014c). Previously, it already announced to split off Automotive Lighting and Lumileds. After these major changes there are three separate companies (Figure 1.2) each of them leading and able to excel in their own sector. The business group Automotive Lighting is influenced by these changes since Philips will soon divest the combined Automotive and Lumileds business. This divestment will formally be completed at the end of the first quarter of 2015.

Hereafter, whenever Philips is mentioned in this report, it refers to the business group Automotive.

1.2 Market

Automotive Lighting is organized in two businesses: Original Equipment Manufacturing (OEM) and Aftermarket. OEM is the market for lamps in new automobiles, while aftermarket is the market in which lamps for replacement are sold. This is primarily done by retailers and car dealers. The main focus of this report will be on aftermarket in Europe, Middle East and Africa (EMEA). The aftermarket has a special challenge, since in general new LED lighting does not have to be replaced. Therefore in the future, the aftermarket for replacement will be declining, as LED becomes more common in automotive lighting.
Within automotive the products are divided over three categories: Lamps, LEDs and Mobility. Within the product categories Lamps and LEDs there are specific types of lamps such as headlights, signaling lights and interior lighting. Mobility includes all other products such as car air purifiers. LED products are mainly sold in to OEM, Mobility products are mainly sold in the Aftermarket and Lamps is sold in both the OEM as well as in the Aftermarket.

The aftermarket in EMEA consists mainly out of Wholesalers, Retailers, Online and Original Equipment Suppliers (OES). Where Wholesalers sell products to other business such as car dealers, Retailers are focused on the consumer market. Online is also focused on the consumer market but via the internet. The last category is OES which provides for instance car replacement kits.

1.3 Report outline

This thesis will focus on getting more insight in the costs of serving customer and the customer profitability. The main contributions of this thesis are:

- Combination of accurate cost estimation & correct cost allocation by making a distinction between variable and fixed costs.
- Create an easy and applicable model that can be used for tariff estimation and forecasting, in order calculate the cost-to-serve performance of individual customers
- Analyzing the impact of changing the supply chain design based on cost-to-serve information

How to get these insights will be covered in three parts. In the first part (chapter 4) the cost-to-serve model and method for tariff estimation will be discussed in general. In the second part (chapter 5 to 8) the model will be applied in a business environment. In the third part (chapter 9) the cost impact of change in activities will be analyzed based on cost-to-serve information. How the cost impact can be analyzed will be shown by the example of reducing the number of warehouses.

In the third chapter a small literature review will be given in order to gain some more knowledge of the cost-to-serve concept and current cost-estimation methods. Chapter 4 discusses the most important part of this thesis, namely the model and the methods that will be used to estimate the cost to serve and calculate the customer profitability. Chapter 5 & 6 will give a more accurate description of the processes within the scope in order to get a clear view of where the costs are within the organization and what is driving these costs. Chapter 7 consequently discusses the application of the model within the business environment previously described. Chapter 8 shows how the model can create the visibility required. In chapter 8 the accuracy of different tariff estimation methods are being compared as well as their forecasting accuracy. Then in chapter 9, which contains the third part of this thesis, the cost impact of a change in the supply chain structure will be analyzed. Lastly a conclusion and some recommendations will be given.
2. Research approach
The research approach will start with a problem definition, in which the general context is described. Secondly in the problem statement the problems, opportunities, challenges and needs related to this project within the organization will be discussed. Subsequently the research question and sub-research questions will be formulated. Lastly the approach and the steps towards answering the research question will be discussed.

2.1 Problem definition
In the first chapter an introduction is provided to cost-to-serve and some general company information is given. In this section we will sketch the general problem definition (not Philips specific) in more detail. This will be done from three different perspectives: a company perspective, a customer perspective and a scientific perspective.

Company perspective (seller/firm)
In order to improving profitability it is important to have a clear idea of the main cost drivers. These main cost drivers can be seen at activity and at customer level. At activity level the costs of a specific process or service can be allocated. With analysis at customer level, the cost to serve an individual customer can be compared with a peer group. If the costs are exceeding the costs of the competitors, actions can be undertaken. At the customer level it can be determined how often a service is used by a customer, for instance due to the amount of orders placed. Most companies know their major cost objects such as labor, direct material and freight, but insights in these costs are insufficient to determine customer profitability (Norek & Pohlen, 2001). The main reason for this is that the product is no longer the cost object but the customer and it is more difficult to trace cost to specific customers. To achieve higher profitability, a central issue is to meet or exceed customers’ expectations in terms of services, at affordable costs in relation to prices customers are prepared to pay (Braithwaite & Samakh, 1998). In order to know what is affordable in terms of offered services detailed information is required on customer level.

Due to competition further customization is needed and businesses are being forced to adapt their products, packaging and services to individual customers’ requirements. (Freeman, Haasz, Lizzola, & Seiersen, 2000). However, it is often unclear what services can be offered to a customer. Gaining insight in the costs and margin of individual customers or types of customers can help in this decision making process (Mulhern, 1999). Lastly, insights can be gained in the future profitability of serving a customer. If a customer is growing rapidly with increasing margins, a temporary drop/reduction in profit margins might not disturb the relation. With cost information known it is possible to deal with customers that are currently unprofitable or have low margins, for instance by increasing prices, lowering services or ending the customer relation.

Another important question from a company perspective is how to allocate resources among customers (groups) and is the focus of this effort directed towards the right customers. For instance, some customers may require a lot of extra services but without paying a premium for these services. In the business decision making process it might therefore be worthwhile to look into the margins. Through higher visibility, the customer service offer can be changed for specific customers or customer groups. For instance by changing some aspects in the customer service offer, customer demands can be fulfilled without decreasing margins.

The cost knowledge obtained can be used to focus on the most important product and customers to improve profitability & customer service and for negotiations with other members of the supply chain (Norek & Pohlen, 2001). Concluding companies are interested in relation between costs, profitability & services in order to manage customer relations and internal processes.
Customer perspective
As mentioned in the previous paragraphs the customer has certain expectations, and would like to see that these expectations are met with services delivered by the supplier. But often it is unclear at what cost certain services will be delivered. For example it is unknown what costs are related to placing orders and the corresponding ordering frequency. Therefore higher transparency in costs and cost drivers will allow the customer to make his own decision about the affordability of certain additional services. This transparency can be created towards the customer when information about the cost factors and cost drivers is known. A customer can consequently decide upon cost drivers. For instance if the customer understands the costs related to daily deliveries and small orders, he might require less frequent deliveries in exchange for lower prices. Besides, it improves the possibility to manage customer expectation by using financial incentives (e.g. discounts) and therefore provides an extra opportunity to meet customer requirements. Besides, a customer might not understand that his behavior strongly influences costs and possibly indirectly influences the prices.

Scientific perspective
As becomes clear from the previous paragraphs, profitability and performance are often determined in the relation between a company and its customers. Performance measurement is “a process of quantifying action, where measurement is the process of quantification and the action leads to performance” (Neely, Gregory, & Platts, 1995). Performance measurement can be related to quality (e.g. TQM), time (JIT), flexibility and costs (e.g. ABC & Cost-to-serve). The cost-to-serve method measures the costs in the customer channel and is the performance measurement instrument that will be investigated and discussed during thesis project. Due to lacking cost to serve information the customer performance is unclear, both due to inaccurate cost estimation and lacking correct cost allocation. Therefore a model should be developed that is able to measure the cost-to-serve performance in an accurate and correct manner.

Figure 2.1: Cause & effect diagram

In the beginning of this section the need for a good cost-to-serve method and information is described. In Figure 2.1 the most important insights as discussed above are given. There are several reasons why companies are unable to manage customer costs and profitability. First there is the internal reason that there is no detailed visibility regarding customer costs profitability, customer costs and customer cost drivers. Besides there are also external causes that there is no control over customer cost and profitability. The main reason is that customer behavior is cost inefficient due to for instance small orders and lacking
incentives to improve behavior. Another reason is both internal and external and is that it is currently lacking an accurate method available that can measure the customer performance.

2.2 Problem statement
Related to the problems defined in the previous section four clear needs can be identified in order to increase the ability to manage customer costs and profitability:

- **Determine the customer profitability and value customer relations:** At first it is important to know something more about margins, costs and possible future value, before future actions can be undertaken.
- **Identity the cost drivers in customer costs:** When cost drivers for specific customer services are clear, better customer service offers can be created and customers’ expectations and demands can be managed.
- **Cost control & transform business processes:** Besides the management of the relation with the customer, own business processes can be adapted in order to control cost or improve services.
- **Communicate solutions & establish transparent customer relations:** A last need in the organization is to communicate the solutions and establish a transparent relation with the customer to create understanding and manage the customers’ expectations. For instance if the customer demands an additional service the corresponding cost can be given.

Note that the first two needs clearly require some more information regarding the cost-to-serve performance. On the other hand the last two needs can be met by the analysis and application of the outcomes.

Related to the different general perspectives as described in the previous section, some problems and opportunities can be derived within Philips. The following challenges can be identified within Philips related to the visibility of the cost to serve individual customers.

- **Improving customer relations:** Good and close customer relations contribute to the health of a company. When customers’ expectations are closely monitored, it is possible to react to demands with corresponding products and services.
- **Decreasing market:** Due to developments in automotive lighting, the introduction of LEDs and lower sales in the automotive industry, the aftermarket is declining. However there are still lots of opportunities in the market. A challenge is therefore how to capture the value in these opportunities and simultaneously be able to respond to the changing market environment and customer demands.
- **Contribution to Philips’ automotive lighting business:** While fulfilling demands for the market the contribution to Philips’ business is for Philips of equal or even higher importance. By measuring the contribution/profitability of clients and products to Philips, new services and products can be offered to certain customers, while others will have less.
- **Customer service offer:** Creating a better customer service offer can help to respond to different market circumstances and helps to manage customer expectations and demands. The customer service offers includes all the services offered to a customers, for instance daily deliveries or weekly deliveries.

2.3 Research question
In the problem definition a context is given of the problem, besides it provides interest from the different perspective. The problem statement provided the main challenges and needs from the organization’s perspective. To summarize both the general context in the problem definition and the organization specific context in the problem statement three types of insights should be acquired by performing a cost-to-serve analysis:
1. **The cost structure of serving customers**: If a customer places an order which costs are there involved (activity costs & cost drivers)?

2. **Distribution of resources, profitability & costs among customers**: How are the costs & resources distributed among customers groups?

3. **Profitability / costs related to serving a customer**: What are the costs related to serving a customer and is this customer profitable given its current behavior (e.g. ordering behavior)?

The objective is to create a model that is able to create these three insights. After this model is created it will be tried to estimate, calculate and allocate costs in such a way that the allocated costs to customers give an accurate representation of their actual costs.

**How to estimate the costs on a customer level and create visibility in the costs structure?**

As previously identified, cost-to-serve information can be used for a lot of purposes. But it is of key importance which model is being used and what are the main input variables.

1. **What is a cost-to-serve analysis? How can activity costs be estimated?**

The first sub research question aims to get insight in the literature available. In this initial step an investigation will be done in order to gain insight in what a cost-to-serve analysis is in relation to other cost accounting methods. Secondly also a classification is made of different costs estimation techniques.

2. **How can the costs per customer be calculated? Is it possible to create an easy and applicable model that is able to calculate the cost-to-serve performance?**

Before getting into the actual analysis with real data, a model will developed for calculation of the cost-to-serve a customer. The model will include all the activities related to serving a customer and will be derived from a general supply chain structure and a general order-to-collection cycle. Also the general relations in the model between variables will be explained.

3. **What cost factors and cost drivers can be identified? What is the distribution of costs among customer? What is the profitability of each customer?**

In this part the model will be applied to a business situation in order to calculate the costs per activity per customer. In order to do this first an overview of the processes will be given within the scope of the Cost-to-serve. Consequently the values for all the input variables for the model will be estimated and the model will be applied in order to calculate the cost of serving customers. This part therefore describes the application in a specific business environment delivers three types of insights: (1) the degree of profitability for each customer and (2) the distribution among customers and (3) the cost structure in terms of cost factors and cost drivers.

4. **What is the accuracy of the model? And can it be used for forecasting?**

In order to say something about the accuracy of the model, the outcomes of the model will be compared with other methods for tariff estimation. The tariff will be used since an accurate tariff is essential for a correct cost allocation and a tariff describes the relation between costs and volume of an activity. Beside the model verification the model will also be validated and the validation results of different models will be compared.

5. **Can cost-to-serve information be used to determine the impact of a changing supply chain design?**
In this last sub research question the visibility created by the cost-to-serve analysis will be used to determine the cost impact if the supply chain structure changes (e.g. reduction of the number of warehouses).

2.4 Requirements
From a business perspective there are additional requirements regarding to the thesis. A first additional requirement is that it should match with current financial reporting, preferably on a quarterly basis, in order to be able to recognize the results and increase the acceptance of the results. Another requirement is that the cost-to-serve analysis and the application of the model is repeatable over multiple quarters during a period over maximal three years, without redoing the complete analysis. Therefore an easy and applicable model should be developed. To make it repeatable a general model should be developed, which can also be used in other environments. Besides the model should be simple and fast to execute, so that accurate costs estimations can be estimated in a relative efficient manner. This implies that an in-depth investigation in each activity and looking at all sub-activities during each quarter is too time consuming.

2.5 Scope
The customer channel is separated from the product channel by the customer order decoupling point in a make to stock environment (Figure 2.2). In the customer channel the supply chain actions are triggered with a customer order. For practical implications the whole warehousing process is within our scope to cover all the costs not incorporated in the product cost and in order to match the Profit & Loss statement. It is chosen to match the cost in the Profit & Loss statement to increase recognition of the outcomes within the company and therefore gain support throughout the company.

This thesis will cover all operational and overhead costs in the customer channel, such as warehousing, distribution & order administration. Costs related to the production channel, such as manufacturing costs, will be outside the scope of this thesis. The region within the scope of this report is Europe. Besides the focus will be on the Aftermarket only, since the OEM market has different processes and cost drivers. Besides the Aftermarket is considered to be more in control regarding costs and resource allocation.
3. Literature review
As the economy matures, businesses are being forced to adapt their products to individual customers’ requirements and to provide more services (Freeman, Haasz, Lizzola, & Seiersen, 2000). Since there is no general service offer anymore for all customers and the focus is on individual customer requirements, it is important to look into the profitability of these individual customers. “Customer profitability analysis is the reporting and assessment of revenues earned form customers and the costs incurred to earn those revenues” (Horngren, Datar, & Rajan, 2012, p. 310). Customer profitability analysis delivers two types of insights (van Raaij, 2005): first there is the degree of profitability for each customer and secondly the distribution among customers.

