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LOG950 Logistics

Benchmark the efficiency of 15 Norwegian companies regarding their warehouse using Data Envelopment Analysis

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PREFACE

First of all, we would like to thank Steffen Larvoll and Ola Hanø for presenting this problem to Molde University College. Due to their expertise and knowledge of the Norwegian logistics market and their broad network, this analysis will hopefully be a step towards both improving the company's performance and priorities as well as filling a gap in literature. We appreciate their willingness to cooperate with students and Molde University College, and are especially grateful that those students are us. We are also very excited to attend the Lean Conference in Oslo on the 12th of June to present the findings of the study.

We sincerely thank all of the companies participating in this analysis. Without them this thesis would not been possible. We appreciate their time spent on collecting the data needed for the study.

We would also like to express our gratitude to our supervisor Berit Irene Helgheim, who first of all introduced us to this topic and has followed up on us during the whole process. The structure of her guiding is characterized by a great combination of individual work with the push in the right direction when needed. She is dedicated to her students, gives critical feedback and has a lot of experience. This has suited us well.

Additionally, we would like to thank James Odeck who has been our supervisor on the methodology Data Envelopment Analysis. We were first introduced to this method on his seminar Productivity Analysis at the University College. He has been of great value when helping us to carry out the analysis. His positivity has been of great motivation.

Last, but not least we would thank the Molde University College for financial support for the Data Envelopment Analysis software as well as five fine years of studying.

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Abstract

In order for companies to keep up with all dimension in the current ever-increasing demand and requirements in the market, they are highly recommended to be efficient. In order to achieve the title as best performer they must distinguish themselves from similar companies. This study will take a closer look at 15 companies working with the logistics activity warehousing in the Norwegian market. These companies work in different sectors, selling or producing different goods. In common, they have a warehouse where they distribute goods to end-customers or stores. This thesis will benchmark these companies with regard to three inputs and two outputs. The inputs are the number of imperfect orders, the number of employees and space utilization. The outputs are revenue and the total number of orders. The method applied is Data Envelopment Analysis, more specifically the input-oriented CCR-method. Tools used in the analysis are Excel DEA-Frontier Add-In.

The results show five benchmarked companies scoring 1,0 or 100 percent on efficiency. The companies work in various NACE-sectors distributing different goods. Even though these companies are relatively different in nature, indications regarding characteristics of the benchmarks can be found. Companies scoring high on efficiency tend to be characterized with high revenue, few urgent- and delayed orders as well as many order lines per order and a lot of order picks per hour.

Keywords: Data Envelopment Analysis, Efficiency, Benchmarking, Warehouse management, Performance Management.

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List of Abbreviations

3PL	Third Party Logistics
B2B	Business to Business
B2C	Business to Consumer
BCC	Banker, Charnes, Cooper
CCR	Charnes, Cooper, Rhodes
CEO	Chief Executive Officer
CRS	Constant Return to Scale
DC	Distribution Center
DEA	Data Envelopment Analysis
DMU	Decision Making Units
FCCRS	Fixed Charge, Constant Return to Scale
FCVRS	Fixed Charge, Variable Return to Scale
KPI	Key Performance Indicator
LIS	Lager & Industrisystemer
MHE	Material Handling Equipment
NOK	Norwegian Kroners
PIM	Performance Improvement Management
VRS	Variable Return to Scale

1 Introduction

1.1 Background for the thesis

The evolution of marketing theory starts according to Kotler and Keller (2016) with production orientation, from the industrial revolution. The general viewpoint of a company's success was to produce as efficient as possible and to achieve mass production in order to reduce costs. The second stage of the evolution is product orientation. Companies tried to produce the perfect differentiated product the companies thought a customer might want. After this, the sales orientation phase became most common. In order to sell products, it was thought that a good sales pitch was needed as well as a good customer support and after-sales services. Today, the most common viewpoint is marketing, also called customer orientation. The main focus is the customer's needs. It is assumed that customer needs goes beyond the basic product itself and includes for instance information, availability of products and so on. The most recent viewpoint is societal marketing. It is thought that companies have responsibility for the needs of the society. Keywords such as sustainability and environment-friendly is relevant. The customer-oriented viewpoint is the most applied approach today, hence the customer is the main focus. Customer needs are ever-increasing due to higher expectations offered by companies. Technology is rapidly changing, it brings, amongst other things, automation and speed. Customer demands and requirements are influenced by this. Currently, when for instance a customer is ordering a product online, it is expected to be delivered within a few days. In order to do so, the companies must do the right things right. The companies need to be both efficient and effective in order to satisfy the customer's demand. The combination of the higher demands and the companies providing good service requires the companies to perform their logistics activities well. Activities like receiving goods, placing them in storage, picking orders, packing and shipping are crucial for performance. The margins are small, and in order to perform the best in the market, many factors must be well handled. An efficient warehouse is critical in order to satisfy the customer's ever-increasing demands and requirements, it helps to ensure quick and accurate deliveries. Efficiency may help making the difference between profit and loss and might help improve performance in order to stay a step ahead of competitors.

1.2 Research Problem

The aim of this thesis is to compare the efficiency of 15 Norwegian companies operating with warehouse management and benchmark the best performant(s).

Three inputs and two outputs will be used as performance measures. The study will apply Data Envelopment Analysis as the methodology and use the software tool Excel DEA-Frontier Add-In.

1.2.1 Research Questions

Research question I is intended to identify which key performance indicators, inputs and outputs are chosen in previous literature of relevance. The most frequent and appropriate measurements from relevant literature will be the source of inspiration, and the measurements chosen in this thesis will be based on this. Research question I is divided into two parts. The first part regarding previous studies, will be answered in the literature review, chapter 2. The second part, where the measurements in this study is chosen will be based on the literature review and will be answered in section 3.2.4 regarding the choice of inputs and outputs as well as supported in the discussion, section 5.3.1. The main contributing factor of the results from the DEA is the choice of inputs and outputs. For this reason, it is crucial to choose the most applicable measurements for efficiency at warehouses

I: Based on previous literature of relevance, how should efficiency at warehouses be measured?

Based on the choice of inputs and outputs the data envelopment analysis will be conducted. Research question II will answer which companies score the highest on efficiency hence seen as benchmarks.

II: Which of the companies are the most efficient according to DEA?

This thesis will answer which companies are efficient, it will not go in depth of why they score the way they do. The DEA results may be utilized in order to improve performance for a not so good, but comparable DMU based on the performance of a peer. This thesis will examine indications of characteristics regarding the benchmarked DMU(s) and observe if there are any observations in common for the peer(s).

Ⅲ: Are there any indications of characteristics in common for the benchmarked companies?

1.3 Statement of Purpose

This study is intended to be useful for the participants of the study, academics and companies operating with warehousing. This study provides an insight in fundamental factors that may explain why some companies are efficient while others are inefficient. The participants may compare themselves externally with other similar companies and their internal performance year to year if the study is continued annually as planned. Additionally, the key performance indicators are theoretically argued by literature and based on experience in the sector, therefore this can be of great value when companies are dealing with strategic choices.

There are several published articles and theoretical contribution concerning inventory management and DEA. To our knowledge there are few maybe even no research done in this angle: comparing the efficiency of Norwegian warehouses using Data Envelopment Analysis. The fact that Lager og Industrisystemer wants us to perform a DEA on behalf of their customers and their positive feedback is a good indication that it is desired. This study can confirm that the operators in the market thinks it is up to date and relevant since the customers agrees to participate in and spend time on the analysis. Hence, the theory may be transferred to reality.

1.4 Lager & Industrisystemer AS

Lager & Industrisystemer AS (LIS) is a total supplier of warehousing services and internal logistics solutions for the Norwegian business market. LIS has 24 employees and is a part of the German company SSI Schäfer. Their customers operate in various sectors, from automotive, construction, electronics, the pharmaceutical industry, retail to e-commerce. LIS supply products for storage such as specialized boxes, rails, cabinets, pallets and work benches. They offer automation for the warehouse for instance transportation systems, automated guided vehicles, auto cruiser, case picking, monorail, program for designing a warehouse by 3D matrix, quad systems, warehouse management software and robo pick.

1.5 Structure of the Thesis

This thesis is organized into six chapters. Chapter 1 covers the introduction and includes the research problem, statement of purpose and a brief presentation of Lager & Industrisystemer. Chapter 2 presents the literature review, this is divided into the parts, DEA, Warehouse Management, Performance Management and Benchmarking. These subcategories consist of several articles of relevance. Chapter 3 describes the research methodology and starts with the research design, followed by the data collection, continued with choosing inputs and outputs in order to measure efficiency and ends with the methodology. Chapter 4 presents the empirical findings, which is divided into initial data assessment, literature overview, DEA results and efficiency results compared against different variables. In chapter 5 the discussion based on the results will be presented. Chapter 6 is the last part of the thesis and deals with the conclusion, limitation of the study and ends with further research.

2 Literature Review

2.1 Data Envelopment Analysis

The term Data Envelopment Analysis was first introduced by Charnes, Cooper, and Rhodes (1978) based on Farrell (1957), further developed by Banker, Charnes, and Cooper (1984). This section will briefly elaborate on the history of DEA as well as the contribution in literature in the recent years.

2.1.1 The Measurement of Productive Efficiency – Farrell

According to Farrell (1957), the purpose of his article is to formulate a measure of productive efficiency. Previously the most popular measure used was the average productivity of labour. The method and definition of terms is provided through an example of the agricultural production in the United States. The efficiency of a company is defined at page 254: "*to produce as much output as possible for a given set of input" (Farrell 1957).* Further, he explains the efficient production function as the output that a perfectly efficient company could obtain from any given combination of inputs and is based on best observations. The efficient production function is an isoquant characterized by being convex, having a negative slope and no observations between the isoquant and the origin. The function is shown in Figure 1, named s or s`.

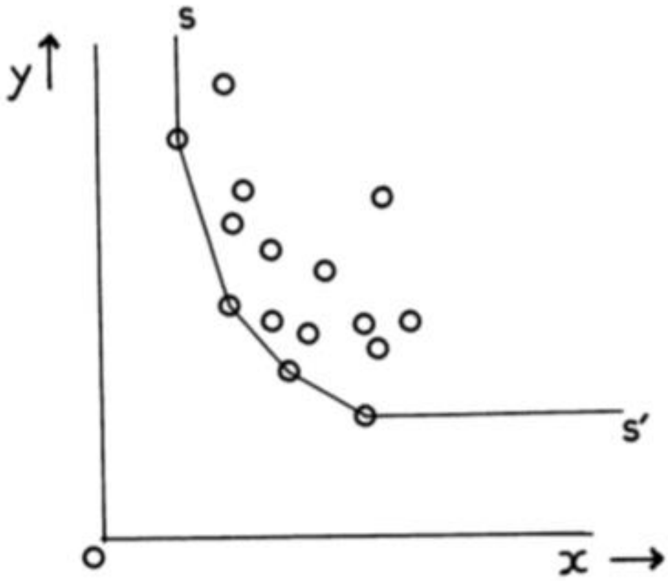


Figure 1- *The efficient production function (Farrell 1957)*

The definition of technical efficiency is defined at page 259 as: "*a firm's success in producing maximum output for a given set of inputs*" (Farrell 1957). The efficiency score of a company will change according to different scenarios; a company can be 100 percent efficient nationally but does not necessarily need to be in an international point of view. The price efficiency is described as the success in choosing an optimal set of inputs.

2.1.2 Measuring the Efficiency of Decision Making Units – Charnes, Cooper, Rhodes

Charnes, Cooper, and Rhodes (1978) wrote an article where they extended the work of Farrell (1957) and linked the estimation of technical efficiency and production frontiers. Their CCR-model is mainly built for public sectors without competition, but they measure efficiency in many different ways, for instance, in both economics and engineering concepts. On page 430 Charnes, Cooper and Rhodes define the measure of the efficiency of any DMU as "*the maximum of a ratio of weighted outputs to weighted inputs subject to the condition that the similar ratios for every DMU be less than or equal to unity*" (Charnes, Cooper, and Rhodes 1978). Further it is described how to replace fractional programming with linear programming equivalents and further research on Farrell (1957) isoquant analysis, technical-, cost- and allocative efficiency.

2.1.3 Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis – Banker, Charnes and Cooper

The next contribution in the history of DEA is the article by Banker, Charnes, and Cooper (1984) where a new variant of DEA was introduced, hereafter the BCC-model, which is built on the theory of the CCR-model. The BCC-model focuses on estimating technical and scale efficiencies of decision making units with reference to the efficient production frontier. While the CCR-model assumes constant returns to scale, meaning any change in inputs should produce a proportional change in outputs, the BCC-model opens up for the possibility of variable returns to scale (Benicio and Mello 2015).

2.1.4 **DEA Literature in General**

Emrouznejad and Yang (2018) made a literature review of the literature published in journals regarding DEA from 1978 until 2016. Their findings show an exponential growth of publications in the theory and applications of DEA in the recent years. The top three journals which have published the greatest number of DEA-articles is the European Journal of Operational Research, Journal of the Operational Research Society and Journal of Productivity Analysis. The top five application fields of DEA in 2015 and 2016 was agriculture, banking, supply chain, transportation and public policy. In total 11 975 authors have written 10 300 articles about DEA until the end of 2016. Some of these articles will be elaborated in detail below.

2.2 Warehouse Management

The first part of this chapter will provide some definitions of a warehouse. Then the most crucial activities in a warehouse will be defined.

2.2.1 **Warehouse Theory**

A definition of a warehouse is adapted by Van den Berg (2013)[1] on page 1 in the book Warehouse Management by Richards (2014) "*A warehouse should be viewed as a temporary place to store inventory and as a buffer in supply chains. It serves, as a static unit – in the main – matching product availability to consumer demand and as such has a primary aim which is to facilitate the movement of goods from suppliers to customers, meeting demand in a timely and cost-effective manner".* Further, Richards (2014) specifies that *"Primarily a warehouse should be a trans-shipment point where all goods are despatched as quickly, effectively and efficiently as possible*."

Gaither and Frazier (2002) defines warehousing on page 441 as: "*the management of materials while they are in storage. It includes storing, dispersing, ordering, and accounting for all materials and finished goods from the beginning to the end of the production process. Warehousing facilities may range from small stockrooms to large, highly mechanized storage facilities*."

[1] Unavailable primary source. Citation from Gwynne Richards´s book "Warehouse Management" 2nd edition.

Based on (Berg and Zijm 1999), (Hamdan and Rogers 2008), (Gergova 2010), (Gu, Goetschalckx, and McGinnis 2010) and (More 2016) the main activities in any warehouse is:

1. **Receiving**: Activities like unloading goods and materials on the receiving dock, random quality and quantities checks are performed and the products are labelled so it is ready for transportation to the storage area.
2. **Storage**: The warehouse management system allocates storage locations to incoming materials.
3. **Order picking**: The process of retrieving products from the storage area to fill customer orders. This happens either manually or automatically depending on the warehouse management system.
4. **Packing**: When the order is picked complete it must be packed, priced, labelled, scanned and prepared for sending.
5. **Shipping**: Finishing the order by verifying quantity, no damage and order accuracy and then loading the materials on to the mode of transport.

2.3 Performance Management

This section will discuss different articles regarding input and output measurements. It will provide information regarding which KPIs are chosen in relevant literature. The terms “efficiency”, “productivity” and “effectiveness” will also be defined.

2.3.1 Warehouse Management – Richards

Ackerman[2] suggest four areas within the warehouse that should be measured: reliability, flexibility, cost and asset utilization. **Reliability** includes on-time delivery, fill rates and accuracy. Order cycle time is according to Ackerman the best measure of **flexibility** since it covers the whole customer order process; everything from how the order is initially handled, whether it is available on stock, how much time it takes to process the order through the warehouse and how quickly it is delivered to the customer. **Cost**

[2] Unavailable primary source. Referred from Gwynne Richards´s book “Warehouse Management” 2nd edition.

measurements include cost as a percentage of sales and productivity against labour hours. **Asset utilization** measures the efficiency as the use of warehouse space, material handling equipment and storage equipment: "*Warehouse utilization is normally measured in the amount of floor space utilized. However, it is more realistic to measure the cubic utilization of the building. Other companies will look at the number of pallets locations utilized against the total number of locations available*" (Richards 2014), page 295.

2.3.2 The study of Efficiency and Effectiveness of Warehouse Management in the Context of Supply Chain Management – More

According to More (2016) a vital area that determine the efficiency of warehouses is storage locations, as well as storage assignment policies and routing methods. Order picking method, size and layout of the storage system, material handling system, product characteristics, demand trends, turnover rates and space requirements are also crucial factors when measuring efficiency.

More (2016) recommends these metrics to consider when evaluating warehouse performance:

1. **A perfect order** is an error-free order including activities like pick accuracy, on-time delivery and invoice accuracy.
2. **Order performance** which includes:

- Fill rate. This metric measures lines shipped versus lines ordered by a customer. It depends on items in stock and available, can be seen as the service level from a customer's perspective.
- Ship to promise. Measures the timeliness of order filling, while the shipping accuracy rate measures the accuracy of order filling.
- Customer retention. The number and percentage of customers during the prior time period.
- New customers. The number and percentage of new customers in each time period.

3. **Carrying cost of inventory**. Calculated as inventory carrying rate multiplied with the average inventory value.
4. **Inventory turnover**. How many times per year a DC is able to go through its entire inventory. Found by dividing cost of goods sold by the average inventory.

5. **Order picking accuracy**. Total number of orders divided by perfect order rate.
6. **Inventory to sales ratio**. End-of-month inventory balance divided by sales for the same month.
7. **Units per transaction**. Number of units sold divided by number of transactions.
8. **Inventory accuracy**. Measures as the database inventory count divided by physical inventory count.
9. **Back order rate**: Found by dividing orders unfilled at time of purchase by total orders placed.

Further More points out the following metrics to measure warehouse effectiveness.

10. **Product turnover time**. The amount of time it takes for a product to be sent out of a warehouse to a customer after it has arrived in the system.
11. **Unloading and recording the product**. The time it takes to unload the goods and record what is received.
12. **Organizing and storing the delivery**. The organization of the processes for unloading, checking and put-away will affect the overall product turnover time.
13. **Processing orders**. The time it takes in receiving an order send it to the warehouse.

2.3.3 Benchmarking Warehouse and Distribution Operations: An Input-Output Approach – Hackman, Frazelle, Griffin, Griffin, Vlasta

Hackman et al. (2001) examined operational efficiency of 57 warehouse systems. The research use three inputs and three outputs. The first input is **labour**, measured as the sum of the direct and indirect labour hours needed to perform receiving, put away, storing, order picking and shipping. The second input **space** is measured by the square feet of areas reserved for receiving, storage and shipping. The third input is **material handling and storage equipment**, calculated as the summation of the number of units of each type of equipment used by the warehouse weighted by the average replacement cost per unit of equipment.

The first output factor is **movement**, driven by number of orders and the number of lines per order. The orders and lines are broken down into full case, pallet picking and broken case. The second output is **accumulation** output, defined as the workload required accumulating lines picked into orders shipped. Measured as the difference between the annual lines picked and the annual orders shipped. The last output is storage, measured as the cost to store the inventory at a warehouse.

Five regression models were used to analyze the data collected: constant return to scale (CRS), variable return to scale (VRS), non-increasing return to scale (NIRS), fixed charge, constant return to scale (FCCRS) and fixed charge, variable returns to scale (FCVRS). The results led to three conclusions:

I. Smaller warehouses tend to be more efficient than larger warehouses.
II. Warehouse using lower levels of automation tend to be more efficient. This association is more pronounced in small firms.
III. Unionization is not negatively associated with efficiency and in fact may actually contribute to higher efficiency.

The results from VRS and FCVRS show a negative association between warehouse size and efficiency due to a significant correlation between the size and level of automation. Factors that may affect the efficiency negatively are long travel distances, poor workflow visibility, difficulties communication and supervision. The automation in material handling systems is measured by the level of investment. Results from VRS and FCVRS showed high automation levels are significantly associated with low efficiency. Reasons of this might be lack of maintenance and “burn-in” difficulties combined with small possibilities of changes. Results from CRS and VRS models showed that unionization resulted in high efficiency. This might be explained by better incentives to motivate high productivity, good communication and good supervision.

2.3.4 Warehouse Management - Richards

The literature review in section 2.1 regarding DEA focuses on inputs and outputs chosen from various articles. Richards (2014) exemplifies traditional productivity measures with 9 examples. **Labour hours utilization, warehouse area utilization, MHE utilization** and **units picked** are all measured by amount used divided by amount available as a ratio. **Cost as a percentage of sales** is calculated by total warehousing cost divided by total sales revenue. **Cost per order dispatched** is measured as the total warehouse cost divided by total number of orders shipped. **Dock-to-stock time** is the time it takes from arrival of a vehicle until the goods are visible in the system. **Order accuracy** is measured by orders picked and dispatched accurately divided by total order received. The last measure is **on-time shipments** found by dividing orders delivered as per customer's request by total orders received. The new performance metrics are exemplified with five measures. **Stock cover in days** found as the current level of stock divided by the total annual sales multiplied with 365. When dividing the total number of units sold by the average number of units in stock the **stock turn** is found. **The stock /inventory accuracy** includes three dimensions, location stock accuracy percentage, stock line accuracy and stock unit accuracy. **The damaged inventory** is the amount of damage caused in the warehouse and calculated as the total number of damaged items divided by the total number of items processed through the warehouse. **On time and in full** must fulfill the requirements of on-time delivery, in full and damage free.

2.3.5 An Efficiency/ Effectiveness Approach to Logistics Performance Analysis – Mentzer and Konrad

Mentzer and Konrad (1991) divide performance measures in five broad areas of logistics, transportation, warehousing, inventory control, order processing and logistics administration. According to Mentzer and Konrad a performance measure consists of efficiency and effectiveness. A guideline is provided for managers to help them choose the most appropriate measures, the five areas are broken down in more detailed measurements.

The most important measures in **transportation** is labour, cost, equipment, energy and transit time, for example activities like loading and driving. **Warehousing** is broken down into labour, cost, time, utilization and administration. This includes for instance activities like receiving, put-away, checking, packing, shipping, staging and consolidation. **Inventory control** is subdivided into measurements of purchasing and overall inventory management. Purchasing inputs covers for instance sourcing, procurement and cost control. The inventory management measures include activities like forecasting accuracy, inventory-carrying costs, availability, timeliness and quality of order fulfilment. **Order processing** regard order entry, order editing, scheduling, shipping and billing. The last area is **logistics administration** which is the ability to manage operations on a day-to-day basis regarding activities such as customer communication and service, production planning and control, scheduling and dispatching.

2.3.6 Large-Scale Internet Benchmarking: Technology and Application in Warehousing Operations – Johnson, Chen and McGinnis

Johnson, Chen, and McGinnis (2010) developed a model which identifies the most critical inputs and outputs that define the production process for the warehouse industry**: labour, space and equipment** (inputs) and **broken case lines shipped, full case lines shipped, pallet lines shipped, accumulation** and **storage** (outputs).

The most relevant measurements will be elaborated in detail. **Labour** is measured as annual labour hours including both direct and indirect labour. By this, the model includes employees performing receiving, moving, storing, picking, shipping, planning and maintenance. Security, cleaning staff, office assistants, accounting, human resources, customer service and any labour assigned to value-adding activities are not counted. **Space** is measured as the area in square feet reserved for areas like receiving, put away, storing, retrieving, order picking, packing and shipping. Areas for instance bathrooms, offices, cafeteria and break rooms is not included. A **customer orde**r is an individual customer's request to be fulfilled by the warehouse. It generally includes product types and the quantity for each order line.

The article also takes pitfalls into account and points out the four most important considerations. First of all, companies should use the same type of resources to produce the same types of outputs. Secondly, companies should have access to the same technology and identify the controllable differences in practice of the contrasting systems. Additionally, it is important to be able to identify system attributes which may affect performance for instance seasonality or demand volatility.

2.3.7 Using Data Envelopment Analysis to Evaluate the Performance of Third Party Distribution Centres – Ting and Fang

The aim of this research Ting and Fang (2010) is to find the key performance indicators through a survey of a set of Distribution Centres (DC's) in Taiwan. The efficiency for the period 2005-2007 using both CCR- and BCC-models as well as Malmquist productivity index based on selected performance indicators as inputs and outputs will be evaluated. In addition, the study aims to identify the best practice as well as the inefficient DC's. First the top ten KPIs in the DC's were found: order picking accuracy, on-time shipment, employee productivity, distribution cost per order, average warehouse capacity used, order picking productivity, inventory turnover, revenue per area, asset turnover rate and return order process. This was then narrowed down to three inputs and two outputs. The first input is **number of imperfect orders**. Further Ting and Fang claim a perfect order should fulfill the following components, delivered on time, shipped complete, shipped damage free and correct documentation. The second input is **number of employees** measured as the sum of the number of direct and indirect labour performing all operations in the warehouse. The third input is average **warehouse capacity used** which is measured as the ratio of average capacity used (in number of pallets) and capacity available. The outputs are **revenue** in NT$1000 and **total number of orders**. The empirical result shows the efficiencies of the DC's concluding that the major reason of the inefficient DC's are due to scale inefficiency.

2.3.8 Evaluating the Efficiency of 3PL Logistics Operations – Hamdan and Rogers

The aim of this article written by Hamdan and Rogers (2008) is to use DEA in order to evaluate 19 homogeneous warehouses operated by third-party logistics companies. The warehouses are more or less similar when it comes to their processes, products, the inputs and outputs. The study has chosen four inputs and three outputs. **Labour hours** are one of the inputs, measured as total annual man-hours for all direct full-time employees who are directly involved in all of the inbound and outbound warehouse activities including unloading and receiving into the storage as well as picking, packing, and shipping products. The second input is **warehouse space**, calculated as the total warehouse space used for receiving, storage, staging, order consolidation, shipping, aisles, material handling equipment staging and offices. Warehouse space is both measured as the total warehouse floor area in square feet, as well as the warehouse cubic space. The third input is **technology investment**, which is the total annual cost of technology development that supports each warehouse operation. The fourth input is **material handling equipment** and is measured as the total annual cost of material handling equipment used to handle products within the warehouse.

The first output is **shipping volume**, measured in total annual boxes shipped. The second output is **order filling** defined as the total number of orders filled completely and on time. The last output is **space utilization** calculated as the total product cubic displacement divided by the total warehouse cubic space. The method used in this study is the input-oriented CCR-DEA-model. Both an unrestricted and a restricted DEA model with weights is applied. The results of the efficiency scores are compared for the two models. Then the study determined the impact of each input and output of the efficiency of each warehouse. In addition, the results provided info regarding each warehouse characteristics and recommendations were given to the management.