One could say that the profitability can be calculated by deducting all costs from total sales. This is a rather simple though correct statement, but some more refinement seems necessary in order to comprehend the costs in a company. In costs accounting there are two general types of costs (Seal, Garrison, & Noreen, 2009): manufacturing cost and non-manufacturing costs. The manufacturing costs can be divided into the categories; direct materials, direct labor and manufacturing overhead. The manufacturing costs are product related cost, not part of the customer channel and therefore not directly related to individual customer behavior. The non-manufacturing costs are part of the customer channel and therefore included in a cost-to-serve analysis. Further on, the cost-to-serve method will be discussed in more detail, but for now it is important to understand what is included in the non-manufacturing costs. Marketing or selling costs are non-manufacturing costs and includes all costs necessary to secure orders and get the finished product into the hands of a customer. Examples of selling costs are: sales, marketing, shipping and warehousing of finished goods costs. The other category in non-manufacturing costs is the administrative costs. These costs include all costs related to general management of an organization and not related to manufacturing, marketing and selling.

For accurately determining the costs per activity per customer two steps can be identified. The first step is about creating a model and allocating specific costs (e.g. warehousing costs) to a customer. The second step is about estimating the input coefficients for accurately determining the cost of serving a customer. In order to discuss both steps, first a classification of cost estimation techniques will be given.

3.1 Cost estimation techniques
Naizi, Dai, Balabani & Seneviratne (2006) classified the different techniques for product cost estimation. In this section the main techniques will be described shortly. Naizi et al. (2006) distinguishes qualitative and quantitative estimation techniques. Qualitative techniques make comparison with other existing cases in order to determine the similarities with the new case. Quantitative estimation techniques are based on an in-depth analysis of processes and cost. Costs in quantitative techniques are calculated as a function of certain variables or the sum of its elementary units.

In their article Naizi et al. (2006) identified two types of qualitative techniques, namely intuitive and analogical techniques. Intuitive techniques are based on using past knowledge. In this category a domain expert’s knowledge is used in structured way to generate cost estimates of a particular domain. There are two intuitive techniques:
- Case-Based Methodology: makes use of closely related previous cases and adapts this information to the new case
- Decision Support Systems: these systems have as main purpose to assist estimation experts in making better judgments and decisions, by using stored expert knowledge in the field

Analogical cost estimation techniques use similarity criteria based on historical cast data with known costs. These methods are particularly useful when criteria can be connected to activity characteristics. The analogical techniques are:
• Regression Analysis Models: regression makes use of historical cost data to establish a linear relation between the costs and values of certain characteristics
• Back-Propagation Neural-Network Models: the neural-network stores knowledge to infer the answers to questions that they have not even seen before. This model is particularly useful with uncertain conditions and can deal with non-linearity as well

In cases where exact data is lacking both qualitative techniques are particularly useful.

The types of quantitative techniques identified are Parametric Techniques and Analytical Techniques (Niazi, Dai, Balabani, & Seneviratne, 2006). Both quantitative techniques require in-depth knowledge of the activities and the cost structure. Parametric models are derived by expression costs as a function of its constituent variables. Analytical techniques require a decomposition of the product or service in to elementary units that represent the resources consumed. The four Analytical techniques are:

• Operation-Based Approach: allows for estimating the costs as a summation of the costs associated with the time performing an activity, nonproductive time and setup times.
• Tolerance-Based Cost Models: the objective is to give a cost estimation based on tolerances in the requirements as a function of the product cost.
• Breakdown Approach: estimates the total costs by summing al costs such as material cost, overhead costs etc.
• Feature-Based Cost Estimation: identifies cost-related features and determines the associated costs.
• Activity-Based Costing System: focusses on calculating the costs incurred on performing the activities. Also overhead is allocated as a proportion of the activities performed.

![Cost estimation techniques classification](image)

**Figure 3.1: Cost estimation techniques classification (Niazi, Dai, Balabani, & Seneviratne, 2006)**

### 3.2 Cost-to-serve

In order to determine the profitability per customer it is important to allocate the activity costs as accurately as possible. Consequently these costs can be deducted from the total sales per customer in order to determine the profit per customer. In order to allocate activity costs as accurately as possible, costs should be allocated according to the amount of resources being used. In Activity Based Costing the costs are typically allocated to the cost objects according to the amount of activity resources being used. The ABC method focuses on calculating the costs incurred on performing activities to manufacture a
product (Niazi, Dai, Balabani, & Seneviratne, 2006). The costs that will be allocated in ABC are including overhead costs related to the activity.

Activity Based Costing (ABC) has traditionally been used for cost measurement in industrial activities. However, an Activity Based Costing approach can also be applied to customer service activities (Guerreiro, Bio, & Merschmann, 2008). In an ABC approach it becomes clear that not every product requires the same type and level of activities. Similarly, customers also differ in the consumption of resources (van Raaij, 2005). Cost to Serve and Cost of Products should be separated to allow accurate cost allocation and allow for better decision making. Cost of Product (e.g. manufacturing costs) relate to the product without knowing which customer will buy it. On the other hand there are the Cost to Serve, for instance when a customer places an order the costs involved are order administration, warehousing and transportation. In this case the cost object is the customer service and the costs should be allocated to the customer while the relation with products matters less. Therefore for the application in cost-to-serve the cost object will not be a product but the services incurred to a customer.

Cost-to-serve is solidly grounded in Activity Based Costing and draws on Economic Value Creation (Freeman, Haasz, Lizzola, & Seiersen, 2000). Other conventional costing methods as contribution margin and gross profit margin only focus on overall profitability, without looking into spending related to customer-service activities (Guerreiro, Bio, & Merschmann, 2008; Christopher, 2011). A shortcoming is that these methods do not have the opportunity to identify how customer service activities influence the cost structure of a company. A solution to this shortcoming is the cost-to-serve approach which has the opportunity to look into service activities towards individual customers and therefore into the profitability of an individual customer.

The cost-to-serve concept is a customer driven approach that enables a company to focus on an individual customer and improve its profitability by serving customers in a differentiated manner (Guerreiro, Bio, & Merschmann, 2008). The fundament behind this costing approach is a thorough research in the calculation of the cost-to-serve per customer, before drawing conclusions and making suggestions for possible improvements. The cost-to-serve method aims to facilitate customer profitability analysis, by allocation of cost objects to the customer. These cost objects include administrative, commercial and logistics activities related to customer-service delivery. The cost-to-serve concept is a customer driven approach that enables a company to focus on an individual customer and improve its profitability by serving customers in a differentiated manner. Therefore it offers a higher level of detail than customer profitability analysis, by looking into the various cost objects and cost drivers of serving a customer.

Within cost-to-serve and Activity Based Costing there is some terminology that needs to be defined unambiguously in order to avoid confusion (Themido, Arantes, Fernandes, & Guedes, 2000):

- **Resources**: input required for the production of goods and services
- **Activities**: tasks that require a set of resources to transform products or complete a specific service
- **Cost object**: the final goods or customer service created by the activities
- **Cost driver**: a variable that shows a logical and quantifiable cause and effect relationship between the utilization of resources, the performance of activities and the final cost object.

For cost-to-serve analysis only the customer related costs from a customer profitability analysis should be taken into account, this means the focus will be on the avoidable costs (Christopher, 2011). Figure 3.2 gives the structure of customer profitability. The costs that can be directly related to the customer are the distribution service cost, because those costs are part of the order-to-collection cycle and will be discussed later in this section. Marketing costs includes both costs which are directly related to the
customer (e.g. sales calls, in-store promotion, merchandising) as well as costs that are indirectly related to the customer (e.g. sales force management, national advertising).

The order-to-collection cycle (Figure 3.3) is initiated by a customer order (Christopher, 2011). After the order is placed it will be entered in the system and a credit check will be performed. After that the documentation for order picking and transportation is prepared. After the document is prepared the physical warehousing and distribution processes take places. Once the products have arrived at the customer, the customer can be invoiced and the collection process will start. Note that the order-to-collection cycle is directly related to a customer and part of the customer avoidable costs, since the cycle is initiated by a customer order. Therefore the main focus of a cost-to-serve analysis is on the activities in the order-to-collection cycle.
4. The cost-to-serve model

In this thesis, a general model will be developed, based on both practical and theoretical findings. The customer profitability model will be created as a combination of the activity costs and cost drivers that will be identified. The goal is to formulate an easy, general applicable and accurate model that is able to calculate profitability and cost factors of an individual customer based on the cost drivers. This model will be created in three steps. The first step is to understand fixed and variable costs within an activity and therefore understand activity costs. The second step is about creating a model for the allocation of fixed and variable costs based on cost drivers. Finally the third step will be about estimating the fixed and variable costs per activity as accurately as possible. In the last three sections of this chapter is described how the model can be used for costs estimation at customer level, the advantages and disadvantages of the costs estimation model and general description of activities within the scope of cost-to-serve.

Currently most cost accounting methods are using fixed tariffs for allocation of the cost for instance for the allocation to individual customers. This activity cost tariff is determined by:

\[
Tariff = \frac{Total\ activity\ costs}{Total\ cost\ driver\ volume}
\]

Since both the total activity costs and the total cost driver volume varies (e.g. Figure 4.1), a fixed tariff does not represent the activity cost accurately during multiple periods. The main disadvantage of using fixed tariffs is that all costs are assumed to be variable. This means that there is no distinction between fixed and variable costs both on activity level and on the total level. In a stable business environment this will not cause any trouble, but in business environments with any variance (e.g. seasonality) the effects can be large. If assumed that there are only variable costs and that the tariffs are fixed throughout the year, then there is a huge overestimation of total costs in the high season, while in low season there is a large underestimation of the cost. Therefore the costs are not matching the (quarterly) financial statements and therefore recognition and acceptance is influenced in a negative manner. This can be solved by in-depth analysis in activities and sub-activities, such as done by van Damme & van der Zon (1999), but this method is very time consuming since it requires knowledge of all sub processes. In this chapter a method will be used that has the relative easiness of tariff but takes into account (seasonal) changes in the activity levels.

![Figure 4.1: Cost driver volume and activity costs](image-url)
4.1 Understanding fixed and variable costs

This section will focus on estimating the costs by understanding the allocation to fixed and variable costs. This estimation is quite often needed since a lot of activities are lacking accurate cost data, besides data gathering in an accurate way can be time consuming. In order to estimate the activity cost as accurate as possible, a further breakdown and detailed analysis seems time consuming. Besides, there is often no absolute data available to investigate these processes in detail, since the costs details at a lower level are often an allocation of costs on a higher level. Therefore appropriate cost estimation methods are limited to qualitative methods.

From the qualitative methods the Case-Based Methodology seems inaccurate, since there are only limited amount of cases available to compare costs. Therefore the most closely related case, according to an expert opinion, could still be off by a significant amount. For similar reasons Decision Support Systems are not always accurate. It should be noted that both methodologies can help to identify closely related cases and if necessary slight changes could be made, but it seems rather subjective to determine how much the costs deviate from the most closely related case.

Analogical techniques are classified qualitative techniques for the comparison with other cases, though it might be argued that they are quantitative techniques because they are less dependent on expert opinions and make comparisons based on objective characteristics. Neural networks are especially appropriate if one has a poor idea of the underlying cost behavior or suspects that there are functional discontinuities and significant nonlinearities (Smith & Mason, 1997). On the activity level there is no indication to suspect either one of them, besides it might even be argued that there is some idea of the cost structure due to known cost drivers.

The goal of activity cost estimation method is to determine the fixed and variable costs per activity (Drury, 2004) and therefore get an accurate prediction of the activity costs if the cost driver is known:

\[
Total \ costs = fixed \ costs + variable \ costs \ tariff \times cost \ driver
\]

From the methods described in chapter 3, a regression analysis seems most appropriate. A regression analysis uses mathematical methods to estimate a cost equation with the highest fit to the data point available. Least squares regression has often been used for cost estimation (Smith & Mason, 1997), besides it is particularly useful in case of limited sample sizes (Mason & Sweeney, 1992). The regression describes the relation between a cost driver and the total activity costs, by means of the regression coefficients. In this particular regression the constant is equal to the fixed cost, while the other regression coefficient represents the variable costs tariff. These insights in the variable and fixed costs are an additional benefit, besides it provides the desired insights in the total costs.

Note that the costs per unit can be applied for estimating the costs per customers for a certain cost factor based on the corresponding cost drivers, such as the quantity sold to a customer. In the previous chapter some cost estimation methods are described for estimating the activity costs.

4.2 Model description

In this section the general cost-to-serve model will be described. In order to determine the costs per activity per customer an activity-based cost estimation method will be used. The ABC method focuses on calculating the costs incurred on performing activities to manufacture a product (Niazi, Dai, Balabani, & Seneviratne, 2006). The costs that will be incurred are including overhead costs related to the activity. For the application in cost-to-serve the cost object will not be a product but the services incurred to a customer. In ABC, any cost group can be analyzed in terms of activities and cost drivers.
In order to determine the cost allocation to a customer \((Y_c)\) the cost driver needs to be identified as well as the tariffs related to these cost drivers. Note that in in ABC model all costs including variable costs and overhead costs are allocated to a customer by using a tariff multiplied with a cost driver. Besides it is assumed every activity has a single cost driver for allocation of costs.

Indices

\(i\)  
Activity \((i \in I)\)

\(c\)  
Customer \((c \in C)\)

Variables

\(Y_c\)  
Total cost allocation to a customer \(c\)

\(A_i\)  
Total activity costs that needs to be allocated for activity \(i\)

\(a_i\)  
Activity cost tariff for activity \(i\) and for the cost driver related to activity \(i\)

\(X_i\)  
Total volume of cost driver that is used as allocation key for activity \(i\)

\(x_{ic}\)  
Cost driver level of customer \(c\) used for allocation of costs in activity \(i\).