2.3.9 Definition of Efficiency, Effectiveness and Productivity – Mentzer and Konrad

Mentzer and Konrad (1991) define logistic performance as both effectiveness and efficiency in performing logistics activities. Effectiveness is defined as the extent to which goals are accomplished and efficiency is the measure of how well the resources expended are utilized (Mentzer and Konrad 1991) (Fugate, Mentzer, and Stank 2010). In section 3.4.1, regarding DEA, efficiency is as defined by the ratio of resources utilized by the results derived. The difference is often phrased as effectiveness being equivalent to “doing the right things” and efficiency are “doing things right”.

Research within this field has led to the “either-or” debate whether efficiency and effectiveness are mutually exclusive or not. Fugate, Mentzer, and Stank (2010) claim logistics managers face a tough choice with conflicting objectives, either strive for efficiency or strive for effectiveness. Griffis et al. (2004) suggest in later research these performance objectives to be mutually exclusive, but Fugate, Mentzer, and Stank (2010) thinks this dilemma is unwarranted. On one side of the conflict, there are researchers like

Davis and Pett (2002), who argues that efficiency and effectiveness are two separate dimensions or goals and should be distinguished from one another. Mahoney (1988) argues there is a trade-off between the two incompatible dimensions and claims organizations can be either efficient or effective, but not both. On the contrary, researchers such as Ostroff and Schmitt (1993) and Ford and Schellenberg (1982) claims organizations can have multiple goals, hence organizations can be effective, efficient, both or neither.

The next part of this discussion leads us to the term productivity which is defined in literature by Mentzer and Konrad as the combination of effectiveness and efficiency. A common mistake is to use the terms productivity and efficiency interchangeably. Productivity views a process as a whole while efficiency looks at one thing at a time. In order to be productive, a company must maximize output for the total input and to do so the company must both do the right things and in the right way, hence both effective and efficient (Avital 2015). As written in the first paragraph of this section 2.3.9, Mentzer and Konrad (1991) define logistic performance as both effectiveness and efficiency. Even though these terms are used interchangeably in the everyday, the definitions provided above will be current in this study.

2.3.10 Evaluating the Efficiency of 3PL Logistics Operations

Hamdan and Rogers (2008) focuses on 3PL warehouse logistics operations from 19 warehouses located in the US. Their inputs are **labour hours** for full-time employees, **warehouse space, technology investment** and **materials handling equipment**. The outputs are **shipping volume/throughput, order filling** and **space utilization**. These measures are defined in previous sections and will not be repeated. The conclusion from the analysis offered managers information on the current situation of their warehouses and useful information on performance.

2.4 Benchmarking

The Merriam-Webster Dictionary (Webster 2018) explains the verb benchmarking "*to study (something, such as a competitor's product or business practice) in order to improve the performance of one's own company."* Richards (2014) describes at page 309 benchmarking as "*a process of comparing performance with operations of other* *companies, or operations within the same company, identifying high-performance or best-in-class operations and learning what is they do that allow them to achieve that high level of performance.*"

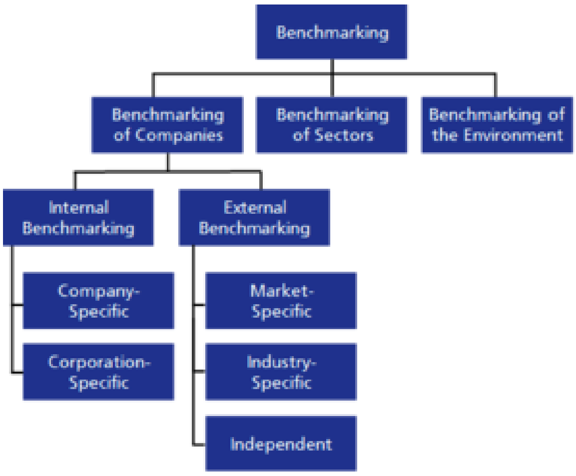


Figure 2- *Types of Benchmarking*
(http://www.globalbenchmarking.org/benchmarking/types-of-benchmarking/)

According to Global Benchmarking Network (Network) a general way to distinguish types of benchmarking is by companies, sectors or the environment, as can be seen in Figure 2. When benchmarking by sectors, it is usual to compare performance of individual sectors. When benchmarking the environment, it is typical to compare either political, social or economic environments. Benchmarking of companies is subdivided into internal and external benchmarking. Companies can either learn from their own way of doing things, internal, or by other similar companies, hence external. The internal benchmarking is further divided into company-specific and corporate-specific benchmarking. The internal company-specific can be difficult to measure, there is rarely internal processes that can be compared, for this reason it is usual to measure technology, organizational and personal influences. The corporate-specific method compares several plants or parts of a company within a corporation. The market specific analyze direct competitor's activities, strengths and weaknesses. Industry-specific goes beyond the comparison of two companies and focus on trends and the efficiency of a certain function industry-wide. The main differences from industry- and market-specific is the number of participants and that it mainly looks for trends, not competitive positions. The last sub-category is independent-specific. It studies the best-performing companies and try to answer how they respond and adapt to different challenges. This study is in the category called external industry-specific benchmarking. It compares several companies in the same sector, but they are not necessarily direct competitors even though they all work with warehousing and storage.

2.4.1 Tools used in Supply Chain Benchmarking

This part will elaborate on tools and methods used to benchmark. Based on the review of Wong and Wong (2008), examples will be provided within the field of supply chain. The theory is divided into parametric and non-parametric measurements. First, examples of parametric methods will be given, then non-parametric.

Gap analysis is a method mainly used for performance measurement, more specific the "spider" or "radar" diagram and the "Z" chart. Another method is the ratio, comparing the relative efficiency of the output versus the input. Then there is a multi-attribute utility technique called the analytic hierarchy process maturity matrix. To analyse data in performance benchmarking there are statistical methods such as regression and various descriptive statistics.

An example of a tool in non-parametric methods is balanced scorecard which is a framework to make the strategic objectives into a set of performance measures. DEA is also a common tool used for benchmarking, further explained in section 3.4.1 regarding methodology. Why DEA is chosen as the method applied in this study can be read in section 3.4.4.

3 Research Methodology

This part of the thesis will first discuss benefits and limitation with DEA, then the method of collecting data is described, followed up with the feedback of the survey and estimations of data. Further, the participants are divided into NACE-codes. Then the chosen KPIs, inputs and outputs will be presented as well as an argumentation of why we have chosen the input-oriented method.

3.1 Research Design

The design of this study is cross sectional, since the survey collects data in order to make inferences on a population at one point in time. The population in this study is the 15 Norwegian companies with warehouses. The data is collected from 2017 and will be the point in time when the population is analyzed. The advantage of doing a cross sectional study is the fact that the data can be compared on an annual basis.

3.1.1 Data Collection

The participants in this study are companies working with warehouses in Norway. The companies are selected through Lager & Industrisystemer's customers. Together with Steffen Larvoll working at LIS and Ola Hanø working at Ehandelsforum, we have made a set of ten KPIs. This collaboration made our theoretical contribution work well with their knowledge and experience from the sector and logistics in practice. They were aware of typical problems regarding logistics in general, such as measuring return policies and service level. The result of our collaboration, are the ten KPIs described in section 3.2.1. Since they already had established a strong network with their customers, they were in charge of collecting the data. This was done by making a webpage were the KPIs were described and the participants could fill in the answers and leave a comment. The link to the webpage as well as information were distributed by mail. The survey design can be seen in Appendix 1.

We realized that these companies were operating with a broad variation of products and ways of doing business, see further information about the NACE-codes in section 3.1.3, participants. For this reason, it became problematic to compare the companies on behalf of the KPIs, so we aggregated it into three inputs and two outputs, which resulted in total five variables. The aggregation aligns with the rule of thumb: it should be more than twice as much (Cooper, Seiford, and Zhu 1962). The result of the aggregation is the input and outputs in section 3.2.2 and 3.2.3. Due to this change, we had to ask a couple of additional questions to the companies. We received the contact-list with e-mail addresses and made personalized mails to each company or contact person. The mail included the missing data from the first survey, a more detailed description of the lacking KPI(s) and the additional questions regarding the new inputs and outputs. We also offered them to call us if they had any questions, which three companies did. Additionally, one of the companies invited us to see their warehouse for a better understanding of what and how they were operating. This gave us a deeper understanding of how their warehouses are operated in reality.

The data can be divided into two categories, primary and secondary data. This study will mainly use primary data, which is defined as data that has not been previously available, and which have been obtained directly by the researcher by means of surveys, observations or experimentation in order to achieve the objective of a particular study (Hox and Boeije 2005). Considering the aim to make an annual analysis or report, we asked for data from last calendar year, 2017. This makes it easier for the report to be extended for 2018 and so on. Eventually, the hope is to have enough companies to enable a comparison for each industry or sector. Another benefit would be that companies could compare themselves against other similar companies, against sector and against themselves year to year.

3.1.2 Feedback on the Survey

Initially, there were 28 interested companies that wanted to participate or know more about the survey. All of them were eager when they heard what the report was covering and found it relevant for them. When they became aware of which data we were looking for, some companies had to decline because they were not able to find this data in their systems. We ended up with 15 companies participating in our analysis.

First, Steffen Larvoll and Ola Hanø sent out the link to the companies where they could fill in the 10 KPIs and additional information if needed. From the first data collection, the response rate was 80,67 percent of the 10 KPIs. Then we aggregated the KPIs and added some additional KPIs. We made personalized mails where we pointed out the missing data as well as the nature of the data in more detail. It turned out, some of the missing data were due to misunderstandings of terms. After the second round of data collection, the new response rate of the 10 KPIs increased to 93,67 percent. In addition, the new input and output measures had a response rate of 95,56 percent. In total, the overall response rate of all question asked was 94,1 percent. This is sufficient data in order to carry out the analysis. The missing data, will be estimated by us, and explained in section 3.3, regarding data estimation.

3.1.3 Participants

The statistical classification of economic activities in the European Community, abbreviated as NACE is the classification of economic activities in the European Union. In order to keep the companies anonymous in this thesis, the NACE-sector classification system is used. The code stands for the sector a company is mainly working in. Since the companies are quite different in nature this coding system can help the reader understand reasons behind the results in the analysis and comparison of companies. The codes are found by searching for each company at (Forvalt) then the NACE-code is translated at (Ekse 2013) in order to get the correct description according to international standards. Table 1 is an overview of the companies in this study and their respective sector. Some companies have three codes, in order to divide them into smaller groups for comparison the major field is chosen. The chosen code is marked in bold in Table 1.

Company number	NACE- code
1	**46.740 Wholesale of hardware, plumbing and heating equipment and supplies**
2	**47.510 Retail sale of textile in specialized stores** 46.410 Wholesale of textiles 13.921 Manufacture of household linen
3	**46.900 Non- specialized wholesale trade** 77.400 Leasing of intellectual property and similar products, except copyright works
4	**46.441 Wholesale of china and glassware**
5	**47.521 Retail sale of variety of a hardware, paints and glass in specialized stores** 46.739 Wholesale of construction materials n.e.c
6	**16.210 Manufacture of veneer sheets and wood-based panels**
7	**28.920 Manufacture of machinery for mining, quarrying and construction** 62.010 Computer programming activities
8	**46.740 Wholesale of hardware, plumbing and heating equipment and supplies**
9	62.020 Computer consultancy activities **46.510 Wholesale of computers, computer peripheral equipment and software**
10	**46.390 Non- specialized wholesale of food, beverages and tobacco**
11	**46.499 Wholesale of other household and personal goods n.e.c**

12	82.110 Combined office administrative service activities **46.900 Non-specialized wholesale trade**
13	70.100 Activities of head offices **20.410 Manufacture of soap and detergents, cleaning and polishing preparations** 20.420 Manufacture of perfumes and toilet preparations
14	**22.210 Manufacture of plastic plates, sheets, tubes and profiles** 22.220 Manufacture of plastic packing goods
15	**46.693 Wholesale of machinery and equipment for manufacturing n.e.c.**

Table 1- *Number of company and their respective NACE-code (own table)*

3.2 Efficiency Measurements

3.2.1 Key Performance Indicators

These are the 10 initial KPIs which is the foundation of the first survey sent out, as well as three additional KPIs in the second round of the survey:

1. **Order picking**: The number of order lines picked per hour for each employee.
2. **Dock-to-stock:** The number of order lines received at the dock and put away to its location at the storage per hour for each employee.
3. **Service level**: The percentage of order lines sent according to the pre-determined service level agreement (SLA).
4. **Internal order cycle time**: The average internal time between when the order was received from the customer and the order shipment by the supplier. Order shipment is defined as off the dock onto the shipping conveyance and ready for transit.
5. **Total order cycle time**: The average end to end time between order placement by the customer and order receipt by the customer.

6. **Order picking accuracy**: Number of orders picked correctly for each orders picked measured in percent.
7. **Urgent orders**: An order handled deviant compared to a regular order. For instance, over-night and express deliveries or rush orders.
8. **Return**: The percentage of total orders being returned from customers for any reason.
9. **Inventory utilization**: Rate of space occupied in the storage. Measured in percent.
10. **Order size**: Average number of order lines for each order.
11. **Delayed orders**: Number of orders delivered that differ from scheduled time.
12. **Total cubic meters**: Total available space in cubic meters reserved for storage. For example, aisle space and pallet space, does not include floor area between the aisles.
13. **Cubic meters in use:** Space occupied by goods measures in cubic meters.

3.2.2 Inputs

These are the three aggregated inputs based on the KPIs above:

1. **Number of imperfect orders**: An imperfect order is the summation of the following components: delayed, returned, not picked accurately, urgent order and out of stock.
2. **Number of employees**: Full-time, part-time and temporary employees directly and indirectly involved in warehouse activities. Including for instance unloading and receiving products into storage, picking, packing and shipping.
3. **Space utilization**: Total cubic meters utilized divided by total cubic meters available. Includes both floor space used for storage and aisles.

3.2.3 Outputs

These are the two aggregated outputs based on the KPIs above:

1. **Revenue**: The total revenue last calendar year in NOK (2017).
2. **Total orders**: The total number of orders last calendar year (2017).

3.2.4 Choosing Inputs and Outputs in Order to Measure Efficiency

Based on (Richards 2014), (Hamdan and Rogers 2008), (More 2016), (Hackman et al. 2001), (Ting and Fang 2010), (Johnson, Chen, and McGinnis 2010), Steffen Larvoll and Ola Hanø the authors of this thesis have chosen the KPIs and the aggregated inputs and outputs in sections 3.2.1, 3.2.2 and 3.2.3.

The first input is the **number of imperfect orders** buildt on the components delayed, returned, not picked accurate, urgent and out of stock. These components reflect an imperfect order and are all used to measure it. At first glance, one might say an imperfect order mainly focuses on inefficiency. Since this thesis is input-oriented, the inputs are minimized and the aim is to reduce or minimize the number of imperfect orders. The opposite would be to look at number of perfect order, hence oriented towards efficiency, but then the overall strategy would be to minimize the number of perfect orders. Which is obviously not desired by any of the parts involved. The choice of number of imperfect orders may be a contradicting input and can even be seen as inconsistent when measuring efficiency. Regarding the discussion above, it makes more sense to use imperfect orders instead of perfect orders. To support this choice, we will compare the results with and without imperfect orders as can be seen in Table 2.

When including imperfect orders, the result are five benchmark companies. The average efficiency score is 68 percent giving a 32 percent potential improvement. The lowest value is 25 percent and the standard deviation is 29 percent. Table 2 shows the difference in results when including or excluding the input imperfect orders. When imperfect orders are excluded, the outcome of the analysis show two benchmarked companies. The average efficiency score is 40 percent which means a 60 percent potential improvement. The minimum score is 7 percent and the standard deviation 31 percent. First, it is doubtful that a warehouse could have the possibility to improve by 93 percent. The efficiency scores without imperfect order are relatively low in comparison with the table including imperfect orders.

	With imperfect orders		
DMU No	Input-Oriented (CRS)	RTS	Rank
1	0,63903	Increasing	3
2	**1,00000**	**Constant**	**1**
3	0,60176	Increasing	6
4	0,62072	Increasing	5
5	0,92117	Increasing	2
6	0,62573	Increasing	4
7	0,43334	Increasing	8
8	0,49181	Increasing	7
9	**1,00000**	**Constant**	**1**
10	**1,00000**	**Constant**	**1**
11	**1,00000**	**Constant**	**1**
12	0,27228	Increasing	10
13	**1,00000**	**Constant**	**1**
14	0,32786	Increasing	9
15	0,25449	Increasing	11
Average	**0,68**		
Max	**1,00**		
Min	**0,25**		
S.D.	**0,29**		

	Without Imperfect orders		
DMU No	Input-Oriented (CRS)	RTS	Rank
1	0,47926	Increasing	4
2	0,14523	Increasing	11
3	0,40069	Increasing	5
4	0,37129	Increasing	6
5	0,84136	Increasing	2
6	0,12585	Increasing	13
7	0,30950	Increasing	7
8	0,49181	Increasing	3
9	**1,00000**	**Constant**	**1**
10	**1,00000**	**Constant**	**1**
11	0,07056	Increasing	14
12	0,27228	Increasing	8
13	0,18040	Increasing	9
14	0,13385	Increasing	12
15	0,17228	Increasing	10
Average	**0,40**		
Max	**1,00**		
Min	**0,07**		
S.D.	**0,31**		

Table 2- *Comparison of including or excluding imperfect orders (own table)*

The second input factor is **number of employees,** this includes both part-time and full-time employees. The variable is narrowed down to include only employees directly involved with warehouse activities, because this reflects the efficiency at a warehouse better. Even though management and administration have a great influence on the warehouse these employees are not directly involved with the choice of indicators such as order picking accuracy, dock-to-stock and order picking.

The third input is **space utilization.** In previous studies the square meters have mostly been applied. In this thesis the height will be included as well, because this may have an affect on the efficiency scores. There are different aisles and ways to store products. Some companies use customized aisles when storing their products, other use standardized measures. Products and goods are not just stored on the surface measured in square meter but also in the height, therefore we choose to include it and use cubic meters. The participants are operating with a broad spectre of products, with great variations in size and quantities. These differences should be taken into consideration.

Therefore, we choose to make a ratio of the space utilized. Some companies might need a big area for their warehouse because they are operating with large products, others on the other hand might be operating with few and smaller products resulting in less area needed.

The space utilized compared to the space available is therefore a better representation of how well they are managing their resources.

In theory, an important measurement of efficiency may be technology. Automation and the use of technology and advanced equipment at the warehouse will have a great impact on the overall efficiency. In general, highly automated warehouses tend to have fewer employees. When robots, trucks and equipment that can lift pallets and goods higher than human beings can, the warehouse space is higher utilized and will most likely result in better efficiency. Another benefit is less mistakes and less time spent on picking, which also may affect the efficiency. Even though technology and automatization have a great impact on the efficiency we have chosen not to include it. The main reason is that these topics are so extensive it could be a topic in itself. We were not able to find a method to any standard measure for technology since there is many different ways to measure technology.

The outputs are revenue and the total number of orders. There are many factors influencing these variables but in general we might say that a company with many orders and a high income is doing something right. For instance, high customer satisfaction, high product quality and agreements that are kept, undamaged as well as orders delivered on time and products available on shelf in stores.

The KPIs, inputs and outputs are illustrated in Figure 3. It is shown what the aggregated inputs, outputs are based on, what makes up the DEA, and that it provides the efficiency scores.

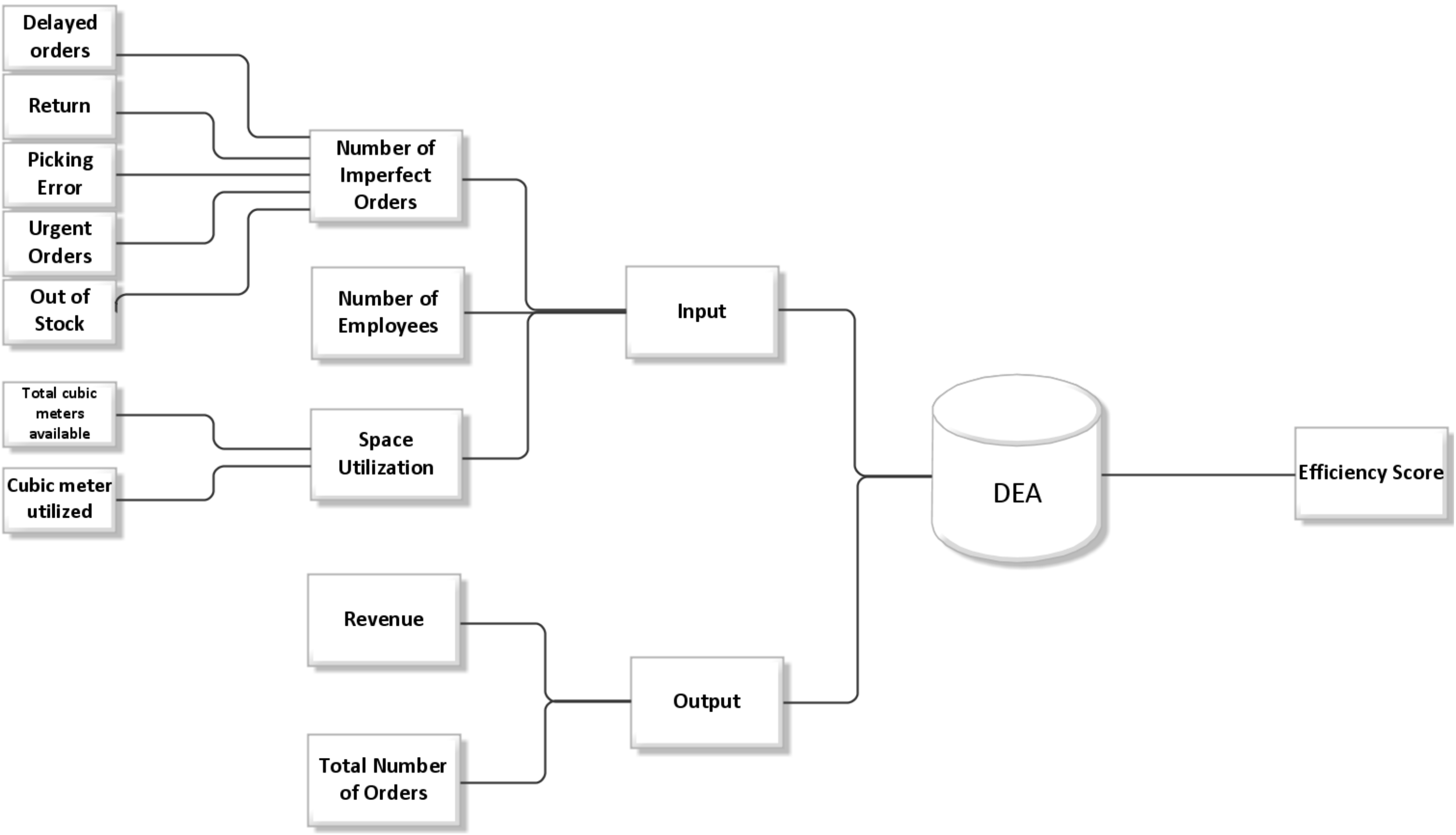


Figure 3- *Overview of components in the analysis (own figure)*

3.3 Data Estimations

In some cases, the companies were not able to give an answer the data requested in the survey. The first thing we did, was to ask them for a qualified guess or estimation. If this was not possible, we did it for them based on information provided from them or statistics. The method of substituting missing data with an estimation from information is more accurate compared to statistics methods. This will serve as a better method of estimation than statistics from the dataset. For this reason, this method will be the preferred choice between the two methods.

The yellow cells from Table 3, Table 4 and Table 5 indicates missing data, the companies were not able to find this data, nor an estimation. Since these KPIs are replaced by new aggregated ones and are not directly included in the analysis, we have chosen to allow missing data on these specific KPIs. For the missing data included in the analysis, estimations has been done, these cells are marked in green. We will go through these in detail in the next paragraph.

The KPI delayed orders, is missing data from company 5 and 15. The new values are estimated by finding the median for delayed orders for all the companies, which is four percent. This is then multiplied with the total number of order for company 5. By doing so, we found the weighted value from the total dataset and applied it for the specific company. The same procedure where done for company 15, as well as company 1 and 9 for the KPI out of stock. For the KPI called return, company 2 specified under 1 percent of total orders are returned. Since we did not know exactly how much under 1 percent we chose the worst-case principle and calculated 0,99 percent of total number of orders as returned. The same procedure is applied for urgent orders for company 2. Company 12 stated one urgent order per day. We assumed five working days a week and multiplied it by 52 weeks, which gave a result of 260 urgent orders per year, this equals two percent of their total orders.

Company 4 did not provide data on the utilized cubic meter, but the inventory utilization was said to be 88 percent and the total available cubic meter was 19 500. These KPIs should in theory indicate the utilized cubic meter. For company 13 we did the opposite, here they had information about inventory utilization and the cubic meter utilized and calculated a total of 4480,61 cubic meters available for storage. Company 5 responded with the height and the square meter of the warehouse for the total cubic meters available. We multiplied these with each other and the result is the total cubic meter for the warehouse. To exclude halls, offices, bathrooms and break rooms we assumed an estimate of 20 percent of the total warehouse for these areas, resulting in total cubic meters available of 84 000.

For the internal cycle time in the survey, company 2, 6, 12 and 15 answered in days, the question asked for hours. For instance, company 6 specified between one and three days. For companies in the same situation we decided to use the average, hence two days or 48 hours. The same principle is applied for KPI 5 total order cycle time. Company 6 divided their market into two to five days for Southern Norway and five to twelve days for the Northern part of Norway, we assume Norway as one market and measured the average from two to twelve, which gave seven days or 168 hours. The last estimate regarding inventory utilization for company 9 where calculated by dividing cubic meters utilized by the total cubic meters available.