\(V_i\)  
Total variable costs for activity \(i\)

\(v_i\)  
Variable cost tariff for activity \(i\)

\(F_i\)  
Total fixed costs for activity \(i\)

\(e\)  
Estimation error

\[Y_c = \sum_{i \in I} a_i x_{ic}\]  
(1)

With \(a_i\) the tariff for activity \(i\) and its related cost driver and \(x_{ic}\) the observed cost driver for activity \(i\) and customer \(c\). In order to determine the value of the cost allocation there are certain restrictions. At first it is important that all the costs will be allocated over customers and activities sums up the total costs under investigation. Secondly the total activity costs should be equal the total costs that are allocated to all customers. Lastly the total of a cost driver allocated the all customers should both be equal to the total of volume of a cost driver \((X_i)\) that needs to be allocated, as well as less than the capacity available.

\[\sum_{c \in C} a_i x_{ic} \equiv A_i \quad for \quad \forall i \in I\]  
(2)

\[\sum_{c \in C} x_{ic} \equiv X_i\]  
(3)

\[\sum_{c \in C} x_{ic} \leq \text{Capacity}(X_i)\]  
(4)

Activity costs are often described by fixed and variable costs (Drury, 2004). Fixed costs are the amount of costs independent of the cost driver \((e.g. \# \text{ units})\), while variable costs are purely related to the cost driver. Costs are variable only if they vary with monthly or quarterly changes in volume (Cooper & Kaplan, 1987). Cost estimation methods are used to estimate a fixed and variable component of a cost factor. For example:

\[A_i = F_i + V_i\]  
(5)

Dividing equation 5 by the total cost driver volume \(X_i\), gives the activity tariff \(a_i\) for the total cost driver volume:
\[ a_i = \frac{F_i}{X_i} + V_i \] \hspace{1cm} (6)

By using equation 5, the total activity costs \( A_i \) can be calculated by using the fixed costs \( F_i \) and variable costs tariff \( v_i \) as discussed in section 4.1:

\[ A_i = F_i + v_i X_i \] \hspace{1cm} (7)

With \( v_i \) being the variable cost tariff and \( X_i \) the total volume of cost driver related to activity \( i \).

\[ v_i = \frac{V_i}{X_i} \] \hspace{1cm} (8)

Note that the knowledge about fixed and variable costs can be used to estimate/predict the cost for next periods without requiring the detailed costs by using the determined fixed activity costs \( F_i \), variable costs \( V_i \) and the new total volume of the cost driver \( X_i \). This is subjected to the assumption that the fixed activity costs \( F_i \) and the variable activity tariff \( v_i \), do not change.

### 4.3 Estimate fixed and variable activity costs

As stated by Cooper & Kaplan (1987) costs are only variable if they vary directly with the volume. In this case the activity level is the primary driver of variable costs. In Figure 4.1 an example of the relation between the total activity costs \( A_i \) and the cost driver volume \( X_i \) is given. In this figure it can also be seen that the estimation error for a linear regression model is far more accurate an average cost estimate. Besides due to the linearity of the relation, using more complicated model seems inappropriate and superfluous. Besides, strong theory of fixed and variable costs can support the idea of applying a regression analysis to model the relation between costs and activity levels.

For creating a cost-to-serve model that is independent of periods analyzed (section 4.2), a simple linear regression for each of the activities can be performed for determining the fixed and variable costs. The costs in different periods will be analyzed according to the cost driver volume in order to determine the estimates for the fixed and variable costs. This gives the following regression equation:

**Indices**

\( p \) \hspace{1cm} Period with \( p \in \{ 1, 2, 3, \ldots, n \} \)

**Variables**

- \( A_{ip} \) Total activity costs that needs to be allocated for activity \( i \) in period \( p \).
- \( \alpha_{ip} \) Activity cost tariff for activity \( i \) and for the cost driver related to activity \( i \) in period \( p \)
- \( X_{ip} \) Total volume of cost driver that is used as allocation key for activity \( i \) in period \( p \).
- \( \varepsilon_{ip} \) Estimation error for costs in activity \( i \) in period \( p \).

\[ A_{ip} = \alpha_{ip} X_{ip} + \tilde{F}_i + \varepsilon_{ip} \] \hspace{1cm} (9)

With \( \tilde{F}_i \) and \( \tilde{v}_i \) being the estimates of respectively the variable cost tariff and the fixed costs.

### 4.4 Cost estimation at customer level

Combining both the regression model with the equation for fixed and variable costs it is possible to determine the activity cost for a customer. In order to do that the total costs need to be divided by the total activity level and accordingly be multiplied by the activity level for activity \( i \) and customer \( c \).

\[ a_i = \frac{F_i}{X_i} + v_i \] \hspace{1cm} (10)
The customer costs for activity $i$ are then:

**Variables**

$Y_{ic}$  
Cost allocation to a customer $c$ for activity $i$.

\[ Y_{ic} = a_i \times x_{ic} \]  
(11)

When considering a typical example of with both fixed and variable costs, the relation between the activity level and tariff can be described as given in Figure 4.2. As can be seen in the figure tariff decreases when the volume of the cost driver increases. This is caused by the relative decreasing impact of the fixed costs. However it should be noted that this is only true if the activity level is not larger than the capacity.

![Figure 4.2: Relation between activity level and tariff with both fixed and variable activity costs tariffs](image)

With the customer activity costs calculated in equation 10 and 11, the total customer costs can be calculated by adding the separate cost factors.

\[ Y_c = \sum_i Y_{ic} \]  
(12)

So this method includes a regression for each activity, with for each regression a cost driver is used as independent input variable and the activity costs as output variable. The advantage of using regression is that the activity costs could be recognized in the regression coefficients and the meaningfulness remained while the applicability and easiness is improved. Besides, activities can be managed actively due to the improved visibility. A disadvantage of this method is that the error terms could be correlated with the dependent variables and therefore a better estimation of the profitability could be possible. In order to make a distinction between customers it is required to apply an activity based cost accounting method and apply a separate regression for each activity.

For the model there are some general assumption underlying the model, which need to be taken into consideration:

- Assumptions underlying the applicability of a regression analysis (Hair, Black, Babin, & Anderson, 2010):
• Tariffs behave in a similar way on the overall level as on a customer level. This means for instance that a tariff based on a quarterly sales of 80000 order lines, is the same for a customer with only 10 order lines during that quarter.
• Additional deviations from the general tariff due to specific customer behavior, which not displayed in the cost driver, are not taken into account (e.g. additional shipment documentation).

4.5 Applying regression for tariff estimation

In the previous two sections is explained how to allocate the costs to individual customers. The regression used for determining the tariffs related to the level of activity let us determine tariffs in a more accurate manner than by using fixed tariffs (e.g. Figure 4.3) in case of variable cost driver volumes. By not using fixed tariffs but different tariffs related to the different activity levels, there is a slight deviation from current practices for cost allocation. In this section the advantages and disadvantages will be discussed in order to get an idea which methods are preferred in a certain type of business environment.

Figure 4.3: Activity tariff estimation methods

4.5.1 Advantages
The first advantage is that our method takes fixed costs into consideration. As stated before conventional methods apply fixed tariffs and therefore all costs are assumed to be variable. When all costs are assumed to be variable it is implied that if the activity level rises the activity costs are rising at an equal amount. For example if the activity level increases with 50%, the activity cost will also increase with 50%. While in case of some fixed cost the costs can rise at a relatively lower factor than explained by the increase in activity level. This makes the conventional methods less applicable in dynamic, seasonal and non-stationary businesses, unless a new tariff is determined for each period by using the actuals of that period.

In stable businesses the distinction between fixed and variable cost does no matter for cost allocation since the level of activity and the total cost remain the same. In variable businesses the distinction matters since a wrong estimation of fixed or variable cost can lead to wrong estimation of the total cost. Besides the fixed cost are often representing a large part of the total cost and therefore the visibility is decreased when assuming that all the cost are variable Therefore by applying our method reduces workload, once a good regression equation is determined for each activity. In subsequent periods only the activity levels
need to be filled out to determine the tariff and allocate the cost. If fixed tariffs are used, the complete cost identification process needs to be redone every period. Another option is to determine tariffs for sub activities and also do ABC allocations at lower levels as for instance done by van Damme & van der Zon (1999). But as mentioned before quantitative costs estimations are not an option since it requires a further breakdown of activities and costs, besides it requires additional in-depth knowledge. On the contrary a regression can be done with data that can easily be obtained.

A last advantage is that the method used is more structural modeling, which increases the long term visibility. This includes determining an accurate equation for estimating the tariff, by describing the relation between the activity costs and the cost driver. Gaining insight in this relation and in the fixed and variable cost of every activity, the understanding of the individual processes is increased. This increased understanding of the relation between costs and activity levels can help long term decision making. Besides it is much easier and less time consuming to gather information and describe the relation between activity levels. Often information about the activity levels (cost drivers) can be downloaded from an ERP/SAP system. Consequently by using the regression equation the tariff can be calculated that corresponds with the current level of activity. By forecasting the future levels of activity, the cost can be calculated based on existing data. Therefore the regression gives not only allocations for the periods in scope, but also estimations for other periods. Besides the costs do agree with the financial statements for a longer period without redoing the complete analysis every period. The regression estimation can be used to forecast the tariff and therefore the cost in a following period without redoing the complete analysis. When there are no significant changes in revenue or supply chain structure compared to the previous quarter the total estimated costs will agree with the financial statements to a large extent.

### 4.5.2 Disadvantages

The fixed and variable cost used in the regression equation is based on past performances. The calculation of the tariff and the distribution of cost are based in past figures, which might not always be as accurate. Changing the way of working might influence the costs, in a manner that is not accurately represented by the current tariffs and the current structure of fixed and variable costs. For instance the might be activities that will be organized differently compared to the past. In the current regression equations and tariffs these costs are assumed to be fixed, since these activities did not change in the analyzed periods. But it might be possible to change the way of working and therefore these costs are variable while in the model they are assumed to be fixed. By using regression only information given in the current data can be modeled, if certain cost is the same over all periods they are assumed to be fixed. Only by handpicking fixed and variable costs this can be avoided. To incorporate changes in the cost structure of the activity the regression should be update frequently.

Since a model is used and the tariffs are derived from the regression model, the total cost will not completely match the financial statements and the actual cost in detail. The only way to achieve a 100% match with the current financial statements is by using actuals, but a large disadvantage is that this is a very time consuming process if this needs to be done frequently. Therefore the methods of using a regression equation are more accurate than fixed tariffs and less accurate than using actuals. Besides the allocation of costs is more time consuming than fixed tariffs but far less time consuming than using actuals. Depending on the accuracy of required and the time available a method it can be chosen to use one of these three available methods.

Another disadvantage is that by using this model the temporary changes and disturbances might not always be accurately included. As said before the visibility created on a more structural level, the cost is modeled looking at the relation between the costs and the cost driver. If this relation changes the due temporary disturbance, the impact of these costs related to these is not given in the model. Some of
temporary of incidental changes in cost are small and not worthwhile to investigate while others are larger
and should be taken into account. Since it is not possible to include this in a model the costs related to
temporary or incidental cost should be added manually.

4.6 Activities in distribution service costs
In the distribution service costs, three groups of activities can be distinguished. For each of the cost
categories (groups) some activities with related cost drivers can be identified. The allocation of costs to
activities and the identification of costs and cost drivers are primarily based on the papers of Freeman,

1. Order administration:
The order administration costs are all costs related to customers placing an order and therefore all ‘paper’
flows related to this order. The order administration process consists of the following steps (Figure 3.3):
Order placement & communication, Order entry, Credit check, Documentation and Invoicing & collection.
The Order placement & communication is the first step and initiates order-to-collection cycle. The second
step is the order entry in the system. The third step is the Credit check and can also involve other forms
of data validation in the order placed by the customer. The documentation step is largely the creation and
preparation of documents related to the deliveries (e.g. shipping documents). Lastly is the Invoicing and
collection process, which includes sending the invoice, follow-up of the invoice and checking the payment.

The most important cost factor are the labor costs. Allocation of these costs can best be done by the
number of orders per customer, since they are driving the cost within all order administration activities.
Depending on the stage in the order-to-collection cycle it the cost driver is:
- Sales order (lines): Order placement & communication, Order entry, Credit check
- Delivery order (lines): Documentation
- Invoice (items): Invoicing & collection

In order administration there could be large differences in true costs between customers. The main
differences are explained by the number of orders placed by the customer. A second important difference
is between regular customers and new unfamiliar customers. The first group will rarely ask support or
more information and will likely use an EDI system for order application. On the other hand it is likely that
the second group will use a lot of resources (e.g. support from order desk employees). Note that for our
allocation both customer groups will not be distinguished other than by the number of orders placed.

2. Warehousing
The warehousing costs are all operational costs related to the flow of goods within the warehouse. There
needs to be made a clear distinction with the transportation costs, which are outside the warehouse. The
warehousing costs consist of order picking costs, special packing and dedicated storage costs (Freeman,
Haasz, Lizzola, & Seiersen, 2000). For the sake of completeness one might also consider inbound order
picking, storage and inventory costs. With inventory cost being the cost of capital related to the value of
the products stored and storage costs being the cost related to the space used such as warehouse rent.

Due to the fact that the physical activities are initiated by a delivery order, allocation of warehousing costs
can best be done by the number of delivery orders, the number of delivery lines or the number of units
sold. For the other costs which are not directly related to the order-to-collection cycle, it also possible to
consider revenue as main cost driver.

3. Transportation
The transportation costs include the physical movement of goods from the distribution center to the
customer (Freeman, Haasz, Lizzola, & Seiersen, 2000). The costs are therefore limited to the costs made
by the transportation company. The cost drivers for this are besides number of shipments and the mode of transportation, also the number of units in a shipment and therefore the required space in for instance a truck. There can be large difference between shipment by truck or by express delivery. Other differences occur for instance between customers that order full truck loads once per month and customers that require deliveries of a few units every day.
5. Overview of business

In this chapter the part of the organization that is within scope is described, first by describing the supply chain and secondly by describing the order-to-collection cycle. Both sections will provide an additional insight in the business processes.

The marketing and sales processes cannot be described in high detail, due to various reasons. At first the sales and marketing processes are less clear, for instance it is unclear what the cost objects are and what the cost drivers are within these processes. In general they can be allocated to for instance markets, but it is hard to connect them to cost drivers and allocate the costs in detailed way to individual customers, such as by the number of sales visits. The most important reason for this is that is not always possible to acquire detailed information due to legal requirements, such as the number of sales visits from a key account manager to a specific customer and therefore there is simply no data available. Besides not all effort is directed to current customers or future customers, since some effort is directed towards leads which will never become customers and therefore these costs are difficult to allocate. Lastly the sales and marketing costs can hardly be divided in generalized processes in order to allocate cost accordingly. Generalized processes in sales and marketing one could think of are contacting leads, managing current customer relation, administrative processes, brand promotion and brand promotion at the customer. But as explained before there is insufficient information available to be able to allocate costs accordingly.

In general the sales processes can be described as acquisition of new customers and managing of existing customer relations. For marketing the main processes are brand communication to the market and the creation of product awareness in the market. As discussed before our focus will be on the Distribution Service Costs and the (Sales) Marketing Costs will be out of scope.

5.1 Supply chain overview

The supply chain within the scope of this project is given in the Figure 5.1. As previously discussed the supply chain consists of a product channel and a customer channel. The internal product channel roughly consists out of manufacturing and packaging, while the customer channel roughly consists of warehousing and distribution. As can be seen in the figure there are three factories which supply one packing facility. After packing, the goods are forwarded to the central distribution center (CDC), which supplies two regional distribution centers (RDC1 & RDC2). Besides supplying RDC’s the CDC also directly delivers to customers both within its region and in the other regions via direct shipments.