	Inputs								Outputs	
Name	Input 1 : Number of imperfect orders					Input 2: Number of employees	Input 3: Space utilization		Output 1: Revenue	Output 2: Total number of orders
Company (DMU)	Delayed orders	Return	Picking error	Out of stock	Urgent orders	Total number of employees	Total cubic meters available	Cubic meter utilized	Revenue	Total number of orders
1	1 100,00	1 041,00	33,20	4 761,91	4 318,90	18,00	13 300,00	12 635,00	kr 696 000 000	110 742
2	154,00	8,27	8,35	0	8,27	19,00	15 026,00	10 953,00	kr 930 000 000	835
3	0	0	291,83	10 036,77	1 299,40	204,00	72 508,53	65 323,00	kr 3 906 514	104 224
4	2 020,00	1 326,90	65,55	1 063,12	3 996,70	22,00	19 500,00	17 160,00	kr 240 000 000	79 934
5	3 864,64	1 352,62	289,85	966,16	1 932,32	57,00	84 000,00	35 716,80	kr 1 100 000 000	96 616
6	440,00	27,50	110,00	440,00	38,00	5,00	30 000,00	16 500,00	kr 409 000 000	11 000
7	3 317,00	255,45	9,95	3 284,33	424,64	13,00	3 174,60	2 116,40	kr 1 800 000 000	33 175
8	4 320,00	1 080,00	140,40	1 566,00	10 800,00	20,00	15 000,00	13 500,00	kr 850 000 000	108 000
9	20,00	3 014,00	544,33	9 362,39	1 197,52	12,00	2 400,00	2 200,00	kr 7 800 000 000	217 730
10	150,00	1,70	102,00	442,00	25,50	7,00	16 000,00	12 000,00	kr 388 000 000	17 000
11	35 621,96	2 595,87	80,96	35 621,96	12 823,91	450,00	234 543,00	227 272,17	kr 12 000 000 000	323 836
12	0	0	28,22	0	260,00	11,60	4 907,33	4 416,60	kr 200 000 000	14 850
13	6 000,00	1 232,96	26,23	3 497,76	1 005,61	8,85	4 480,61	4 243,00	kr 260 400 000	43 722
14	3 400,00	504,00	63,00	157,50	4 095,00	16,00	24 991,00	24 491,18	kr 390 000 000	31 500
15	188,72	4,72	4,72	217,03	20,34	27,00	34 560,00	32 256,00	kr 1 500 000 000	4 718

Table 3- *Input and output estimations (own table)*

Number	KPI 1	KPI 2	KPI 3		KPI 4	KPI 5
Company (DMU)	Order picking (orders)	Dock-to-stock(orders)	Actual service level	Planned service level (SLA)	Internal order cycle time (hours)	Total order cycle time(hours)
1	38,2	8,8	95,70 %	97 %	0	28,8
2	80		100 %	100 %	28	48
3	48,77	0,47	90,37 %	94 %	24	57,12
4	27,38	32,8	98,67 %	95 %	24	
5	43	14	98 %		6	
6	0,5		96 %	96 %	48	168
7	8	2,8	90,10 %	90 %	48	
8	27	17	98,55 %	98 %	1,5	18
9	6,24	7,4	95,70 %		456	504
10	24		97,40 %	98 %	48	72
11	63,32	1 936,08	89,00 %	94 %	35,25	42,45
12	70	12	100 %	100 %	12	36
13	17	8,6	92 %	96 %	0,166666667	
14	18,3	5,5	99,50 %	100 %	7	24
15	7,7		95,40 %	98 %	48	

Table 4 - *Estimations of KPIs one to five (own table)*

Number	KPI 6	KPI 7	KPI 8	KPI 9	KPI 10
Company (DMU)	Order picking accuracy	Urgent orders	Return	Inventory utilization	Order size(orderline per order)
1	0,03 %	3,90 %	0,94 %	92 %	4,78
2	1 %	0,99 %	0,99 %	80 %	80
3	0,28 %	0,70 %	0 %	92 %	57,13
4	0,08 %	5 %	1,66 %	88 %	4,49
5	0,30 %	1 %	1,40 %	42,52 %	14
6	1,00 %	0,35 %	0,25 %	99 %	12
7	0,03 %	1,28 %	0,77 %	82 %	4
8	0,13 %	10 %	1 %	90 %	45
9	0,25 %	0,55 %	1,38 %	91,60 %	6
10	0,60 %	15 %	0,01 %	80 %	5,1
11	0,03 %	3,96 %	0,80 %	96,90 %	17,4
12	0,19 %	2 %	0 %	80 %	45
13	0,06 %	2,30 %	2,82 %	94,40 %	3,8
14	0,20 %	13 %	1,60 %	99 %	4,6
15	0,10 %	0,43 %	0,10 %	88 %	23

Table 5- *Estimations of KPIs six to ten (own table)*

3.4 Methodology

3.4.1 Data Envelopment Analysis

Data Envelopment Analysis is a non-parametric approach to efficiency measurement. In general, DEA aims to identify the most efficient or best performing unit(s) and it compares the rest of units in the analysis against the frontier. According to Charnes, Cooper, and Rhodes (1978) the organization under study is called a Decision Making Unit (DMU). A DMU is regarded as the entity responsible for converting inputs into outputs and whose performance are to be evaluated (Cooper, Seiford, and Tone 2007).

Figure 4 shows Constant Return to Scale (CRS) as the linear frontier with B as the only optimal DMU, because the coordinate is located on the frontier. The best practice or efficient production possibilities are located on the so-called production function or the efficient frontier. The frontier A-B-E is the Variable Return to Scale (VRS) and has three optimal DMUs. In the VRS case the DMUs C and D is inefficient compared to the other DMUs while looking from the CRS perspective only B is optimal, and the rest is seen as inefficient.

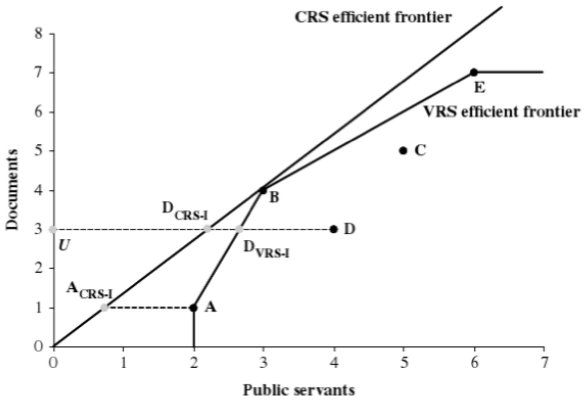


Figure 4- *Example of CRS- and VRS- frontiers (Ishizaka and Nemery 2013)*

DEA is based on the measure of an input-output ratio. An example of efficiency is cost per unit or profit per unit. It could also measure productivity such as output for each labour hour or output per employee. In general, efficiency can be expressed by the formula (1):

$$Efficiency = \frac{\text{Output}}{\text{Input}} \tag{1}$$

A DEA model can be subdivided into an input-oriented model or an output-oriented model. The former model aims to minimize input for a given level of output, while the latter intend to maximize the output for a given amount of input (Ji and Lee 2010).

3.4.2 The CCR-Model

The CCR-model is named after Charnes, Cooper and Rhodes who introduced it in 1978. It assumes constant return to scale (CRS) as explained above in Figure 4.

3.4.2.1 Input- Oriented

3.4.2.1.1 The Fractional Linear Programming Model

The CCR-model is expressed as a fractional programming problem as follows:

Maximize$_{(u,v)}$: $$e_0 = \frac{\sum_{r=1}^{s} u_r Y_{r0}}{\sum_{i=1}^{m} v_i X_{i0}} \quad (2)$$

Subject to: $$\frac{\sum_{r=1}^{s} u_r Y_{rj}}{\sum_{i=e}^{m} v_i X_{ij}} \leq 1 \quad (3)$$

$$v_i,\ u_r \geq 0, \qquad \forall\ i\ ,j,r \quad (4)$$

^{0}	=	evaluated DMU
e^0	=	efficiency score of DMU0
Y_{rj}	=	output r for DMU j
Y_r^0	=	output r for the evaluated DMU
X_{ij}	=	input i for DMU j
X_i^0	=	input i for the evaluated DMU
v_i	=	variable weight for input i
u_r	=	variable weight for output r
n	=	total number of DMUs being evaluated
s	=	total number of outputs
m	=	total number of inputs

The efficiency of a DMU is given by the ratio (2) expressed as the sum of the weighted outputs over the sum of the weighted inputs. Constraint (3) means that the sum of the weighted output and weighted inputs for the DMU being evaluated must be lower or equal to one. This means the best performing DMU has a total score of one or 100 percent, and the DMU with a score lower than one is considered relative inefficient compared to the peers in the analysis. Constraint (4) is a non-negativity constraint regarding the weights for inputs and outputs.

3.4.2.1.2 The Linear Programming Model

The CCR-formula (2) yields an infinite number of solutions. In this section we will derive the linear programming model equivalent to the fractional program introduced by Cooper, Seiford, and Zhu (1962). This formula enable only one solution.

Maximize$_{(u)}$: $$e_0 = \sum_{r=1}^{s} u_r Y_{r0} \tag{5}$$

Subject to: $$\sum_{i=1}^{m} v_i X_{i0} = 1 \tag{6}$$

$$\sum_{r=1}^{s} u_r Y_{rj} - \sum_{i=1}^{m} v_i X_{ij} \leq 0 \quad \forall j \tag{7}$$

$$u_r, v_i \geq 0 \qquad \forall\ i, r \tag{8}$$

By duality, this model is equivalent to the linear programming model, the difference is the point of view, either minimum or maximum.

$Minimum_{(\theta)}$: $$\theta - \varepsilon \left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right) \tag{9}$$

Subject to: $$\sum_{j=1}^{n} \lambda_j X_{ij} + s_i^- = \theta X_{i0} \qquad \forall\ i \tag{10}$$

$$\sum_{j=1}^{n} \lambda_j Y_{rj} - s_r^+ = Y_{r0} \qquad \forall\ r \tag{11}$$

$$\lambda_j, s_i^-, s_r^+ \geq 0 \qquad \forall\ i, j, r \tag{12}$$

θ	=	performance of the DMU_0
s_i^-	=	input excess
s_r^+	=	output shortfall
λj	=	upper and lower limit of the evaluated DMU
ε	=	the non-Archimedean constant, in other words a small constant to maintain positivity

3.4.3 Input-Oriented Approach

Each company have internal goals and strategies to achieve. In this thesis we assume all companies strive to minimize the level of input for a given level of output hence input-oriented. By this, it is assumed the main objective for the companies is to be as efficient as possible. For instance, try to keep the number of employees low without affecting the number of orders. The Data Envelopment Analysis will therefore measure the efficiency in an input-oriented point of view. Since the companies are quite different in nature, the revenue will be influenced on what they are selling. Some companies would naturally have higher revenue than others which can be explained by what they are selling or doing.

3.4.4 Why DEA?

Wong and Wong (2008) claims DEA to be the most appropriate tool in benchmarking, even with its limitations. The underlying concept of measuring efficiency in DEA lies on the utilization of efficient frontier, and information regarding the most efficient as well as the inefficient DMUs is given. This is exactly what we are measuring in this thesis. Some additional information will be elaborated in order to understand the result, but the participants will be anonymous. The result shows the companies score and then compares it to the peer(s). One of the benefits of DEA is the ability to handle multiple inputs and outputs models, allowing for variables having different units in one analysis. At the same time, this positive aspects might cause problems. The method is very sensitive to noise, measurement mistakes can cause significant problems. For this reason, it is important to be aware of these factors when collecting data. The result provides information of which DMUs are efficient and how the inefficient DMUs are performing compared to the peers, but only valid for the participating DMUs in the analysis. In order to claim whether the participants are efficient for the whole market, or the theoretical maximum this method cannot be applied. On behalf of the benefits and limitation mentioned in this section, we summarize DEA to be the most beneficial method for this thesis.

4 Empirical Findings

This chapter will present the results and findings from the analysis together with a brief explanation. The first chapter regards the correlations from the initial data assessment. In the next part the DEA results are presented, and the last part will compare variables and efficiency scores. This will later be discussed in the discussion part, section 5.

4.1 Initial Data Assessment

4.1.1 Correlation

In order to be sure that the output and input are correlated to each other a scatterplots in Excel is used as a tool to prove this. We have chosen two outputs and three inputs in the analysis, and these will be examined. First, the output total number of orders is measured against each input: imperfect orders, number of employees and warehouse capacity. Then the same procedure will be done for the output, revenue.