Factory 2, Packing and the CDC are located in the same city. In order to avoid complexity some of the flows which are outside the scope, such as products for OEM manufacturers, are not given in figure 5.1
5.2 Order-to-collection cycle

The order administration, distribution and transportation costs are very customer related. They are part of the order-to-collection cycle which is initiated by the customer (Christopher, 2011). Figure 5.2 shows an adapted version of the original order-to-collection cycle (Figure 3.3) as given by Christopher (2011). Besides Philips’ order-to-collection cycle, also the part of the organization in which the activity takes place is given in the figure. Lastly also different document types can be identified, again these document types are closely related to the processes and the organizations identified in Figure 5.2.

A sales order is entered into the system by the Order desk and is the first document type in the order-to-collection cycle. After entering the data in the system, the sales order is validated by the commercial planners. The sales order is mainly connected to the Order placement & communication, Order entry and Data validation processes. The second document type is the delivery order, which is created by the commercial planning. The delivery order is created by looking to the current outstanding sales orders from a customer, the current stock and the expected production. After the delivery orders are created the delivery orders are prioritized. The delivery order is the main document type used in Delivery creation, Orders prioritization, Order picking, Transport planning and Delivery. The last document type in the order-to-collection cycle is the invoice, which is used by the financial operations department in the Invoicing & collection process.
Order placement & communication
Order entry
Data validation
Delivery creation
Orders prioritization
Order picking
Transport planning
Delivery
Invoicing & collection

Order desk
Commercial planning
Warehousing & Distribution
Financial operations

Figure 5.2: Order-to-collection cycle & departments
6. Identification of model parameters

This chapter contains an initial analysis in order to define the input for the cost-to-serve analysis. This will be done in three parts: describing the activities, relating cost drivers to activities and determining the periodicity.

The first step is getting a complete overview on the various activities and the cost drivers within scope. Secondly the respective cost drivers of the activities will be determined. Once the costs are identified and allocated to the activities, it can be determined how these costs will be derived from data and information available. The identification of the various cost factors and cost drivers will largely be done from a Philips perspective and will not always coincide with literature. Consequently the cost activities will be specified further by looking into the business and the organization. The result of this identification process both from the general, financial statement perspective and operational, business perspective will be discussed in this chapter.

It is important to note that not all alternatives will be discussed in detail. The number of possible alternatives is innumerous and for most of them it is obvious that they are not plausible alternatives. For instance the cost driver for order entry is the number of order lines placed, not the amount of shipments, or the number of invoiced items (they are related to later steps in the order-to-collection cycle). Therefore some likely alternatives will be given based on common sense, literature and the experience of subject matter experts.

6.1 Activities

This section will discuss the activity costs and cost drivers for the activity categories within scope: Order administration, warehousing and transportation. The costs and cost drivers identified at Philips are extensively discussed with the subject matter experts. In this section a selection of activities is given, based on found cost factors found at Philips.

The order administration, warehousing and transportation costs are customer related. They are part of the order-to-collection cycle (Figure 5.2) and are initiated by the customer (Christopher, 2011). In this report, the activity costs related to order administration, warehousing and transportation will be discussed separately.

Order administration

The order administration process consists out of the following steps (Figure 5.2): Order placement & communication, Order entry, Data validation, Delivery creation, Orders prioritization and Invoicing & collection. The most important cost factor is the wages. Allocation of these costs can best done by the number of orders per customer, since they are driving the cost within all order administration activities.

The order entry process is done at Order desk, which is the first point of contact for customers. The order entry process also includes complaints and all other tasks done at the Order desk. The primary cost driver for the processes performed at the Order desk is the number of order lines. Delivery creation, data validation, order prioritization and transport document processes are done in the distribution centers and are all the administration processes that relate directly the shipment or the order picking process in the warehouse. The cost driver for the distribution center processes are the number of delivery lines. For transport documentation the costs could also depend on the profile of the customer and its preferences (e.g. number of delivery documents). However these differences in individual preferences are small, especially in comparing to the total costs and are therefore not taken into consideration. The invoicing process is triggered per shipment, with one invoice sent per shipment. Besides due to outsourcing there is a fixed tariff per invoice.
**Warehousing costs**
The warehousing costs related to a customer order are: order picking costs, special packing and dedicated storage costs (Freeman, Haasz, Lizzola, & Seiersen, 2000). For now, it seems that special packing costs and dedicated storage costs are not applicable. Special packing are customer related but are not relevant for our scope, since it is included in the bill of materials and are therefore in manufacturing cost.

Due to the supply chain structure (Figure 5.1), there are different supply chain flows in the central DC: order picking for third parties & order picking for the regional DC’s, where the regional DCs only have the order picking flow for third party customers. The allocation for distribution costs at Philips will be done by the number of delivery lines. This choice for the number of delivery lines as cost driver is made, because there is hardly any time involved with starting a new order. Also the size of the order and quantity of the order are not of significant influence due to a high correlation with the number of picking lines (figure 6). Besides a minimal reduction in the quality of the results, leaving these cost drivers out of the scope reduces the complexity of the model and the amount of data needed.

In this case it is also chosen that warehousing overhead cost is not part of the direct warehousing cost, but of other overhead costs. This is done due to the activities performed which are also related to other activities such as new product introduction and other not typical warehousing activities. Besides the customers with few order lines typically seem to use a lot of the overhead capacity, for instance by large, infrequent customer orders from a customer located on a different continent. Therefore it is chosen to allocate the warehousing overhead using sales as cost driver.

**Transportation costs**
The transportation costs include the number of shipments, the quantity shipped and the rate of the freight forwarder. The transportation costs within the scope are the transportation to third parties as well as the shipments from the central DC to the regional DC’s. Because the transportation costs depend on the location of the customer and the transportation mode (e.g. air, parcel & regular), actual cost will be used in order to get an accurate view on the profitability of a customer. Besides there are a lot of different customers, shipment volumes and transportation modes, therefore constructing tariffs sheets will be a time consuming process especially if the actual costs per shipment are readily available.

### 6.2 Allocation of costs
In figure 6.1 the correlation of the most important cost drivers is given. The correlations are derived from the cost driver data for all 998 individual customers over 3 quarters. As can be seen in Figure 6.1 the different cost drivers have a strong to very strong correlation. Besides the high correlation, business matter experts indicated that for most processes there is only one cost driver used for managing the business. Considering both the correlations and the statements from the subject matter experts it is chosen to use only one cost driver as independent variable to predict the different activity costs. Theoretically this could imply that any factor can be chosen as cost driver since they are all describing the volume in the order-to-collection cycle. However from a practical perspective, at each stage one cost driver is more applicable than another.
Figure 6.1: Pearson Correlations of cost drivers and their significance

Given these correlations and the information of the subject matter experts, the cost drivers that are used to allocate costs are:

- Sales per customer
- # Order lines
- # Deliveries
- # Delivery lines
- # Invoices

Besides the cost drivers there are also an allocation to the business managed such as market regions and shipping regions. In Table 6.1 an overview of the activities, the business managed and the cost drivers is given.

In order to determine the cost-to-serve a lot of data has been gathered from different sources. At Philips most of the cost drivers can be downloaded from an SAP system, while the activity costs were gathered in cooperation with subject matter experts. Both the cost driver data as well as the cost data, should be representing the actuals in the respective quarters. Due to the design decision to make the model time independent (chapter 4), the identification of activity costs is an exercise that has to be done only every few years.

<table>
<thead>
<tr>
<th>Correlations</th>
<th>Revenue</th>
<th>COGS</th>
<th>Adjusted IGM</th>
<th>Orderdocs</th>
<th>Orderitems</th>
<th>Deliverydocs</th>
<th>Deliveryitems</th>
<th>Invoicedocs</th>
<th>Invoiceitems</th>
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</table>

* Correlation is significant at the 0.01 level (2-tailed).
### Table 6.2: Overview of cost allocations

<table>
<thead>
<tr>
<th>Category</th>
<th>Activity</th>
<th>Business managed</th>
<th>Cost drivers ($X_i$)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Order</strong></td>
<td>Order desk (communication &amp; entry)</td>
<td>Market</td>
<td>Order lines</td>
</tr>
<tr>
<td><strong>Administration</strong></td>
<td>Data validation</td>
<td>All customers</td>
<td>Order lines</td>
</tr>
<tr>
<td></td>
<td>Delivery creation</td>
<td>All customers</td>
<td>Delivery lines</td>
</tr>
<tr>
<td></td>
<td>Orders prioritization</td>
<td>All customers</td>
<td>Delivery lines</td>
</tr>
<tr>
<td></td>
<td>Invoicing &amp; collection</td>
<td>All customers</td>
<td>Invoices</td>
</tr>
<tr>
<td><strong>Distribution</strong></td>
<td>Outbound order picking</td>
<td>CDC (excl. via RDC)</td>
<td>Delivery lines</td>
</tr>
<tr>
<td></td>
<td>Transport planning CDC</td>
<td>CDC (only customers directly served)</td>
<td>Deliveries</td>
</tr>
<tr>
<td></td>
<td>Overhead CDC</td>
<td>CDC (incl. via RDC)</td>
<td>Sales</td>
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<td></td>
<td>Finished goods inventory</td>
<td>CDC (excl. via RDC)</td>
<td>Sales</td>
</tr>
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<td>Outbound RDC1</td>
<td>RDC1</td>
<td>Delivery lines</td>
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<tr>
<td></td>
<td>Overhead RDC1</td>
<td>RDC1</td>
<td>Sales</td>
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<td></td>
<td>Finished goods inventory</td>
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<td>Overhead RDC2</td>
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<td>Finished goods inventory</td>
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<td>Actuals, sales</td>
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<td>Internal CDC to RDC2</td>
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<td>3rd party</td>
<td>Individual customer</td>
<td>Customer actuals</td>
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<tr>
<td></td>
<td>Not Found</td>
<td>All customers</td>
<td>Actuals, sales</td>
</tr>
</tbody>
</table>

#### 6.3 Periodicity

Besides the activities and their respective cost drivers it is important to determine the periodicity of analysis, since the lengths of the periods highly influence the outcomes. For instance if costs averages for one year are used as input for the regression, the outcome is more stable than when it is done on a monthly basis. It is chosen to do the analysis on a quarterly basis, due to a number of reasons. The first reason is the requirement that it should match the current financial reporting. Depending on the size of the fixed costs related to the variable costs, the cost per cost driver can differ significantly when taking an annual average. This makes that the results of the analysis are almost not recognizable and can strongly deviate from current financial reporting. A second reason for not taking longer periods is that according to the definition of Cooper & Kaplan (1987), costs are variable only if they vary directly with monthly or quarterly changes in volume. Since the model takes into consideration both fixed and variable costs, longer periodicity will not take into account some seasonality and the fixed cost during the various seasons. When not taking into account these fixed cost and using annual averages it is assumed that all cost are variable, which is an inappropriate assumption. The analysis will not be done on a monthly basis since it happens frequently that invoices are accounted for in different periods than when the activity is performed. Using monthly data will assume high variation, which may or may not represent reality (e.g. December due to the Christmas holidays).
7. Model application example

In this chapter an example will be given for determining the costs per customer at Philips. For accurately determining the costs per customer three dimensions of analysis will be covered: cost identification, cost estimation and cost allocation. In this section the activity costs will be identified in the business (identification). Secondly a regression will be created to estimate the relation between the activity costs and the cost driver in order to estimate a tariff for each quarter (estimation). Lastly the new estimated tariff can be applied to allocate the costs to an individual customer (allocation).

Sample size

The regression is done based on the data of five quarters. It is known that the amount of data points available is limited, since it is recommended to have at least a sample size of 5 per independent variable (Hair, Black, Babin, & Anderson, 2010). The size of the sample has direct impact on the appropriateness of the analysis. For instance, an analysis with fewer than 30 observations is only appropriate for simple linear regression with a single independent variable. In this case only very strong relations can be detected with a degree of certainty. In order to obtain a statistical power of at least 0.8 with a sample size of 5, the R-squared should be at least 0.785 (Soper, 2015). Besides the statistical power, the sample size also affects the generalizability of the results (Hair, Black, Babin, & Anderson, 2010). The ratio of observations per independent variable should never fall below 5:1. If the ratio falls below this level there is a risk of overfitting the regression coefficients to the sample, making the results too specific for the sample.

Estimation of the regression coefficients

In this section only the activity Overhead CDC will be discussed as an example. This section will give an application of the model for one specific activity. This example will describe both the relation between the cost driver and the activity costs as well as the allocation of the cost to an individual customer. In table 7.1 the activity costs and the activity level (cost drivers) are given. In order to make it repeatable for all activities it is chosen to determine the regression coefficients and to test the assumptions by using the statistical formulas as given by Montgomery & Runger (2007). These statistical formulas can be implemented in software (e.g. Excel VBA) in order to repeat the calculation for all activities.

Table 7.1: Costs & Cost driver example (Overhead CDC)

<table>
<thead>
<tr>
<th>Year</th>
<th>Activity costs $(A_i)$</th>
<th>Cost driver $(X_i)$</th>
<th>Cost driver Index</th>
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</table>

Indices

\( p \) Period with \( p \in \{1, 2, 3, \ldots, n\} \)

Cost components

\( \hat{A}_i \) Estimate for total costs for activity \( i \)
\( \hat{F}_i \) Estimated total fixed costs for activity \( i \)
\( \hat{v}_i \) Estimated variable cost tariff for activity \( i \) and the related cost driver

Equation 9 and the numbers above in table 7.1 can be used for determining the regression coefficients using the least squares estimates method.
\[ \hat{A}_i = \hat{F}_i + \hat{v}_i X_i \]  
(13)

With:

\[ \hat{F}_i = \overline{A}_i - \hat{v}_i \overline{X}_i \]  
(14)

\[ \hat{v}_1 = \frac{\sum_{p=1}^{n} A_{ip} X_{ip} - \left( \sum_{p=1}^{n} A_{ip} \right) \left( \sum_{p=1}^{n} X_{ip} \right)}{n \sum_{p=1}^{n} X_{ip}^2 - \left( \sum_{p=1}^{n} X_{ip} \right)^2} \]  
(15)

Where \( \overline{A}_i = \left( \frac{1}{n} \right) \sum_{p=1}^{n} A_{ip} \) and \( \overline{X}_i = \left( \frac{1}{n} \right) \sum_{p=1}^{n} X_{ip} \)

The result of this regression exercise is given in Figure 7.1. The regression is based on a limited sample size in combination with the estimates for values. Therefore it is wise to combine these findings into a formula form that describes the relation between the dependent and the independent variable. Rather than assuming that the individual estimates are correct.

By doing a regression the relation between the tariff (dependent) and cost driver (independent) can be described as in equation 7 for overhead CDC:

\[ A_i = 270.62 x_i + 293.636.88 \]

The corresponding error variance can be calculated as the error sum of squares

\[ \hat{\sigma}^2 = \frac{\sum_{k=1}^{n} (A_{ip} - \hat{A}_{ip})^2}{n - 2} \]  
(16)

With \( A_{ip} \) being the observed value and \( \hat{A}_{ip} \) the estimated value gives a standard deviation of 2012.37.