Figure 5- *Correlation between imperfect orders and total number of orders (own figure)*

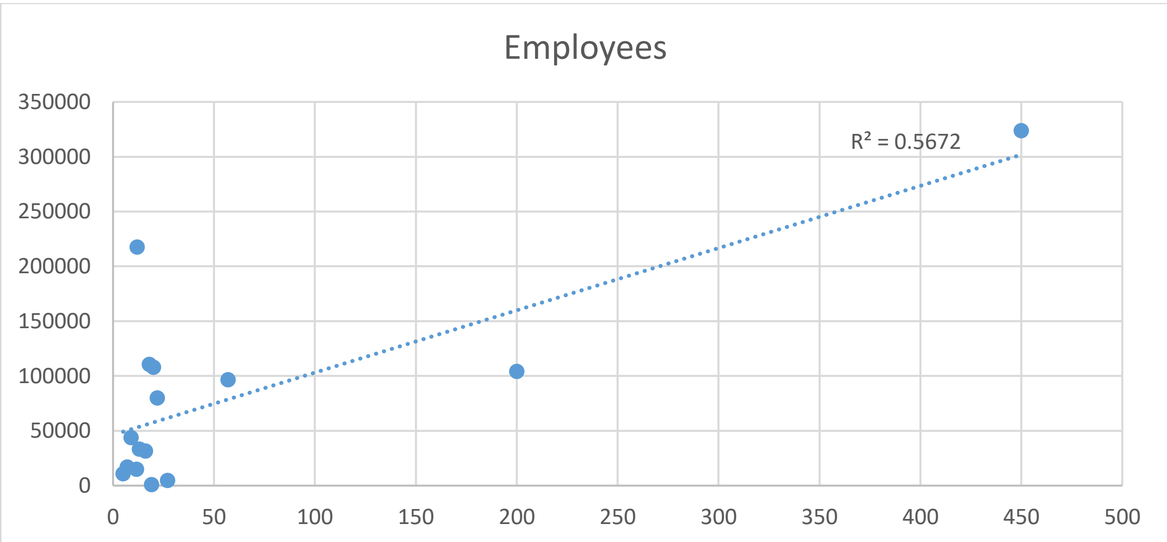


Figure 6- *Correlation between employees and total number of orders (own figure)*

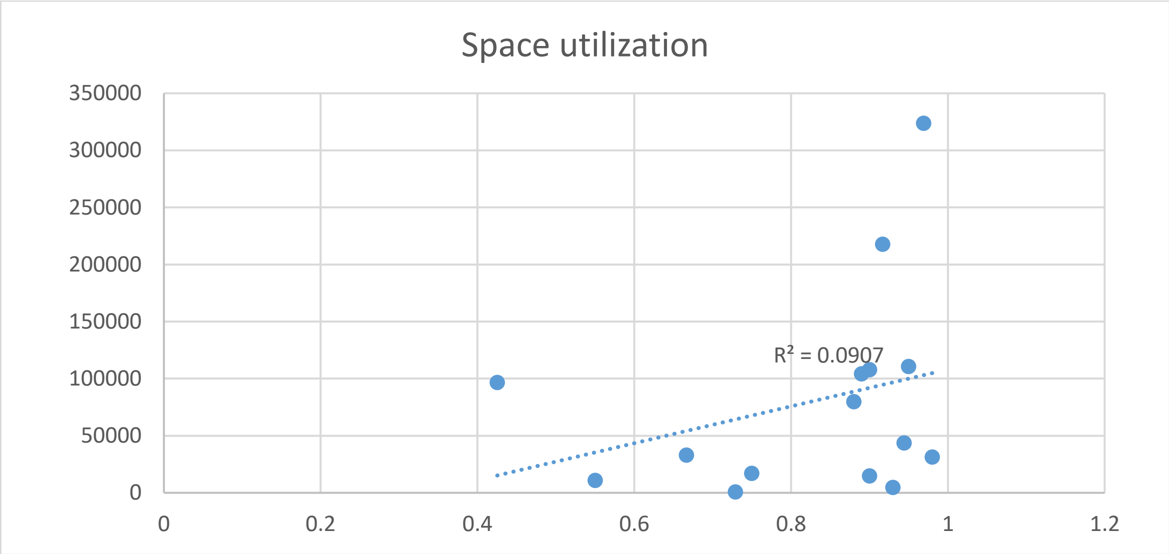


Figure 7- *Correlation between space utilization and total number of orders (own figure)*

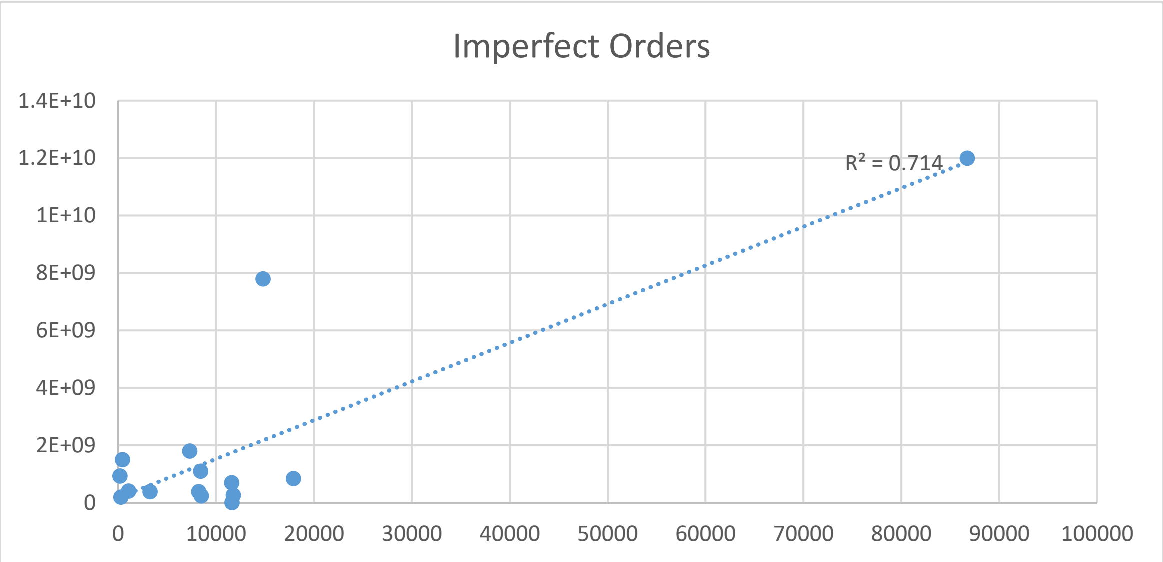


Figure 8- *Correlation between imperfect orders and revenue (own figure)*

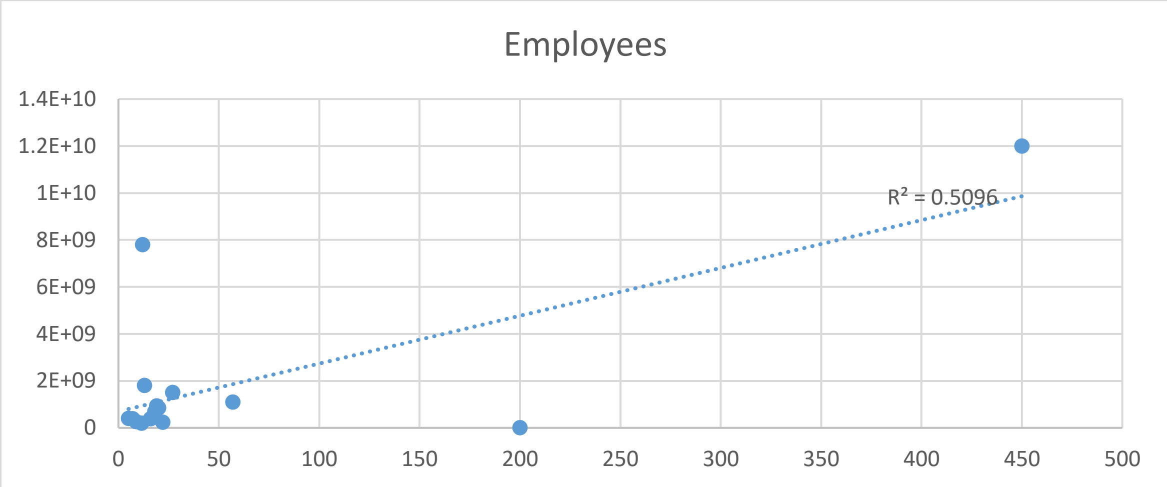


Figure 9- *Correlation between employees and revenue (own figure)*

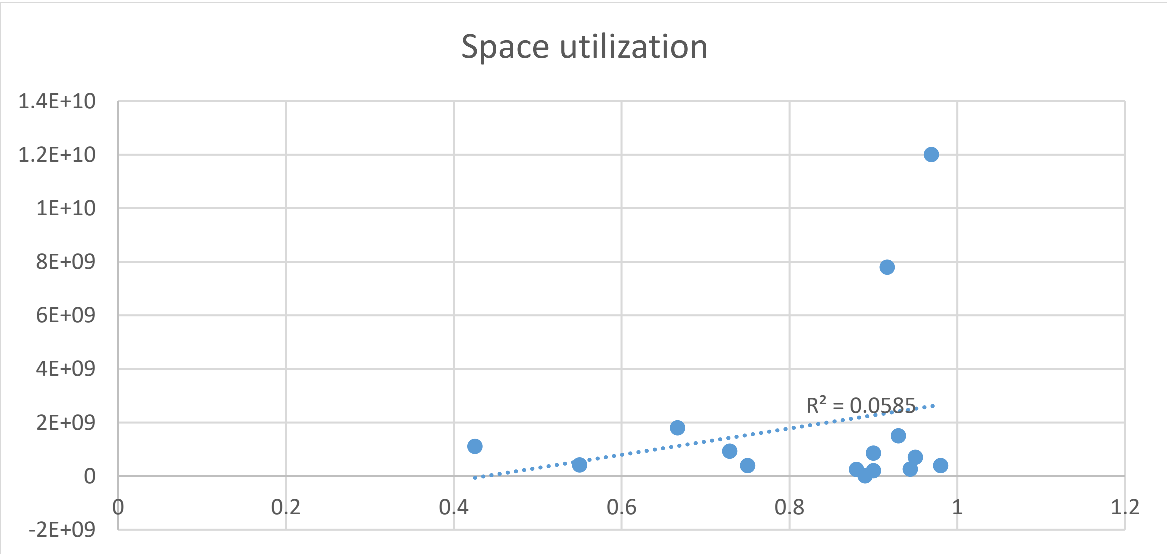


Figure 10- *Correlation between warehouse capacity and revenue (own figure)*

From the regression analysis the scatterplots indicates that all the inputs and outputs are positively correlated. The line R^2 is the best representation of the coordinates and its value decide whether it correlates or not. Table 6 below shows the interval of R^2 and the respectively degree of correlation. If the value is near 1, it indicates a perfect correlation, meaning if one variable increase the other variable tends to increase as well, or the opposite, decrease. If the value is between 0,50 and 1 it is characterized as a high degree of correlation. Between 0,30 and 0,49 there is a medium degree of correlation, below 0,29 a low correlation and none if the value is 0.

Degree of correlation	R^2 - value
Perfect	Near ± 1
High degree	Between ± 0,50 and ± 1
Moderate degree	Between ± 0,30 and ± 0,49
Low degree	Below ± 0,29
No correlation	0

Table 6- *Degree of correlation (own table)*

Table 7 shows the output variable total number of orders compared to the three different inputs with the corresponding R^2-values, then the correlation degree is defined. Number of orders and imperfect orders as well as employees is highly correlated. Number of orders and space utilization has a low correlation

Input	R2- value	Degree of correlation
Imperfect orders	0,7514	High correlation
Employees	0,5672	High correlation
Space utilization	0,0907	Low correlation

Table 7- *Correlation between the output; total number of orders, and the inputs (own table)*

Table 8 shows the effect between revenue and the inputs imperfect orders, employees and space utilization. As we can see there are two highly correlated variables and one with a low degree of correlation.

Input	R2 -value	Degree of correlation
Imperfect orders	0,714	High degree
Employees	0,5096	High degree
Space utilization	0,0585	Low degree

Table 8- *Correlation between the output; revenue, and the inputs (own table)*

Table 9 is an overview of the correlation between all the variables in the analysis; both inputs and outputs. All variables are compared to one another on behalf of correlation as well as a 2-tailed test. In general, the results indicate correlation between the variables, revenue, total number of orders, number of imperfect orders and number of employees. Space utilization is the one variable that distinguish itself from the others. The numbers marked with a star (*) is characterized as both correlated and a level of significance below 0,05. The spread of the values of correlation lies between 0,051 and 0,818, in other words, a broad variation of the degree of correlation.

		Revenue	Total numbers of orders	Number of imperfect orders	Number of Employees	Warehouse capacity
Revenue	Correlation	1	0,767*	0,714*	0,510*	0,059
	Sig. (2-tailed)		0,000	0,000	0,003	0,385
	N	15	15	15	15	15
Total numbers of orders	Correlation	0,767*	1	0,751*	0,567*	0,091
	Sig. (2-tailed)	0,000		0,000	0,001	0,275
	N	15	15	15	15	15
Number of imperfect orders	Correlation	0,714*	0,751*	1	0,818*	0,098
	Sig. (2-tailed)	0,000	0,000		0,000	0,256
	N	15	15	15	15	15
Number of Employees	Correlation	0,510*	0,567*	0,818*	1	0,051
	Sig. (2-tailed)	0,003	0,001	0,000		0,419
	N	15	15	15	15	15
Warehouse capacity	Correlation	0,059	0,091	0,098	0,051	1
	Sig. (2-tailed)	0,385	0,275	0,256	0,419	
	N	15	15	15	15	15

Table 9- *Correlation of all combination, for inputs and outputs (own table)*

4.2 Literature Overview

Table 10 below is an overview of the most relevant studies from the literature review. It shows the article name, author and the inputs, outputs or measurements used.

Article	**Author**	**Inputs**	**Outputs**
Benchmarking Warehouse and Distribution Operations: an Input-Output Approach	Hackman, Frazelle, Griffin, Griffin and Vlasta	Labour Space (square feet) Material handling and storage equipment	Movement Accumulation Storage
Evaluating the Efficiency of 3PL Logistics Operations	Hamdan and Rogers	Labour hours Warehouse Space Technology investment Materials handling equipment	Shipping volume/throughput Order filling Space utilization
Large-scale Internet benchmarking: Technology and Application in Warehousing Operations	Johnson, Chen and McGinnis	Labour Space Equipment	Broken case lines shipped Full case lines shipped Pallet lines shipped Accumulation Storage
Using Data Envelopment Analysis to Evaluate the Performance of Third Party Distribution Centres	Ting and Fang	Number of imperfect orders Number of employees Warehouse capacity	Revenue Total number of orders
Article	**Author**	**Measurements**	
The study of Efficiency and Effectiveness of Warehouse Management	Sneha Vishnu More	Perfect order Order performance Carrying cost of inventory	

in the Context of Supply Chain Management		Inventory turnover Order picking accuracy Inventory to sales ratio Units per transaction Inventory accuracy Back order rate Product turnover time Unloading and recording the product Organizing and storing the delivery Processing orders
Warehouse management	Gwynn Richards	Labour hours utilization Warehouse area utilization MHE utilization Units picked Cost as a percentage of sales Cost per order dispatched Dock-to-stock time Order accuracy On-time shipments Stock cover in days Stock turn The stock /inventory accuracy Damaged inventory On time and in full
An Efficiency/ Effectiveness Approach to Logistics Performance Analysis	Mentzer and Konrad	**Transportation**: Labour Cost Equipment Energy Transit time **Warehousing**:

		Labour Cost Time Utilization Administration **Inventory control:** Purchasing Inventory management **Order processing:** Order entry Order editing Scheduling Shipping Billing **Logistics administration:** Customer communication Service

Table 10 - *Literature overview (own table)*

4.3 DEA Results

The result from the solver DEA Frontier in Excel is shown in Table 11. The first column represents the DMU number which is the companies participating, a more detailed description is given in section 3.1.3 regarding the participants and the NACE-codes. The second column represents the efficiency score for each company, assuming constant return to scale and an input-oriented point of view. The third column stands for Return to Scale (RTS) and is either increasing or constant. The last column ranks the companies by the efficiency score. If several companies result in the same score, they are given the same rank. The bottom of the table provides some descriptive statistics of the results. As we can see, the average efficiency score is 0,68, maximum score is as expected 1,0, the minimum score is 0,25 and the standard deviation is 0,29.

DMU Nr.	Input-Oriented (CRS)	RTS	Rank
1	0,63903	Increasing	3
2	**1,00000**	**Constant**	**1**
3	0,60176	Increasing	6
4	0,62072	Increasing	5
5	0,92117	Increasing	2
6	0,62573	Increasing	4
7	0,43334	Increasing	8
8	0,49181	Increasing	7
9	**1,00000**	**Constant**	**1**
10	**1,00000**	**Constant**	**1**
11	**1,00000**	**Constant**	**1**
12	0,27228	Increasing	10
13	**1,00000**	**Constant**	**1**
14	0,32786	Increasing	9
15	0,25449	Increasing	11
Average	**0,68**		
Max	**1,00**		
Min	**0,25**		
S.D.	**0,29**		

Table 11- *Efficiency scores for each DMU (own table)*

The warehouses with the efficiency score of 1,0 are the peers or the benchmarked companies in this analysis. Table 12 present each DMU and their benchmarked DMU(s) respectively. For instance, DMU 1 is benchmarked 0,497 with DMU 9 and 0,165 with DMU 11. The five best performing DMU is benchmarked against themselves. Most companies are compared against company 9, then company 11, 13, 10 and 2. Some companies are benchmarked to one DMU, others two and one with three companies.

DMU Nr.	Efficiency score	Benchmark					
		Score	DMU	Score	DMU	Score	DMU
1	0,63903	0,497	9,000	0,165	11,000		
2	**1,00000**	**1,000**	**2,000**				
3	0,60176	0,471	9,000	0,115	11,000		
4	0,62072	0,351	9,000	0,238	11,000		
5	0,92117	0,417	9,000	0,018	10,000		
6	0,62573	0,041	9,000	0,127	11,000	0,043	13,000
7	0,43334	0,211	9,000	0,105	13,000		
8	0,49181	0,483	9,000	0,009	10,000		
9	**1,00000**	**1,000**	**9,000**				
10	**1,00000**	**1,000**	**10,000**				
11	**1,00000**	**1,000**	**11,000**				
12	0,27228	0,201	9,000				
13	**1,00000**	**1,000**	**13,000**				
14	0,32786	0,069	9,000	0,126	11,000		
15	0,25449	0,140	9,000	0,067	11,000		

Table 12- *Table of which company each DMU should learn the most from (own table)*

4.3.1 Efficiency Results Compared Against Different Variables

Efficiency will put up against different variables, for example revenue, size in cubic and order size. By doing so, we can analyse if there are tendencies in common for the peers. The tables are divided into three columns. The first column is the DMU number in other words the companies, then the variable under research and the last column represent the efficiency score. The tables is also divided into three groups or categories per size. If we take warehouse size as an example, the first five companies are the smallest regarding the size, the next five companies are the ones in the middle and the last five are the largest in size. Then the efficiency scores of the companies can be found in the last column, and we can see if the distribution of the peers might have anything in common. Companies marked with green are the five benchmarked companies, the five red are the companies scoring the lowest on efficiency and the yellow are the ones in the middle. The companies will have the same color throughout all the comparison tables because the score is taken from Table 11 and will not change. The sequence on the other hand will be changes according to the variable under research. The reason why we do it this way, is because the main focus of research question III is the benchmarked companies. From Table 13 we can see there is no compliance between the size in cubic and the efficient DMUs. The benchmarked companies are spread out in all three categories, it seems randomly distributed.

DMU Nr.	Warehouse Size	Efficiency score
9	**2 400**	**1,00000**
7	3 175	0,43334
11	**4 907**	**1,00000**
1	13 300	0,63903
12	14 000	0,27228
8	15 000	0,49181
2	**15 026**	**1,00000**
14	16 000	0,32786
4	19 500	0,62072
15	24 991	0,25449
6	30 000	0,62573
13	**34 560**	**1,00000**
3	58 007	0,60176
5	84 000	0,92117
10	**234 543**	**1,00000**

Table 13- *Efficiency compared to warehouse size in cubic meters (own table)*

The same principle is done in Table 11, the only difference is that the variable revenue is compared against the efficiency score. In this case, there is a more distinct connection between the most efficient companies and the revenue. The majority of the efficient DMUs have a high revenue.

DMU Nr.	**Revenue**	**Efficiency score**
3	kr 3 906 514	0,60176
11	**kr 200 000 000**	**1,00000**
4	kr 240 000 000	0,62072
12	kr 260 400 000	0,27228
14	kr 388 000 000	0,32786
15	kr 390 000 000	0,25449
6	kr 409 000 000	0,62573
1	kr 696 000 000	0,63903
8	kr 850 000 000	0,49181
2	**kr 930 000 000**	**1,00000**
5	kr 1 100 000 000	0,92117
13	**kr 1 500 000 000**	**1,00000**
7	kr 1 800 000 000	0,43334
9	**kr 7 800 000 000**	**1,00000**
10	**kr 12 000 000 000**	**1,00000**

Table 14- *Efficiency compared to revenue in NOK (own table)*

The next example is Table 15 where total number of orders is compared against the efficiency score. In this scenario, the most efficient, marked in green are in the categories with lowest and highest number of orders.

DMU Nr.	Total Number of Orders	Efficiency score
2	**835**	**1,00000**
13	**4 718**	**1,00000**
6	11 000	0,62573
11	**14 850**	**1,00000**
14	17 000	0,32786
15	31 500	0,25449
7	33 175	0,43334
12	43 722	0,27228
4	79 934	0,62072
5	96 616	0,92117
3	104 224	0,60176
8	108 000	0,49181
1	110 742	0,63903
9	**217 730**	**1,00000**
10	**323 836**	**1,00000**

Table 15- *Efficiency compared to total number of orders (own table)*

Table 16 shows the characteristics of the companies when comparing order size measured as order lines per order and the efficiency scores. As can be seen, the most efficient companies are with one exception located in the category with highest order lines per order.

DMU Nr.	Order Size	Efficiency score
8	2,3	0,49181
12	3,8	0,27228
7	4	0,43334
4	4,49	0,62072
15	4,6	0,25449
1	4,78	0,63903
14	5,1	0,32786
9	**6**	**1,00000**
6	12	0,62573
5	14	0,92117
10	**17,4**	**1,00000**
13	**23**	**1,00000**
11	**45**	**1,00000**
3	57,13	0,60176
2	**80**	**1,00000**

Table 16- *Efficiency compared to order size (own table)*

Table 17 shows the number of orders picked per employee for each hour compared to the efficiency scores. There are three benchmarks in the category with highest number of orders picked and two in the lowest category.

DMU Nr.	Order picking	Efficiency score
6	0,500	0,62573
9	**6,240**	**1,00000**
13	**7,7**	**1,00000**
7	8,000	0,43334
12	17,000	0,27228
15	18,300	0,25449
14	24,000	0,32786
8	27,000	0,49181
4	27,380	0,62072
1	38,200	0,63903
5	43,000	0,92117
3	48,770	0,60176
10	**63,320**	**1,00000**
11	**70,000**	**1,00000**
2	**80,000**	**1,00000**

Table 17 – *Efficiency compared to order picking(own table)*

The efficiency is compared to on-stock level in percent at the warehouse in Table 18. The companies are spread out in all categories.

DMU Nr.	**On-stock**	**Efficiency score**
10	**89,00 %**	**1,00000**
7	90,10 %	0,43334
3	90,37 %	0,60176
12	92,00 %	0,27228
1	95,40 %	0,63903
9	**95,40 %**	**1,00000**
13	**95,40 %**	**1,00000**
6	96,00 %	0,62573
14	97,40 %	0,32786
5	98,00 %	0,92117
8	98,55 %	0,49181
4	98,67 %	0,62072
15	99,50 %	0,25449
2	**100,00 %**	**1,00000**
11	**100,00 %**	**1,00000**

Table 18- *Efficiency compared to on-stock in percent (own table)*

Table 19 shows the effect order picking accuracy has on the efficiency scores. The scores are distributed randomly in all categories.

DMU Nr.	Order picking accuracy	Efficiency score
10	**0,03 %**	**1,00000**
1	0,03 %	0,63903
7	0,03 %	0,43334
12	0,06 %	0,27228
4	0,08 %	0,62072
13	**0,10 %**	**1,00000**
8	0,13 %	0,49181
11	**0,19 %**	**1,00000**
15	0,20 %	0,25449
9	**0,25 %**	**1,00000**
3	0,28 %	0,60176
5	0,30 %	0,92117
14	0,60 %	0,32786
2	**1,00 %**	**1,00000**
6	1,00 %	0,62573

Table 19-*Efficiency compared to order picking accuracy (own table)*

The effect urgent orders has on the efficiency can be seen in Table 20. Three of the benchmarked companies are located in the first category indicating the companies with few urgent orders. There are as one benchmarked company in the category in the middle and one in the category with the highest number of urgent orders.

DMU Nr.	Urgent Orders	Efficiency score
6	0,35 %	0,62573
13	**0,43 %**	**1,00000**
9	**0,55 %**	**1,00000**
3	0,70 %	0,60176
2	**0,99 %**	**1,00000**
5	1,00 %	0,92117
7	1,28 %	0,43334
11	**1,89 %**	**1,00000**
12	2,30 %	0,27228
1	3,90 %	0,63903
10	**3,96 %**	**1,00000**
4	5,00 %	0,62072
8	10,00 %	0,49181
15	13,00 %	0,25449
14	15,00 %	0,32786

Table 20- *Efficiency compared to urgent orders (own table)*

The best performing companies are spread in all three categories when looking at the effect return has on the efficiency score, see in Table 21.

DMU Nr.	Return	Efficiency score
3	0,00 %	0,60176
11	**0,00 %**	**1,00000**
14	0,01 %	0,32786
13	**0,10 %**	**1,00000**
6	0,25 %	0,62573
7	0,77 %	0,43334
10	**0,80 %**	**1,00000**
1	0,94 %	0,63903
2	**0,99 %**	**1,00000**
8	1,00 %	0,49181
9	**1,38 %**	**1,00000**
5	1,40 %	0,92117
15	1,60 %	0,25449
4	1,66 %	0,62072
12	2,82 %	0,27228

Table 21- *Efficiency compared to return (own table)*

In Table 22 information of how the inventory utilization affects the efficiency scores is provided. All categories include at least one benchmarked company, otherwise it appears random.

DMU Nr.	**Inventory Utilization**	**Efficiency score**
5	42,52 %	0,92117
2	**80,00 %**	**1,00000**
11	**80,00 %**	**1,00000**
14	80,00 %	0,32786
7	82,00 %	0,43334
4	88,00 %	0,62072
13	**88,00 %**	**1,00000**
8	90,00 %	0,49181
9	**91,67 %**	**1,00000**
1	92,00 %	0,63903
3	92,00 %	0,60176
12	94,40 %	0,27228
10	**96,90 %**	**1,00000**
15	99,00 %	0,25449
6	100,00 %	0,62573

Table 22- *Efficiency compared to inventory utilization (own table)*

The effect delayed orders has on efficiency can be seen in Table 23. Most of the benchmarks are located in the lowest scores with one exception which is the last line, which is remarkably much higher than the rest.

DMU Nr.	Delayed orders	Efficiency score
3	0,00	0,60176
11	**0,00**	**1,00000**
9	**20,00**	**1,00000**
14	150,00	0,32786
2	**154,00**	**1,00000**
13	**188,72**	**1,00000**
1	1100,00	0,63903
4	2020,00	0,62072
6	0,00	0,62573
7	3317,00	0,43334
15	3400,00	0,25449
5	3864,64	0,92117
8	4320,00	0,49181
12	6000,00	0,27228
10	**35621,96**	**1,00000**

Table 23- *Efficiency compared to delayed orders (own table)*

The sector diagram in Figure 11 shows the distribution of which sector the companies are operating in. Either wholesale, retail or manufacturer. The majority is working with wholesale, then manufacturing and so retail.

Figure 11- *The distribution of which sector the companies are operating in (own figure)*

Table 24 provides information regarding which sector the most efficient companies are operating in. As we saw from Figure 11 the majority of the companies are operating within wholesale, manufacturing and then retail. All the categories include at least one benchmarked company.