![Figure 7.1: Regression example of total activity costs Overhead CDC](image-url)

Figure 7.1: Regression example of total activity costs Overhead CDC
By using these regression equations the tariffs can be calculated. So, by filling out the activity level (cost driver), the tariff for an activity during a quarter can be determined. The model fit of this specific cost object regression is good the coefficient of determination is quite high ($R^2 = 0.899$).

$$R^2 = \frac{SS_R}{SS_T} = \frac{\sum_{p=1}^{n} A_{ip}X_{ip}}{\sum_{p=1}^{n} (A_{ip} - \bar{A}_{ip})^2}$$  \hspace{1cm} (17)

Also the F test statistic is significant and therefore the regression contributes to the model and explains a significant part of the total variance.

$$H_0: \bar{v}_i = 0$$
$$H_1: \bar{v}_i \neq 0$$

$$F_0 = \frac{MS_R}{\frac{1}{\hat{\sigma}^2}} = \frac{\sum_{p=1}^{n} A_{ip}X_{ip}}{\sum_{p=1}^{n} (A_{ip} - \bar{A}_{ip})^2}$$  \hspace{1cm} (18)

Using equation 18 gives that $F_0 = 26.81$, since $F_0 > F_{a=0.05,1,n-2} = 10.13$ it can be concluded that $v_i$ is not equal to zero. In some situation it might be that the regression has not a significant contribution, in those case averages can be used as best estimation for the tariffs.

**Testing the assumptions**

For the individual regressions four assumptions need to be tested (Hair, Black, Babin, & Anderson, 2010): linearity, homoscedasticity, independence of errors and normality of errors.

1. **Linearity**: First of all the scatterplot (Figure 7.1) of all individual variables do not indicate any non-linearity between the dependent and independent variables.
2. **For heteroscedasticity** the variances of the errors are more or less equal distributed as can be seen in Figure 7.3. Since that sample size is limited it is only possible to make a distinction if the first 3 errors have a far higher average variance than last two or the other way around.
3. **Independence of errors** seems good (Figure 7.3). Again due to the limited sample size it is hard to make a good decision therefore in this case it chosen to doubt the independence of errors in case of three or more subsequent highly positive or highly negative errors.
4. **For normality** it seems like there are some minor violations and there seem to be big tails (Figure 7.2). However it should be considered that it is hard to fit a distribution to only 5 data points.

As can be seen it is hard to test the assumptions for regression due to the small sample size, besides the Q4 (high season) is included twice. For all four assumptions the small sample size should be taken into consideration when assessing these assumptions.

When testing the assumptions of the regressions for the other activities similar things can be noticed. This is partly due to the correlation between the cost drivers. Besides the sample size is the same for all activities which makes hard to clearly reject the individual assumptions.
Besides the assumptions related to the regression model there are some other assumptions which should be taken into consideration when applying this method for cost estimation. Key assumption is that cost estimations on a total level behave in a similar way on the level of an individual customer, since a tariff will be determined on a total level and consequently applied on an individual customer. Sometimes individual customers might have different behavior than the majority, with for instance different cost and cost drivers. Therefore, as said before, in order to be able to allocate the cost it will be assumed that all customers behave in a similar way and get the same tariff for the allocation of a cost within one cost object.

Next to the general assumptions which apply to the method there are also some assumptions related the business environment in which this study took place. Due to the reason that this study is done in a certain business environment means the numbers found are only applicable to this environment. Besides the study is done for a limited period, this means that if there are significant changes to the business environment the tariffs might change as well. Related to that it can be stated that the tariffs only apply to this business environment, in case of a similar revenues, similar supply chain structures and similar activity levels as in the current situation.

**Calculation cost allocation for an individual customer**

After the regression is completed for all activities equation 10 and 11 can be filled out with the total level for the cost driver related to the cost object. So when this is applied to the fourth quarter 2013 it gives:

\[ A_i = 270.62X_i + 293636.88 \]
\[ a_i = \frac{293636.88}{X_i} + 270.62 = \frac{293636.88}{94.80} + 270.62 = 3368,05 \]

The tariffs for each period can be found in table 8.1. Consequently this tariff can be used to calculate the costs that will be allocated to a customer. So if a customer has revenues of 1 (indexed) in Q4, the cost allocation according to equation 11 will amount:

\[ Y_{ic} = a_iX_{ic} = \varepsilon3368,05 \ast 1 = \varepsilon3368,05 \]
8. Philips’ exercise

In this chapter the outcomes of the cost-to-serve exercise at Philips will be discussed and analyzed. In the first section (section 8.1) the outcomes will be discussed in order to gain insights in the increased visibility due to cost-to-serve efforts. The second section (section 8.2) in this chapter will analyze the accuracy of the outcomes in order to validate the results of Philips exercise.

8.1 Results

As mentioned before this study focusses on improving the visibility of cost related to serving a customer. A cost-to-serve analysis provides the following insights:

1. The cost structure of serving customers (activity costs & cost drivers)
2. Distribution of costs among customers
3. Profitability of a customer & the costs related to serving a customer

When the cost structure of serving customers and the distribution of costs among customer is known it is a good indication for internal performance. On the other hand deviations in costs & profitability of a single customer compared to a peer group might give a good indication of the customer performance and the relation with this customer. In this section an example of each of the insights will be given. The focus of this chapter will be on costs. In order to determine the profitability all costs should be deducted from the revenue.

This section will first discuss the cost structure of serving customers and the distribution of costs over the cost categories. Secondly, an example of the distribution of costs among customers and groups of customers is given. Lastly a short overview of the costs & profitability of two random customers will be given. Note that, not only the distribution service costs are given, but also the (sales) marketing costs, production costs and terms of trade (Figure 3.2).

Insight 1: Cost structure

![Figure 8.1: Cost distribution over different categories](image)

The structure of costs to serve a customer is defined by three costs categories: Order administration, Distribution & Transportation. Besides the costs given above there are the production costs, sales costs, marketing cost & terms of trade, which are out of our scope and therefore and some other costs which are not taken into consideration (e.g. R&D). In figure 8.1 an overview of the costs distribution is given.

A general structure for each of the six cost categories can be described in a general regression formula that takes into account the fixed and variable costs. This formula describes the relation between the cost driver (independent) and the costs (dependent). These costs can be used to calculate both the tariff as well as the costs allocated to an individual customer. Table 8.1 shows the cost structure and the tariffs for activity.
### Table 8.1: Cost structure per activity (variable & fixed costs) & tariff \((a_{ip})\) per quarter 2014

| Category          | Activity                        | Market                  | Variable tariff \(a_i\) & Fixed tariff \(F_i\) | Tariff 2014 Q1 \(a_{i1}\) & \(F_{i1}\) | Tariff 2014 Q2 \(a_{i2}\) & \(F_{i2}\) | Tariff 2014 Q3 \(a_{i3}\) & \(F_{i3}\) | Tariff 2014 Q4 \(a_{i4}\) & \(F_{i4}\) |
|-------------------|---------------------------------|-------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|
| Order Administration | Order desk                      | DACH                    | 0.00                                          | 48585.86                                      | 3.6992                                        | 5.0042                                        | 4.1644                                        | 3.3289                                        |
|                   | France & Export EMEA           |                         | 0.00                                          | 72878.79                                      | 4.8178                                        | 5.3517                                        | 5.5266                                        | 3.7954                                        |
|                   | Eastern EU                     |                         | 0.00                                          | 31580.81                                      | 3.1374                                        | 3.8551                                        | 3.4609                                        | 1.4933                                        |
|                   | Central EU                     |                         | 0.00                                          | 48585.86                                      | 3.6716                                        | 4.7011                                        | 4.0610                                        | 3.0733                                        |
|                   | Nordics & UK                   |                         | 0.00                                          | 24292.93                                      | 4.8928                                        | 5.4262                                        | 4.8948                                        | 3.5573                                        |
|                   | Benelux                         |                         | 0.00                                          | 12146.46                                      | 2.9640                                        | 4.1870                                        | 3.4609                                        | 2.6150                                        |
|                   | Italy                           |                         | 0.00                                          | 12146.46                                      | 3.7922                                        | 4.8162                                        | 5.7187                                        | 3.5454                                        |
|                   | Export                          |                         | 0.00                                          | 29151.52                                      | 14.8429                                       | 12.3681                                       | 12.2383                                       | 13.2266                                       |
|                   | Data validation                 |                         | 0.0102                                        | 4289.66                                       | 0.0656                                        | 0.0786                                        | 0.0733                                        | 0.0524                                        |
|                   | Delivery creation               |                         | 0.0177                                        | 7021.98                                       | 0.1160                                        | 0.1319                                        | 0.1235                                        | 0.0884                                        |
|                   | Order prioritization            |                         | 0.0036                                        | 1450.19                                       | 0.0239                                        | 0.0272                                        | 0.0255                                        | 0.0183                                        |
|                   | Invoicing & collection          |                         | 9.6300                                        | 0.00                                          | 9.6300                                        | 9.6300                                        | 9.6300                                        | 9.6300                                        |
| Distribution      | CDC overhead                    |                         | 0.00066                                       | 368101.19                                     | 0.0116                                        | 0.0141                                        | 0.0123                                        | 0.0082                                        |
|                   | CDC outbound order picking      |                         | 0.45833                                       | 43486.36                                      | 1.7019                                        | 1.9266                                        | 1.7658                                        | 1.4219                                        |
|                   | CDC transport planning          |                         | 0.42047                                       | 7632.33                                       | 1.8000                                        | 2.1688                                        | 2.0647                                        | 1.5731                                        |
|                   | CDC inventory                   |                         | 0.00019                                       | 76270.49                                      | 0.0029                                        | 0.0048                                        | 0.0053                                        | 0.0042                                        |
|                   | RDC1 overhead                   |                         | 0.00057                                       | 138627.44                                     | 0.0100                                        | 0.0150                                        | 0.0147                                        | 0.0096                                        |
|                   | RDC1 outbound order picking     |                         | 5.85922                                       | -41463.20                                     | 4.4891                                        | 4.0261                                        | 4.1849                                        | 4.7214                                        |
|                   | RDC1 inventory                  |                         | 0.00000                                       | 56040.23                                      | 0.0038                                        | 0.0058                                        | 0.0057                                        | 0.0036                                        |
|                   | RDC2 overhead                   |                         | 0.00000                                       | 59880.37                                      | 0.0345                                        | 0.0273                                        | 0.0294                                        | 0.0102                                        |
|                   | RDC2 inventory                  |                         | 0.00000                                       | 22249.12                                      | 0.0128                                        | 0.0101                                        | 0.0109                                        | 0.0038                                        |

The last four columns give the tariffs for each quarter, which can be used for determining the cost allocation to an individual customer.

\[\text{CDC outbound order picking} \text{ (100 delivery items in Q1)} = 14,75 \times 100 = €1471.30\]

The cost structure as shown is this part consists out of the costs distribution over the different activities as well as the structure of the costs described by the fixed and variable costs. When analyzing tariffs and cost drivers for each period it becomes clear that there is some seasonality. In table 8.1 can be seen that the tariff of 2\textsuperscript{nd} and 3\textsuperscript{rd} quarter is higher than the tariff for the 1\textsuperscript{st} and 4\textsuperscript{th} quarter, while the costs are largely fixed. The main cause for this is the change in volume and therefore it is recommended to always consider the total activity volume when determining activity cost tariffs.

**Insight 2: The distribution of costs among customers**

The distribution of costs among customers can be shown from different perspectives, such as, revenue, customer classification and region. In this example a distribution of costs among customers will be shown compared to the revenue generated. This is divided into two parts with Group A representing the top 25\% customers with the highest revenue and Group B the 75 customers with the lowest revenue.

From this figure 8.2 some general conclusion can be made, such as

- The top 25\% customers according to revenue represent 87\% of total sales
- Customers with high revenues (Group A) have relatively low Distribution service costs, while low revenue customers (Group B) have a relatively high cost to serve.

As already mentioned it is also possible to look from other perspectives, such as different sales markets and different customer types (e.g. retail, online)
Insight 3: Costs of individual customers

For each individual customer the costs can be calculated by using the tariffs available and the activity level of the specific customer. A typical customer can have the following costs in Q1 (Table 8.2):

Table 8.2: Costs to serve a customer with Distribution service costs details

<table>
<thead>
<tr>
<th>Category</th>
<th>Activity</th>
<th>Tariff 2014 Q1 ($/unit)</th>
<th>Cost driver (x$_{ij}$)</th>
<th>Costs Y$_{ij}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sales (Marketing costs)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Order Administration</td>
<td>Order desk (communication &amp; entry)</td>
<td>4.817795</td>
<td>425</td>
<td>2047.56</td>
</tr>
<tr>
<td></td>
<td>Data validation</td>
<td>0.065591</td>
<td>425</td>
<td>27.88</td>
</tr>
<tr>
<td></td>
<td>Delivery creation</td>
<td>0.115956</td>
<td>450</td>
<td>52.18</td>
</tr>
<tr>
<td></td>
<td>Orders prioritization</td>
<td>0.023947</td>
<td>450</td>
<td>10.78</td>
</tr>
<tr>
<td></td>
<td>Invoicing &amp; collection</td>
<td>9.63</td>
<td>69</td>
<td>664.47</td>
</tr>
<tr>
<td>Distribution</td>
<td>Outbound order picking</td>
<td>1.701861</td>
<td>450</td>
<td>765.84</td>
</tr>
<tr>
<td></td>
<td>Transport planning CDC</td>
<td>1.800013</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Overhead CDC</td>
<td>0.011645</td>
<td>684273.27</td>
<td>7968.58</td>
</tr>
<tr>
<td></td>
<td>Finished goods inventory CDC</td>
<td>0.002468</td>
<td>684273.27</td>
<td>1688.91</td>
</tr>
<tr>
<td></td>
<td>Outbound RDC1</td>
<td>4.489077</td>
<td>450</td>
<td>2020.08</td>
</tr>
<tr>
<td></td>
<td>Overhead RDC1</td>
<td>0.010037</td>
<td>684273.27</td>
<td>6867.88</td>
</tr>
<tr>
<td></td>
<td>Finished goods inventory RDC1</td>
<td>0.003826</td>
<td>684273.27</td>
<td>2618.06</td>
</tr>
<tr>
<td></td>
<td>Overhead RDC2</td>
<td>0.034453</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Finished goods inventory RDC2</td>
<td>0.012801</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Transportation</td>
<td>Internal CDC to RDC1</td>
<td></td>
<td></td>
<td>12960.85</td>
</tr>
<tr>
<td></td>
<td>Internal CDC to RDC2</td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>3rd party</td>
<td></td>
<td></td>
<td>10417.27</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td></td>
<td></td>
<td>132.90</td>
</tr>
<tr>
<td>Terms of trade</td>
<td></td>
<td></td>
<td></td>
<td>8326.05</td>
</tr>
</tbody>
</table>
8.2 Validation

In this chapter the results of the Philips exercise will be analyzed. In the first part the tariff estimation by using fixed and variable costs estimation will be compared to the results of a fixed tariff. In the second part an out-of-sample validation will done in order to analyze the forecasting accuracy of the model.

In activity based costing all costs will be allocated to the cost object according to a certain cost drivers. The tariff for cost allocation to the customers can be determined by dividing the total activity costs by the total volume of the related cost driver. In this chapter different tariff estimation methods will be compared. In order to make a good comparison between tariff estimation methods, a typical example with both fixed and variable cost will be evaluated for multiple tariff estimation methods. The tariff estimation methods that will be evaluated are (example figure 4.3):

1. Average/fixed tariff: This method will derive a fixed tariff which will be applied in all periods. Since a single tariff will be determined for all periods it is assumed that all costs are variable and that the changes in volume represent proportional change in costs. For instance if the total activity level increases by 10%, the activity costs will as well increase by 10%.

2. Regression tariff: this second method will estimate the fixed and variable costs for an overall activity level by using regression. Consequently costs levels will be divided by the activity level.

These methods will be compared in two steps: first the accuracy of the methods will be compared with the actual tariff per period. Secondly the model will be validated by looking at the forecasting accuracy.

Figure 4.3 displays the tariff actuals and the tariff estimation by using each of the two methods with on horizontal axis the cost driver volume and vertical axis the applicable activity tariff. By a visual inspection it can be seen that method 2 is at least as good for tariff estimation for each data point compared to the other method.

Tariff verification

There are different goodness-of-fit measures that can be used to determine the fit of the model to the tariff data. In this section some goodness-of-fit measures will be evaluated to make a good comparison between the tariff estimation methods. It should be noted that the assessment of the fit involves some subjective judgement. For verification of the model the R-squared and Mean Absolute Percentage Error (MAPE) will be used as goodness-of-fit measures in this report (Appendix B).

Table 8.3 shows the result of the selected goodness-of-fit measures for the tariff estimation per activity. As can be seen the fit both for the R-squared and the MAPE is on average higher for method 2, than for methods 1. It should be noted that the R-squared compares how much of the variance from a model with averages only (method 1) can be explained by a more advanced model (method 2).

The model fit of the activities with high fixed costs is close to 1 for the R-squared and close to 0 for the MAPE. For some activities with more variable costs the fit seems less perfect. The lower fit can be explained by for instance some deviations and the limited correlation between the variable costs and the activity costs. This is no coincidence since the fixed costs do not vary and therefore are easy to predict for every activity level. While in case of variable costs there is some deviation than can be described by the relation between variable costs and volume. These deviations are not uncommon and a pure relation between variable costs and volume is rare, since there is always some prediction error and often it takes some time to respond to changes in volume.
When analyzing the tariffs for each individual activity it can be seen only one activity estimate for method 2 has a R-squared below 0.785 (RDC2 inventory), which is the minimum value for the R-squared to have a good fit considering a sample size of 5 (Chapter 7). For all other activities the model fit is good with regards to the lower bound concerning the limited sample size. Besides, for some activities the R-squared is exactly 1 this can easily be explained by the fact that these activities have only fixed cost, which can be estimated with a 100% accuracy independent of the volume. Overall it can be concluded that 95% of the variance of method 1 can be explained by the model used in method 2.

When looking from a different perspective it can be seen that the MAPE is quite high for method 2, while low for method 1. For model 2 it indicates an average error of 1% which is low compared to an average error of 33% for model 1.

Concerning both goodness-of-fit test it can be concluded that there is a higher fit for estimating tariffs by using a regression for determining the fixed and variable costs compared to taking average tariffs independent of the volume.

Another way to test the appropriateness of the fixed tariff method is by testing the significance of the intercept of the regression. If the intercept is significant there is are fixed costs which implies that it is inappropriate to consider to use a fixed tariff and therefore consider only variable cost. In the last column of table 8.3 the outcomes of a t-test are given with the intercept are non-zero if $T_0 > T_{0.025,3} = 3.182$. It can be seen that it is the case for all activities except for the activities: Invoicing & collection and RDC1 outbound order picking, but it was already recognized that these activities had only variable cost.

Concluding there can be three types of activities identified: only variable costs, fixed and variable costs and only fixed costs. In order to make an accurate estimation of the costs and to determine an accurate
tariff for allocation it is therefore important to consider both fixed cost and variable costs. Using only variable costs as done in the ‘fixed tariff method’ is therefore inappropriate.

**Tariff validation**

The validation of the model will be done by determining the forecasting accuracy. An out-of-sample forecast will be performed by splitting up the data series into two segments: one for model fitting and one for model validation. Again the same goodness of fit measures will be used as done in the previous section. The last period of the sample will be used for validation, while the other four periods will be used for model creation. The 4th quarter of 2014 will be used for validation (the quarter for the highest sales of the periods analyzed).

Table 8.4: Tariff validation

<table>
<thead>
<tr>
<th>Category</th>
<th>Activity</th>
<th>Market</th>
<th>R-squared overall</th>
<th>MAPE (sample used for validation)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1. Fixed tariff</td>
<td>2. Regression tariff</td>
</tr>
<tr>
<td>Order</td>
<td>Order desk</td>
<td>DACH</td>
<td>1</td>
<td>0.203802</td>
</tr>
<tr>
<td>Administration</td>
<td>France &amp; Export EMEA</td>
<td>1</td>
<td>0.329579</td>
<td>1.105258</td>
</tr>
<tr>
<td></td>
<td>Eastern EU</td>
<td>1</td>
<td>0.303385</td>
<td>0.339368</td>
</tr>
<tr>
<td></td>
<td>Central EU</td>
<td>1</td>
<td>0.303385</td>
<td>0.303385</td>
</tr>
<tr>
<td></td>
<td>Nordics &amp; UK</td>
<td>1</td>
<td>0.250068</td>
<td>0.373618</td>
</tr>
<tr>
<td></td>
<td>Iberia</td>
<td>1</td>
<td>0.33482</td>
<td>0.373618</td>
</tr>
<tr>
<td></td>
<td>Italy</td>
<td>1</td>
<td>0.33482</td>
<td>0.373618</td>
</tr>
<tr>
<td></td>
<td>Export</td>
<td>1</td>
<td>0.33482</td>
<td>0.373618</td>
</tr>
<tr>
<td></td>
<td>OES/OLM</td>
<td>1</td>
<td>0.632673</td>
<td>0.632673</td>
</tr>
<tr>
<td>Distribution</td>
<td>Data validation</td>
<td>0.924388</td>
<td>0.079699</td>
<td>0.289838</td>
</tr>
<tr>
<td></td>
<td>Delivery creation</td>
<td>0.93328</td>
<td>0.079699</td>
<td>0.308549</td>
</tr>
<tr>
<td></td>
<td>Order prioritization</td>
<td>0.93328</td>
<td>0.079699</td>
<td>0.308549</td>
</tr>
<tr>
<td></td>
<td>Invoicing &amp; collection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CDC overhead</td>
<td>0.999961</td>
<td>0.002605</td>
<td>0.416115</td>
</tr>
<tr>
<td></td>
<td>CDC outbound order picking</td>
<td>0.923085</td>
<td>0.069537</td>
<td>0.250733</td>
</tr>
<tr>
<td></td>
<td>CDC transport planning</td>
<td>0.995661</td>
<td>0.01255</td>
<td>0.190533</td>
</tr>
<tr>
<td></td>
<td>CDC inventory</td>
<td>0.988915</td>
<td>0.046127</td>
<td>0.438126</td>
</tr>
<tr>
<td></td>
<td>RDC1 overhead</td>
<td>0.601461</td>
<td>0.116168</td>
<td>0.184014</td>
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<tr>
<td></td>
<td>RDC1 outbound order picking</td>
<td>0.999751</td>
<td>0.001478</td>
<td>0.093675</td>
</tr>
<tr>
<td></td>
<td>RDC1 inventory</td>
<td>0.992915</td>
<td>0.032678</td>
<td>0.388225</td>
</tr>
<tr>
<td></td>
<td>RDC2 overhead</td>
<td>0.983583</td>
<td>0.285648</td>
<td>2.229356</td>
</tr>
<tr>
<td></td>
<td>RDC2 inventory</td>
<td>0.997335</td>
<td>0.114286</td>
<td>2.213711</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>0.966982</td>
<td>0.041826</td>
<td>0.509983</td>
</tr>
</tbody>
</table>

The model fit for validation is again very high for the second method compared to the first method. RDC1 overhead has a low fit since the costs are not in line with the estimated fixed and variable costs. The costs for RDC1 overhead are significantly higher in the period used for validation. This is likely due to external factors such as price increases, since it cannot directly be explained by the change in volume. Overall it can be seen that the second method with a regression of fixed and variable costs has a good to very good fit and is outperforming the method with a fixed tariff concerning the forecast of the tariff for the fourth quarter of 2014. The higher value for MAPE (lower fit) can be explained by the point that it concerns an out of sample forecast and therefore the average tariff will always be underperforming since the period used for validation is not used for determining the average tariff.
Overall it can be seen that the R-squared is high and that on average 97% of the variance can be explained by the model created by using method 2 compared to using averages. Besides the average absolute error for method 2 (4%), is lower that the average error of method 1 (51%).

When analyzing the results of both the tariff verification and the tariff validation it can be concluded that the tariffs that are estimated by using a regression for determining fixed and variable costs (method 2) have a much better fit compared to the fixed average tariffs (method 1).
9 Supply chain design based on cost-to-serve information

Besides creating visibility over the costs in the current situation, cost to serve information can help to analyze the cost impact of changes in the activities. This chapter evaluates what can be said about a changing supply chain structure, for instance by reducing the number of warehouses. Given the cost-to-serve information the cost impact will be analyzed if all customers will be served from a single warehouse. Since it will be a cost evaluation, service levels and customer lead times will not be evaluated. Because the service levels and lead times are out of scope, it is assumed that these factors do not have an impact on the costs.

There is a very large area that needs to be covered in order to deliver the products to all customers in Europe. In the current supply chain structure the customers are served by one of the three warehouses depending on their location. The transportation is outsourced to a third party logistics provider with a considerable number of branches. For international transportation the shipments are shipped via a local branch to the customers.

In the new supply chain structure all the customers will be served from the Central DC (Figure 5.1) and both RDC1 and RDC2 will be closed. On a high level this means that all activities in the category Distribution (Table 6.2) will only be performed in the Central DC (CDC). For the category transportation it is difficult to estimate the costs. It is known that the logistics service providers (LSP) have a homogenous network of branches. Due to the LSP network and its possibilities for cross docking it can be assumed that the distance due to ending operations in the RDCs will not increase. What will increase is the load inefficiency in the truck since all customer shipments will be prepared in the CDC (e.g. goods on a pallet are not stacked to the roof of a truck). This means the international transportation costs will increase with a factor, due to the load inefficiency.

In table 9.1 an overview is given of changes regarding the individual activities. For most activities the impacts are common sense: the volume for the CDC will increase while for the RDC the volume and costs will decrease to zero. As discussed above it is assumed that the only impact in transportation costs will be in the increased costs due to inefficient space use in the truck since the shipments are already prepared per customer. This means that the internal RDCs will be replaced with a branch of the logistics service provider and the costs will be multiplied with a factor due to the load inefficiency. By assumption the transportation costs to the from the LSP branch or cross docking facility to the customers will be the same. Note that cost impact analysis will be performed on a general level and the changes of individual customers will not be analyzed, since it requires detailed transportation tariffs from the logistics service providers.

Table 9.1: Overview of impact on individual activities

<table>
<thead>
<tr>
<th>Category</th>
<th>Activity</th>
<th>Description of change in new situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distribution</td>
<td>Outbound order picking</td>
<td>Increased number of delivery lines</td>
</tr>
<tr>
<td></td>
<td>Transport planning CDC</td>
<td>Increased number of deliveries</td>
</tr>
<tr>
<td></td>
<td>Overhead CDC</td>
<td>Equal/increased costs</td>
</tr>
<tr>
<td></td>
<td>Finished goods inventory</td>
<td>Equal/increased inventory</td>
</tr>
<tr>
<td></td>
<td>Outbound RDC1</td>
<td>No costs in new situation</td>
</tr>
<tr>
<td></td>
<td>Overhead RDC1</td>
<td>No costs in new situation</td>
</tr>
<tr>
<td></td>
<td>Finished goods inventory</td>
<td>No costs in new situation</td>
</tr>
<tr>
<td></td>
<td>Overhead RDC2</td>
<td>No costs in new situation</td>
</tr>
<tr>
<td></td>
<td>Finished goods inventory</td>
<td>No costs in new situation</td>
</tr>
<tr>
<td>Transportation</td>
<td>CDC to RDCs/LSP branch</td>
<td>Increased costs due to load inefficiency</td>
</tr>
<tr>
<td></td>
<td>3rd party</td>
<td>No changes</td>
</tr>
</tbody>
</table>
In this chapter the costs for this new supply chain structure will be investigated. The basis of this analysis will be the tariffs and costs as determined by the cost-to-serve analysis. For all activities the new costs will be estimated by using uncertainty modeling. The estimation error for the costs and the tariffs will not be included in the model. In chapter 8 it can be seen that the estimations error are relatively small, therefore the impact of this variance is relatively small compared to the changes in costs due to the scenarios that will be developed. In this cost impact analysis it is assumed that these activities and the activity levels are independent of each other. Besides the assumption is made that the activity levels are the same in both the old as well as in the new situation.

<table>
<thead>
<tr>
<th>Table 9.2: List of assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>The out of scope change in service levels and lead times will not have an impact on costs</td>
</tr>
<tr>
<td>Due to use of LSP branches the distance travelled will not increase only the load inefficiency</td>
</tr>
<tr>
<td>The activity levels are assumed to be equal compared to 2014</td>
</tr>
<tr>
<td>Economies of scale in variable costs are assumed to be fixed ((\beta = 0.8))</td>
</tr>
<tr>
<td>If there is an increase in costs it is assumed to be equal to the increase in volume ((\alpha = 1))</td>
</tr>
</tbody>
</table>

### 9.1 Scenario uncertainty

For each scenario the likeliness is being estimated by using the expert opinion and uncertainty modeling for this expert opinion in order to estimation a distribution of the costs. A scenario model with expert opinions is nondeterministic and therefore involves some uncertainty and the relevant uncertainty should be taken into consideration (Ayyub & Klir, 2006). As previously mentioned the uncertainty related to the scenarios is significantly higher than the estimation error for the cost estimate within a scenario. Therefore only the scenario uncertainty will be evaluated in order to determine the costs distribution for the new supply chain structure.

In order to model uncertainty for the subjective non-additive probabilities of events (scenarios), belief functions can be created by applying the Dempster-Shafer theory of beliefs (Ayyub & Klir, 2006). Srivastava & Liu (2003) show that the Dempster-Shafer theory can better map uncertainties in application domains such as business decisions, besides people tend to make judgements about uncertainties in terms of beliefs. In this chapter the definitions of Ayyub & Klir (2006) will be used.

The Dempster-Shafer theory consists out of belief and plausibility measures. An assignment \(m\) of beliefs is defined on the universal set of scenarios \(S\) as a function that maps the power set of \(S\) to the range \([0, 1]\)

\[
m: P_S \rightarrow [0, 1] \tag{19}
\]

This assignment should satisfy the following conditions:

\[
m(\emptyset) = 0 \tag{20}
\]

\[
\sum_{E_k \in P_S} m(E_k) = 1 \tag{21}
\]

With \(E_k\) the elements in the power set \(P_S\). If \(m(E_k) > 0\) for a \(k\), \(E_k\) is called a focal element. The belief measure and plausibility measure for the assignment \(m\) can be calculated for any set \(E_k \in P_S\):

\[
Belief(E_k) = \sum_{\forall E_i \subseteq E_k} m(E_i) \tag{22}
\]
Plausibility($E_k$) = \sum_{\forall E_l \cap E_k \neq 0} m(E_l) \tag{23}

This Belief($E_k$) and Plausibility($E_k$) are respectively the lower and upper bound of the likelihood that $S$ belongs to the set $E_k$.

Belief($E_k$) \leq Plausibility (E_k) \tag{24}

This analysis is based on a single assignment; if multiple assignments are available it is possible to combine these assignments using Dempster’s Rule of Combination or other combination methods (Ayyub & Klir, 2006).

**9.2 Scenarios**

Given that some the costs and volume of some activities might be changing, it is possible to develop some scenarios for each of these activities. Since both the fixed and variable costs are known as well as the tariff corresponding to the activity level, some straightforward scenarios can be derived.

Concerning the fixed costs there are two alternatives: no increase in fixed costs, or an increase in fixed costs (e.g. equal to the increase in volume). If there is insufficient capacity available to deal with the additional volume, an investment in capacity is required and therefore fixed costs will increase. Assuming that there is only an increase in fixed costs the costs impact can be best be described by:

**Variables**

\begin{itemize}
    \item $\Delta X_i$: Total absolute change in the average costs driver level in new situation compared to the old situation
    \item $\bar{X}_i$: Total average costs driver level in the old situation
\end{itemize}

\[ F_i^* = F_i + \alpha F_i * \left( \frac{\Delta X_i}{\bar{X}_i} \right) \tag{25} \]

With $F_i^*$ the estimated value for the fixed costs for activity $i$ in the new situation, $(\Delta X_i/\bar{X}_i)$ as the relative change in average activity level for activity $i$ compared to the old situation and $\alpha$ the multiplication factor ($\alpha = 0$ if there is no increase in fixed costs and $\alpha = 1$ if the fixed costs is equal to the increase in volume).

Concerning variable costs there are two common sense alternatives: an increase equal to the increase in volume or a lower increase due to economies of scale.

\[ v_i^* = \frac{v_i X_i + \beta v_i * (\Delta X_i)}{\bar{X}_i + \Delta X_i} \tag{26} \]

With $v_i^*$ the estimated value for the variable costs for activity $i$ in the new situation, $X_i$ is the current activity level, $\Delta X_i$ is the change in activity level and $\beta$ is the factor the represents the efficiency increase due to economies of scale ($\beta = 1$ means there are no economies of scale and the variable cost factor remains the same). In this exercise the in case of economies of scale $\beta$ is assumed to have a fixed value 0.8 in order to avoid additional complexity.

Based on equation 7 and 10 it is possible to calculate the estimated activity costs for activity $i$ in a new situation $A_i^*$ and the new activity tariff $a_i^*$:

\[ A_i^* = F_i^* + v_i^* X_{ip} \tag{27} \]
\[ a_{ip}^* = \frac{A_i^*}{X_{ip} + \Delta X_{ip}} \]  \hspace{1cm} (28)

In order to determine the total costs activity costs in the new situation using a weighted average of the activity costs/tariff per period is sufficient. On the other hand for accurate activity cost allocations to customers a separate tariff per period should be used. By using the outcome of equation 28 and the old tariff estimated by equation 9 and 10, the weighted average of the tariff \( \bar{a}_i^* \) can consequently be calculated with the following formula in

\[ \bar{a}_i^* = \frac{\sum_{p=1}^{n} a_{ip}^* \cdot (X_{ip} + \Delta X_{ip})}{\sum_{p=1}^{n} (X_{ip} + \Delta X_{ip})} \]  \hspace{1cm} (29)

Note that only some common sense scenarios will be included and that not all possibilities will be discussed. Besides it is assumed that the complete set of scenarios is described and that the probabilities should add up to 1.

In our model we will estimate the future costs and tariffs in a new situation of combined warehouses. The likelihoods (belief & plausibility) are based on subjective reasoning and might therefore deviate for people from different perspective. In the tables in Appendix C you can see the likelihoods allocated to each of the scenarios. Besides these probabilities we will assume that the activity level totals remains the same in order to compare both situation avoid complexity of developing scenarios for both costs as well as for activity levels. The tariffs can be calculated after the changes in fixed and variable costs have been applied as described in equations 9 to 11 in section 4.3. The beliefs and plausibility’s are calculated (Appendix C) as described in the previous section (equations 19-23).

Outbound order picking

A. Economies of scale: No increase in fixed costs, while a higher efficiency of the employees leads to a moderate increase in variable cost. Therefore the amount of new employees that will be hired will be lower than explained by the current tariff. This can occur due to relatively lower variability and increased possibilities to deal with temporary changes in volume. The values used for the fixed costs \( F_i \) and variable cost tariff \( v_i \) can be found in table 8.2. The original total cost driver volumes \( X_i \) and the change in total cost driver volume \( \Delta X_i \) are not given before. The change in total cost driver volume is the sum of the total cost driver volumes in RDC1 and RDC2. Below an example calculation for Q1 2014:

\[ a_{i1} = \frac{F_i}{X_{i1} + \Delta X_{i1}} + \frac{v_i X_{i1} + \beta v_i \cdot (\Delta X_{i1})}{X_{i1} + \Delta X_{i1}} = \frac{43486.36}{34970 + 36460} + \frac{0.45833 \cdot 34970 + 0.8 \cdot 0.45833 \cdot 36460}{34970 + 36460} = 1.02 \]

B. New employees against equal cost: The number of variable costs will increase with the increase in volume and new employees will be hired to handle this additional volume.

\[ a_{i1} = \frac{F_i}{X_{i1} + \Delta X_{i1}} + v_i = 1.07 \]

C. Fixed costs increase & Economies of scale: the current equipment is not sufficient anymore and therefore an investment in new equipment is required. This leads to an increase in fixed costs corresponding to the increase in volume. On the other hand for the variable costs there are some
economies of scale and therefore a slightly lower costs than one would expect due to the increase in volume.

\[ a_{i1} = \frac{F_i + \alpha F_i \cdot \frac{\Delta X_{i1}}{X_{i1}}}{X_{i1} + \Delta X_{i1}} + v_i X_{i1} + \beta v_i \cdot \frac{\Delta X_{i1}}{X_{i1}} = 1.68 \]

D. Fixed costs increase & New employees against equal cost: The equipment and facilities are not sufficient and therefore there is an increase in fixed costs corresponding to the increase in volume. Besides the variable cost will increase due to the increased activity level.

\[ a_{i1} = \frac{F_i + \alpha F_i \cdot \frac{\Delta X_{i1}}{X_{i1}}}{X_{i1} + \Delta X_{i1}} + v_i = 1.73 \]

This provides the set \( S_i \) with scenarios \{A, B, C, D\} for activity \( i \). The power set \( P_{S_i} \) is therefore \{A, B, C, D, AB, AC, AD, BC, BD, CD, ABC, ABD, ACD, BCD, ABCD\}.

For any set \( E_k \in P_S \) the Belief\( (E_k) \) and Plausibility\( (E_k) \) can be calculated with by using equations 19-24 given in section 9.1. For example:

\[
\text{Belief}(E_{AB}) = m(E_A) + m(E_B) + m(E_{AB}) = 10 + 20 + 15 = 45 \\
\text{Plausibility}(E_A) = 100 - \text{belief}(E_{BUCD}) = 100 - 60 = 40
\]

Table 9.2 provides the results of the assignment and the calculation. This Belief\( (E_k) \) and Plausibility\( (E_k) \) are respectively the lower and upper bound of the likelihood that \( S \) belongs to the set \( E_i \).

**Table 9.2: Belief distribution & tariffs for outbound order picking**

<table>
<thead>
<tr>
<th>( E_k )</th>
<th>( m(E_k) )</th>
<th>Belief</th>
<th>Plausibility</th>
<th>Likely</th>
<th>Average tariff ( \bar{a}_{i1} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>10</td>
<td>10</td>
<td>40</td>
<td>21.54</td>
<td>1,093</td>
</tr>
<tr>
<td>B</td>
<td>20</td>
<td>20</td>
<td>70</td>
<td>39.23</td>
<td>1,159</td>
</tr>
<tr>
<td>C</td>
<td>5</td>
<td>5</td>
<td>30</td>
<td>14.62</td>
<td>1,660</td>
</tr>
<tr>
<td>D</td>
<td>15</td>
<td>15</td>
<td>40</td>
<td>24.62</td>
<td>1,726</td>
</tr>
<tr>
<td>A U B</td>
<td>15</td>
<td>45</td>
<td>75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A U C</td>
<td>5</td>
<td>20</td>
<td>55</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A U D</td>
<td>0</td>
<td>25</td>
<td>75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B U C</td>
<td>0</td>
<td>25</td>
<td>75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B U D</td>
<td>10</td>
<td>45</td>
<td>80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C U D</td>
<td>5</td>
<td>25</td>
<td>55</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A U B U C</td>
<td>5</td>
<td>60</td>
<td>85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A U B U D</td>
<td>0</td>
<td>70</td>
<td>95</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A U C U D</td>
<td>0</td>
<td>40</td>
<td>80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B U C U D</td>
<td>5</td>
<td>60</td>
<td>90</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A U B U C U D</td>
<td>5</td>
<td>100</td>
<td>100</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Transport planning CDC
A. Economies of scale: No increase in fixed costs, while a higher efficiency of the employees leads a moderate increase in variable cost. It is likely that the fixed costs will be about the same since additional shipment will not lead to for instance additional investments in planning software (Average tariff = €1.222, Belief = 25% & Plausibility = 50%)
B. Additional costs corresponding to volume: However due to additional requirements it could be the cost per delivery remains the same, and therefore the variable cost will increase with volume (Average tariff = €1.260, Belief = 50% & Plausibility = 75%)

Overhead CDC
A. Economies of scale: No increase in fixed costs, while relatively less management compared to the increase in volume leads to relatively lower variable costs. (Average tariff = €0.012, Belief = 15% & Plausibility = 45%)
B. Additional costs corresponding to volume: However due to additional requirements it could be the cost per order line remains the same and there are relatively a similar amount of management employed. (Average tariff = €0.012, Belief = 20% & Plausibility = 75%)
C. Investment in new warehouse & Economies of scale: The current warehouse is too small and additional space is required. Besides there will be relatively less management compared to the increase in volume. (Average tariff = €0.020, Belief = 5% & Plausibility = 25%)
D. Investment in new warehouse & Additional costs corresponding to volume: Both the current warehouse is too small, while the variable costs remain at the same level and no additional efficiencies are obtained. (Average tariff = €0.020, Belief = 10% & Plausibility = 35%)

Finished goods inventory CDC
A. Economies of scale: Due to the increase in demand the variance will be relatively lower, which lead to relatively lower inventories. (Average tariff = €0.003, Belief = 50% & Plausibility = 75%)
B. Additional costs corresponding to volume: An increase in inventory equal to the increase in volume. Note that in this scenario higher service level will be obtained. (Average tariff = €0.003, Belief = 25% & Plausibility = 50%)

Transportation to branch (Internal CDC to RDC)
A. No additional costs and the costs of transportation to a LSP branch will be equal to the transportation costs to the RDCs (Average tariff RDC1 = €0.012, RDC2 = €0.015, Belief = 15% & Plausibility = 40%)
B. Load inefficiency in transportation to the branch and a cost increase of 200% (Average tariff RDC1 = €0.018, RDC2 = €0.023, Belief = 30% & Plausibility = 70%)
C. Load inefficiency in transportation to the branch and a cost increase of 300% (Average tariff RDC1 = €0.024, RDC2 = €0.030, Belief = 15% & Plausibility = 40%)

9.3 Supply chain costs
In order to calculate the supply chain costs for each activity the belief of a scenario needs to be combined with the cost estimation of that scenario. Since standard probabilistic reasoning is not possible due to lacking evidence, uncertainty can be based on the experience and subjective judgement (Petrovic, Roy, & Petrovic, 1998). Therefore for all the scenarios a triangular distribution will be fitted with a minimum (=belief) and a maximum (=plausibility). It is chosen to use a triangular distribution since it is closely related to the belief of uncertainty in business decision making in terms of minimum, maximum and likely estimations. This belief function combined with the scenario costs estimation can be used to determine
the total cost distribution. In order to do this, the likelihood will be described by a probability density as shown in figure 9.1.

![Triangular distribution of likelihood](image)

**Figure 9.1: Triangular distribution of likelihood**

In order to fit a triangular distribution also a likely scenario needs to be constructed. This construction of a likely scenario is done by adding an equal percentage \( \gamma \) of the difference between the Belief \((E_k)\) and Plausibility \((E_k)\) to Belief \((E_k)\). This gives:

\[
Likely(E_i) = Belief(E_k) + \gamma(Plausibility(E_k) - Belief(E_k))
\]  

(30)

with:

\[
likely(\emptyset) = 0
\]

(31)

\[
\sum_{\forall E_k \in S} Likely(E_k) \equiv 1
\]

(32)

The values for the belief distribution and the tariffs of the exercise for the outbound order picking are given in Table 9.2. Similarly also the belief, likely and plausible scenario can be calculated for the other activities as well as the tariffs per scenario. The details of these calculations are provided in Appendix C.

\[
E(A^*_i) = \sum_{s \in S_i} E(W_{is}) * A^*_is
\]

(33)

\[
W \sim T(Belief, Likely, Plausibility)
\]

With \( T(Minimum, Likely, Maximum) \) is triangular belief function with minimum = belief, maximum = plausibility for activity \( i \) and scenario \( s \). Besides \( A_{is} \) is the costs estimation for activity \( i \) and scenario \( s \) and \( S_i \) is the set of scenarios for activity \( i \). Given the belief, plausibility and the constraint, a likely belief estimation parameter can be derived relative to the belief. Since an estimation of the new activity costs will be done by adding multiplying the estimated scenario activity costs with the expected likelihood, the sum of all likelihoods should be scaled to 1. Therefore the equation for the estimation of the new activity costs is subjected to:

\[
\sum_{s \in S_i} E(W_{is}) \equiv 1
\]

(34)
Given scenarios, beliefs and cost estimation in previous sections it is possible to construct the total cost estimation by summarizing the costs beliefs of each activity:

\[ A = \sum_i A_i \]  

(35)

### 9.4 Results

Given the scenarios information as described in section 9.2, it is possible to construct a belief function of the total supply chain costs as described in section 9.3. For construction of the belief function the information as shown in Table 9.2 and Appendix C, will be used as input for the Monte Carlo simulation in @RISK. In order to do a Monte Carlo simulation, the probability density function of beliefs (figure 9.1) will used. The samples from this triangular probability function of beliefs combined the estimated activity costs for an activity will used in order to determine the distribution of activity costs in the new situation. In this section a short overview of the results will be given using the example of Philips in order to give an idea of the outcomes.

In figure 9.2 the cost belief function is given for the new supply chain where every customer will be served from the CDC. Note that in this figure the costs are scaled relative to the supply chain cost is the old situation with one CDC and two RDCs. Besides only the distribution of beliefs is considered, while the costs estimation for a scenario is assumed to be fixed.

In figure 9.2 it can be seen that the expected value of the costs in the supply chain structure are about 15% lower than the costs in the current supply chain structure. The lower and upper limits of the 90% confidence interval are situated at respectively 74.3% and 101.1% of the original costs. Therefore it can be concluded that it is very likely that the costs will be lower in the new supply chain structure compared to the old supply chain structure subjected to the assumption made. It is also possible to obtain similar figures to for the activity cost belief.

![Supply chain cost belief](image)

*Figure 9.2: Total warehousing and transportation costs (Costs of 3DCs scaled at 1)*
Besides the total costs it is also possible to look the three different perspectives within scope of this cost analysis from a cost-to-serve point of view. The three perspectives are: customers served directly from the RDC, customers served from RDC1 and customers served from RDC2. Given the allocations and estimations of the costs to serve analysis it is possible to analyze to costs impact on specific customers or groups of customers. When using exactly the same allocation and assumptions as discussed in chapter 5 to 8, it is possible to make a comparison. In figure 9.3 an overview of the costs related to each perspective (customers in a service area) is given in terms of costs concerning the current supply chain structure, cost estimates concerning the new supply structure and the confidence interval of the costs in the new supply chain structure.

Considering allocations and assumptions made it can be seen that the costs for customers currently served by either one of the RDCs will decrease. For both RDCs the upper limit of the 95% confidence interval is lower than the costs in the original situation. On the other hand the allocation of costs to CDC is approximately equal and no significant difference could be detected between the supply chain structure with 3 warehouses and the structure with only one warehouse. So it can be concluded that on average there is some costs benefit for customers currently being served from the RDC, while there is no significant difference in costs for the customers being served from the CDC.
10 Conclusions & Recommendations

This project created a model for calculating the cost to serve customers, applied this model at Philips and tested the accuracy of the model. Besides an example is given how cost-to-serve information can be used for analyzing the cost impact of changing activities. In this last chapter the methods and models being used are evaluated and some conclusions and recommendations will be made.

10.1 Conclusions

This project was started in order to create more visibility in the cost to serve customers. The profitability of the customer is calculated by deducting the cost of goods sold and the cost to serve from the total amount of sales to this customer. In general companies are interested in three types of insights: the profitability and costs of serving a customer, the distribution of costs among customers and the cost objects & cost drivers related to serving a customer. From a customer perspective it might be interesting to know how its behavior might influence the cost and therefore indirectly the price of the product. Lastly from a scientific perspective the model for performance measurement is of key interest.

The visibility is created in three general steps: identification, estimation & allocation, which are divided in the following parts:

- Identification of cost activities and cost drivers
- Identify the related costs
- Applying regression techniques for estimating fixed and variable costs
- Using the regression equation to determine the tariff
- Multiply the tariff with the activity level of an individual customer
- Sum all costs allocated to a customer

In these three steps the requirements and interests from all three perspectives are being answered. By knowing the costs allocated to an individual customer the profitability of these customers is known. Similarly the costs are known for groups of customer by either summing the costs allocated to individual customers or multiplying the total activity level with the determined tariff. By going into depth in the activity costs and cost drivers, there is gained more visibility in the cost structure and therefore a better understanding how these costs can be influenced. By gaining insight into cost structure, cost driver and costs for an individual customer and an understanding is created of how to influence these cost drivers in a positively in cooperation with the customer to lead to a mutual benefit (lower costs & better prices).

From a scientific perspective there are some additional benefits compared to the conventional cost accounting methods. As stated before conventional methods apply fixed tariffs and therefore they do not take any fixed costs into consideration. This makes the conventional methods less applicable in dynamic, seasonal and non-stationary businesses, unless a new tariff is determined for each period or an in-depth investigation in activities is being done. Besides in case a fixed tariff is applied the visibility created is limited when assuming that all costs are variable. Therefore another advantage is deeper understanding in the cost structure which is incorporated in more structural modeling instead of descriptive modeling. A last advantage is that costs do agree with existing financial statements and more structural modeling. Disadvantages are related to the properties of the data, such as the use of historical data, a correct distribution between fixed and variable costs and not being able to model temporary changes and disturbances.

As you might see, most of the benefit in this method is in incorporating both fixed and variable costs. But due to the method being used some (additional) assumptions needed to be made. The main assumption is related to the allocation to the customer and is that the tariffs and cost estimations on a total level behave in a similar way at the level of an individual customer. Besides this key assumption related to the
allocation there are assumptions related to the cost estimation and the regression techniques being used. The last key assumption is that since a more structural modeling method is being used is that there are no major changes in cost structure, such as changes in the supply chain structure, the marketing cost & number of people employed. However it should be mentioned that cost to serve information about fixed and variable costs can be used to analyze the costs impact of changing activities.

With the model developed the cost-to-serve performance of Philips is analyzed. This analysis is done in three dimensions: cost identification, cost estimation and cost allocation. The example showed that determining the cost-to-serve performance on a customer level for each activity is done in three steps: determine the fixed and variable costs, determine the applicable tariff for the period & calculate the allocation to a customer. This example can be repeated for each costs bucket and multiple periods, but note that extending the analysis to other period might not be accurate in case of a changing business environment. Once the cost-to-serve for individual customers and the cost structure is clear an investigation can be done into data. By structuring this data it is shown how some customer groups perform compare to other on certain activity in terms of costs. Since all costs are known on the level of an individual customer a deep dive into the data can provide all the cost information required in the customer channel of the supply chain. After the model development, cost-to-serve example, presenting the results and testing the accuracy, it is analyzed how cost information can be used for cost estimation in with changing activities.

By using the example of a changing supply chain structure or the supply chain structure changes (e.g. decreasing the number of warehouses). It is showed that the elements of the cost-to-serve analysis, such as the found cost structure, can be used to identify the implications of certain actions. Through the identification of fixed and variable costs, several scenarios can be developed. Each of the scenarios has a certain belief and plausibility from which a costs belief function can be created. With this cost belief function and by using the cost-to-serve allocation, the costs impact of individual customers or customer groups can be analyzed. Given the assumptions made there it is shown that cost savings are very likely when serving all customers from a single warehouse. Besides by using the cost-to-serve allocation model it is shown that for all customers groups there are no increase in costs and there will be a significant decrease in costs for customers previously served from the RDCs.

Concluding, by applying the model as presented in this thesis the visibility is created in the costs & profitability of an individual customer, the distribution of costs & profitability among customers and insight in the cost structure in the customer channel of the supply chain. Especially the additional insights in the cost structure acquired by using more structural modeling are a contribution to other methods in cost accounting. The acquired understanding in the cost structure can consequently be used to analyze the cost impact of changing activities.

10.2 Recommendations

While developing and applying the model some things came to the attention and some general recommendations can be made. As for every model there are situations that have a better fit for application than others, therefore it is possible to make some recommendations about the preferred business and business environment where the method can be applied. Considering the properties of the method the following recommendations can be made for the ideal environment for application:

- Additional visibility in the customer channel of the supply chain is requested.
- Goal is to gain additional understanding in the costs & profitability of individual customers, the distribution of costs & profitability among customers and the structure of cost.
- Seasonal business where tariffs and costs can vary throughout the year. Since the model applies regression a tariff can be determined for different activity levels.
• When outcomes should match financial statements over multiple periods

The business environment in which the method was applied is a stable but seasonal business, with quite clear cost structures. The method was developed for this especially to meet the requirements of Philips. Therefore the method used for analyzing the cost-to-serve performance is especially applicable in a similar type of business, but it is likely to be applicable in other business environments too. In order to identify the generalizability of the method, first the method should be tested in different business environments. When investigating the generalizability, one should look at business which are for instance less stable, have no seasonality or in case of a different cost structure (e.g. mostly variable cost). These studies can then be used to make a distinction between situations in which this method is preferred and situations in which conventional methods with fixed tariffs are preferred. For the examples that are analyzed in this report it became clear that this model is easily applicable and accurate, besides the gained insight can help to analyze to costs impact of changing activities.

On the basis of the cost-to-serve exercise at Philips some conclusions and recommendation can be made. First it became clear that a large part of the costs are fixed. Large fixed costs implies that some additional revenue will lead to a relatively lower costs compared to revenue. Due to the limited amount of periods analyzed, an important limitation is that it is unknown what happens if the activity level exceeds the capacity, though it is possible to analyze the cost impact of activities of changing activities. In the last chapter is it shown that there are significant cost savings that could be achieved by reducing the number of warehouses. However it should be noted that these cost savings depend on some assumptions. Therefore the impact of lead time, service levels and other services should be investigated, in order to decide whether such a change would be beneficial for both Philips and its customers.

An important requirement from the business was that the outcomes matched current financial statements in order to increase recognition. Other requirements stated that it should by easily applicable and repeatable. Since the business has a high seasonality a special method was developed in order to create a structural model that was able to deal with the seasonality. As a last recommendation I want to emphasize on the fact that improved visibility can help to increase understanding in the costs. Therefore it is recommended to do a deep dive into the cost data for each customer and activity and identify improvement opportunities in for instance customer profitability, cost structures & cost drivers.
Bibliography


Appendix A: List of Abbreviations & Variables

OEM Original Equipment Manufacturing/Manufacturer
OES Original Equipment Suppliers
CDC Central Distribution Centre
RDC Regional Distribution Centre
LSP Logistics Service Provider
EMEA Europe, Middle East and Africa
LED Light-Emitting Diode
ABC Activity Based Costing

Indices
\( i \) Activity \((i \in I)\)
\( c \) Customer customers \((c \in C)\)
\( k, l \) Element/set in universe \( E \)
\( s \) Scenario \( s \)
\( p \) Period with \( p \in \{1, 2, 3, \ldots, n\} \)

Cost components
\( Y_c \) Total cost allocation to a customer \( c \)
\( A_{ip} \) Total activity costs that needs to be allocated for activity \( i \) in period \( p \).
\( a_{ip} \) Activity cost tariff for activity \( i \) and for the cost driver related to activity \( i \) in period \( p \)
\( X_{ip} \) Total volume of cost driver that is used as allocation key for activity \( i \) in period \( p \).
\( x_{ic} \) Cost driver level of customer \( c \) used for allocation of costs in activity \( i \).
\( V_i \) Total variable costs for activity \( i \)
\( v_i \) Variable cost tariff for activity \( i \)
\( F_i \) Total fixed costs for activity \( i \)
\( \varepsilon_{ip} \) Estimation error for costs in activity \( i \) in period \( p \)
\( \Delta X_i \) Total absolute change in the average costs driver level for activity \( i \)
\( \bar{X}_i \) Total average costs driver level for activity \( i \)
\( m \) Mass, assignment of beliefs
\( S \) Set of scenarios for an activity
\( E \) Universe of elements
\( \emptyset \) Empty set
Appendix B: Goodness-of-fit measures
Finding the best fitting model is not straightforward. For this reason the model will be assessed in three steps: first some fit measures are used to describe the model performance. For the second step an out-of-sample forecasts will be used by splitting up the data series into two segments: one for model fitting and one for model validation. As a third step, a rationalized reflection is needed to make the final decision on model provides the best fit. This last step involves some subjective judgement, which will be explained and described carefully in this report.

To analyze the fit of a model, a variety of goodness-of-fit measures can be selected, for example R-squared, RMSE, MAPE, the normalized BIC, and Ljung-Box. The following table, based on Montgomery et al. (2008), Chatfield (2000) and Bisgaard & Kulahci (2011), provides a very short overview of these measures and how to interpret and use them.

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<tr>
<th>Measure</th>
<th>Description</th>
<th>Indication for good fit</th>
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<tr>
<td>R-squared</td>
<td>A measure for the sum of the squared residuals, however it is not adjusted for over fitting so it cannot be used for comparing models with a different size</td>
<td>If the R-squared would be adjusted, the best fit with historical data between models is found by the largest value for R-squared adjusted – it is a common criterion used in regression analysis.</td>
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<tr>
<td>Root Mean Squared Error (RMSE)</td>
<td>The root of the mean squared error, so that it is in the same units as the measured variable</td>
<td>As close as possible to 0; the measure cannot become negative.</td>
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<td>Mean Absolute Percentage Error (MAPE)</td>
<td>Equal to the mean absolute error (MAE), but then relative to the size of the measures (making it scale-independent, which allows for comparison between different time series)</td>
<td>As close as possible to 0%; the measure cannot become negative.</td>
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<tr>
<td>Bayesian Information Criterion (BIC) – Schwarz</td>
<td>A measure for the natural log of SSE + non-negative penalty when unnecessary parameters are added. The penalty is more severe than with the AIC measure. Normalization can be added as a step to allow for comparison between different time series.</td>
<td>The smaller the better; a minimum BIC is preferred. With a very small SSE, i.e. 0&lt;SSE&lt;1, the BIC measure becomes negative, due to the natural log conversion. Thus, a large negative BIC is preferred over a smaller negative BIC.</td>
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For our purposes of comparing models for relatively small sample sizes the first three methods seem the most appropriate. In order to make a relative comparison across different activities it is chosen to use both the R-squared and the MAPE. The BIC measure corrects for the complexity of the model, since our models are all relatively easy this method seems unnecessary complex. Besides it is also chosen not to use RMSE since it is an absolute measure and therefore it makes cross comparison relatively complex.
## Appendix C: Belief and Plausibility calculation

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