DMU Nr.	Sector	Efficiency Score
6	Manufacturer	0,62573
7	Manufacturer	0,43334
10	**Manufacturer**	**1,00000**
14	Manufacturer	0,32786
15	Manufacturer	0,25449
2	**Retail sale**	**1,00000**
5	Retail sale	0,92117
1	Wholesale	0,63903
3	Wholesale	0,60176
4	Wholesale	0,62072
8	Wholesale	0,49181
9	**Wholesale**	**1,00000**
11	**Wholesale**	**1,00000**
12	Wholesale	0,27228
13	**Wholesale**	**1,00000**
Sector	**Average**	**Nr. per sector**
Wholesale	**0,70320**	**8**
Retail sale	**0,96059**	**2**
Manufacturer	**0,52828**	**5**

Table 24- *Overview of all companies and their respective sector (own table)*

5 Discussion

This chapter will discuss the empirical findings and results presented in the previous chapter. First the initial data assessment and DEA results will be commented, then the research problems will be answered. General problems and discussion will also be mentioned.

5.1 Correlation

The correlation in the initial data assessment is done in order to show a connection between the inputs and outputs. They should be somehow correlated, otherwise a change in one variable would not have any impact on the other variable. No correlation indicate that the variables are unnecessary. As we can see, all the variables are correlated, some more than others. In both cases, when comparing the two outputs, the total number of orders and revenue against the three inputs, we can see that the least correlated is space utilization. The number of employees and the number of imperfect orders are both correlated and the latter resulted with a slightly higher correlation, valid for both outputs. In other words, the higher total number of orders, the higher the number of imperfect orders and employees. This could indicate, the more orders the more mistake and more people are needed.

Table 9 is an overview of the correlation of all the variables against each other. The variables marked with a star includes total number of orders, number of imperfect orders and number of employees. Space utilization has a low degree of correlation and a significance level above 0,05 and is not marked with a star. The high significance level may indicate that there is a small connection between space utilization and the other variables, we might say the data collected for space utilization appears random and not dependent on any other variables. The most correlated variables are number of imperfect orders and number of employees which has a value of 0,818, which indicates a relation between them. If there were a perfect correlation of 1, it would be possible to drop one of the variables because the variables would then produce the same impact on the analysis and therefore overlapping each other. This tells us that the impact of the average value of space utilization is of smaller impact then employees and imperfect orders. The higher R^2-value the better the coordinates fits the regression line hence greater correlation.

5.2 Efficiency and/or Effectiveness

As mentioned in the literature review of performance measurement, more specifically section 2.3, there is a debate on whether efficiency and effectiveness are overlapping or not. This thesis assumes an organization can have multiple goals and can be both efficient and effective, hence supporting the literature of Ford and Schellenberg (1982) and Ostroff and Schmitt (1993) amongst other. At the same time, it does not really matter due to the fact that the inputs and outputs are pre-determined for the companies. The companies have different strategies and main priorities decided by their boards, that will not be taken into consideration. The main point of view in this thesis is efficiency.

5.3 Discussion of Research Questions

5.3.1 Research Question I

There are several opinions and viewpoints on how to measure efficiency at warehouses. The aim of research question I is to identify the most frequent measures used in applied research as well as which measures should be used when looking at warehouse efficiency. The background for this is to show the broad diversity of options on how to measure efficiency as well as building a foundation of supportive literature appropriate for this specific topic. As mentioned, the first part was answered with examples in the literature review and a table of the most frequent variables applied can be seen in Table 10 in the result chapter. In summary, the most frequently recurring measurements are labour hours or labour cost, warehouse space or space utilization, material handling equipment and inventory accuracy. In addition, measurement like technology investment, perfect- and imperfect order, fill rate, order cycle time, units picked, dock-to stock, revenue, inventory- and product turnover, carrying cost of inventory, damaged inventory and asset utilization are also applied. All the measurements indicate that there is little agreement on how to most appropriate measure efficiency. The context and characteristics of the research participants will affect the best way to measure efficiency. The optimal solution will therefore be unique depending on the situation and participants. The second part of this research question is elaborated in detail in section 3.2.4, Choosing Inputs and Outputs in Order to Measure Efficiency, because the answer is more an argumentation than a discussion and fits better where the choice of variables are elaborated in the data and methodology chapter.

5.3.2 Research Question II

Our results are mainly based on the key findings in Table 11 showing the efficiency scores of the DMUs. This is the most decisive table for answering research question II because it is the actual results from the analysis. It provides information of which company is efficient and to what extent the inefficient companies are, compared to the best performing companies. According to DEA there are five efficient companies, DMUs 2, 9,10, 11 and 13. These are seen as the benchmarked companies in this analysis. DMU 2 are working as a retailer of textile in specialized stores. Company 9 is a wholesaler of computers peripheral equipment and software. The NACE description for company 10 is non-specialised wholesaler of food, beverages and tobacco. Company 11 is a wholesaler of other household and personal goods and company 13 is a manufacturer of soap and detergents, cleaning and polishing preparations.

The results from Table 11 regarding the efficiency scores shows an average efficiency score of 0,68. This means the average level of inefficiency or possible improvement is 0,32. In other words, the companies should in general be able to improve themselves by 32 percent without any changes of outputs. The result provides both information of the efficiency score per company as well as potential of improvement for the inefficient companies. The standard deviation of 29 percent tells us there is a great variance of the efficiency scores for the DMUs. The lowest efficiency score is 0,25 indicating a 75 percent potential of improvement. Such a high improvement potential can be explained by the relatively high standard deviation. The standard deviation may be explained by the great variance in the company's efficiency score. However, the standard deviation is quite high; even though the average efficiency score and the improvement rate is acceptable.

Table 12, regards which benchmark company or companies the inefficient companies are recommended to learn from. All companies may learn from each other, but this table tells which is the most suitable according to the analysis. According to the table, most companies should learn from company 9. Some companies are recommended to learn from one benchmark, others are recommended to learn from two or three benchmarks. The score indicates how much an inefficient company may learn from the benchmarked companies.

5.3.3 Research Question III

The following part of the discussion will discuss the findings of research question III, regarding characteristics of the benchmarks. It will be built on the results from Table 13 to Table 23. First the variables that seem to have a distinct distribution will be elaborated in detail, then the random distributions will be discussed. These characteristics are just an indication and will only be valid for the 15 participants in this analysis. This assumption will be applied for all of the tables and discussion. There are not enough participants to claim generalized observations. They will still give us a good indication for the companies in question.

How benchmarked companies behave according to the variable revenue can be seen in Table 14. Most of the companies with high revenue marked in green are benchmarked. This might be answered by high revenue indicates satisfied customers and processes are handled in correct ways. The revenue will also be affected by what types of goods are sold, some goods will naturally have a higher price than others. Company 11, selling household and personal goods such as board games, office supplies, books and so on may be an example of this. Even though this company might not be the biggest when it comes to revenue they still manage to do things right and score high on efficiency. Some of the warehouses operate with internal customers such as deliveries from the warehouse to the stores while others are selling directly to the end-customers. This will affect the revenue. In the first case the company are mainly distributing products and do not aim to maximize the revenue. In the second scenario the goal is to make a profit.

Table 16 indicates characteristics of the benchmarks regarding order size. It clearly indicates that larger orders mean higher efficiency scores. The smallest group is mostly marked in red, and the biggest in green. This might be explained by small orders requires more time. Several orders means more time for paperwork, packing, shipping and preparing an order relative to order size. It is more efficient to pick more lines in an order than rapidly change to new orders. This statement can be backed up looking at the average of the three categories. The average for the red companies is 3,96 order lines per order, 18,48 for the yellow category and 34,28 for the green group.

Table 17 analyze the effect order picking has on the benchmarks. One would assume the more orders an employee manages to pick for each hour, the more efficient the company is. From the results, this seems to be true. The top three companies regarding orders picked are benchmarked. Company 10, 11 and 2 all have a broad assortment and one order might consist of many different products or order lines. This results in a great variety of products picked for each hour and might be a reason why they score relatively much higher than the rest.

compares the benchmarked companies against urgent order. In advance, we would assume that fewer urgent orders is better for the performance. With some variation, it seems to be true. Benchmark 13, 9 and 2 are all in the first category with the lowest level of urgent orders. This is strengthened by the top three companies with highest number of urgent orders are all marked in red. The number of urgent orders will depend on what the company do. Some sectors will naturally have a higher level of urgent orders than others. Company 15 manufacture machinery and equipment for manufacturing. If one of the machines break down for a customer, they would need a spare part fast. This unpredictable scenario will result in more urgent orders than compared to company 2 selling household linen like sheets and towels which rarely results in urgent orders. Table 23 compares the benchmarks against the variable delayed orders. From the results, it can be seen that the benchmarks are mostly located in the category with few delayed orders. Delayed orders are obviously not desired and will affect the performance of a company negatively, hence the efficiency score will be reduced. Most of the companies in red are located at the bottom with the highest level of delayed orders. One exception is company 10, which are both efficient and have the highest number of delays. A reason might be that this company have much higher numbers overall, so the percentage of delayed orders of the total might not be that bad compared to the others after all. Another reason may be that this company delivers food and beverages to customers by truck, and one truck might consist of orders for several customers. For instance, if the first delivery is delayed due to traffic, this may affect the subsequent deliveries.

Company 3 and 11 claim they do not have delayed orders. We only have additional information about company 3 on this topic. They have outsourced their transportation of deliveries. The agreement with the 3PL allows them to have a big and high flexibility when it comes to the deliveries. If the driver changes the planned route it is accepted by the customer receiving the goods as long as it is within the day agreed upon. Therefore, the score is 0 in the table.

The NACE-sectors of manufacturing, retail and wholesale all include at least one benchmarked company. There are only two companies in the category of retail, while manufacturing includes five companies and eight in wholesale. Due to this variance in number per category it is hard to compare the sectors. Still, we can point out some indications. The average efficiency score for the category wholesale is 70,32 percent, manufacturing has an average of 65,18 percent and retail 96,05 percent.

The rest of the tables, Table 13, Table 15, Table 18, Table 19, Table 21 and Table 22 show no indications of characteristics. It seems the distribution is random, and no indication can be drawn from it.

6 Conclusion

This study seeks to fill the gap in literature regarding benchmarking of warehouse efficiency. Previously studies regarding benchmarking of distribution centres have been done but not on warehouses. In addition, this thesis focuses on performance measures and how to measure efficiency at warehouses.

The aim of this study is to benchmark the most efficient warehouses. The warehouses participating are 15 Norwegian warehouses operating in the NACE-codes wholesale, manufacturing and retail. The method applied is Data Envelopment Analysis, more specifically input-oriented CCR-method. The software used is DEA-frontier 2007 Add-In Excel. Efficiency is measured by three inputs and two outputs. The inputs are number of imperfect orders, number of employees and space utilization and the outputs are revenue and total number of orders. These measurements are based on previous literature as well as relevance to this study. The data is primary data collected directly from the companies valid for the year 2017.

The results from the analysis show five efficient warehouses, number 2, 9, 10, 11 and 13. These benchmarked companies, according to the NACE-codes, work in the sectors wholesale, manufacturing and retail. More specifically textiles and household linen, computer consultancy, food and beverages, household and personal goods as well as soap, detergents and cleaning products. The rest of the companies are relatively inefficient according to the benchmarks. The average potential improvement is 32 percent for the inefficient companies.

This thesis has also looked at characteristics of the benchmarks. Due to the number of participants these characteristics will only be an indication and valid for this group. In our analysis the benchmarked companies are characterized with the following indications; having few urgent and delayed orders, a high revenue and many order lines per order as well as being able to pick many orders per hour. In order to cope with the ever-changing market and to satisfy customers' needs as well as being one step ahead of their competitors it is crucial to have an efficient warehouse. In order to manage this, companies could start improving the characteristics mentioned above. There are of course many influencing factors that must be taken into consideration, but these variables indicates having an impact and would be a good starting point.

6.1 Limitation of the Study

The terminology within the logistic industry is complex. Depending on the knowledge of the employees, this may result in many interpretations of the terminology. The data for this thesis is collected directly from logistics workers from the participating companies. Their positions are logistic director, operation manager, CEO, warehouse manager, senior manager, logistic manager and warehouse manager. An example of this was inventory utilization. We asked to what degree the storage was utilized compared to the total capacity in percent. One of the answer were 5,60 percent. We then sent a mail and asked if the number was correct and explained what we were looking for. It turned out the contact person was thinking the opposite and the actual number was 94,40 percent. We sent individual mails pointing out the missing data and described the nature of data in question. We received many answers. The context of the feedback made us aware that there were some misunderstandings. After having cleared out the misunderstandings and received new data, the data reached the required quality. According to Johnson, Chen, and McGinnis (2010) communication is the most effective tool to clear up misunderstandings. Johnson, Chen and McGinnis also point out other important pitfalls. For instance, when it comes to the Internet, it provides a quick and safe collection of the data, at the same time typing errors can easily occur. Any error in data will influence the values for the best performing DMU(s) in the analysis.

Hamdan and Rogers (2008) specify the importance of homogeneous DMUs in a DEA. They point out the study of Hackman et al. (2001) to not fulfill this requirement, because they look at a wide range of products resulting in different processes, handling techniques and equipment at the warehouses. This thesis are examining a broad scope of companies dealing with different products indicating different ways of operating the warehouse. In order to compare the companies in the most appropriate way the companies should be as homogeneous as possible. Since this is the first year of hopefully an annual report, this is expected, and the further possibilities based on this limitation will be discussed in the next part.

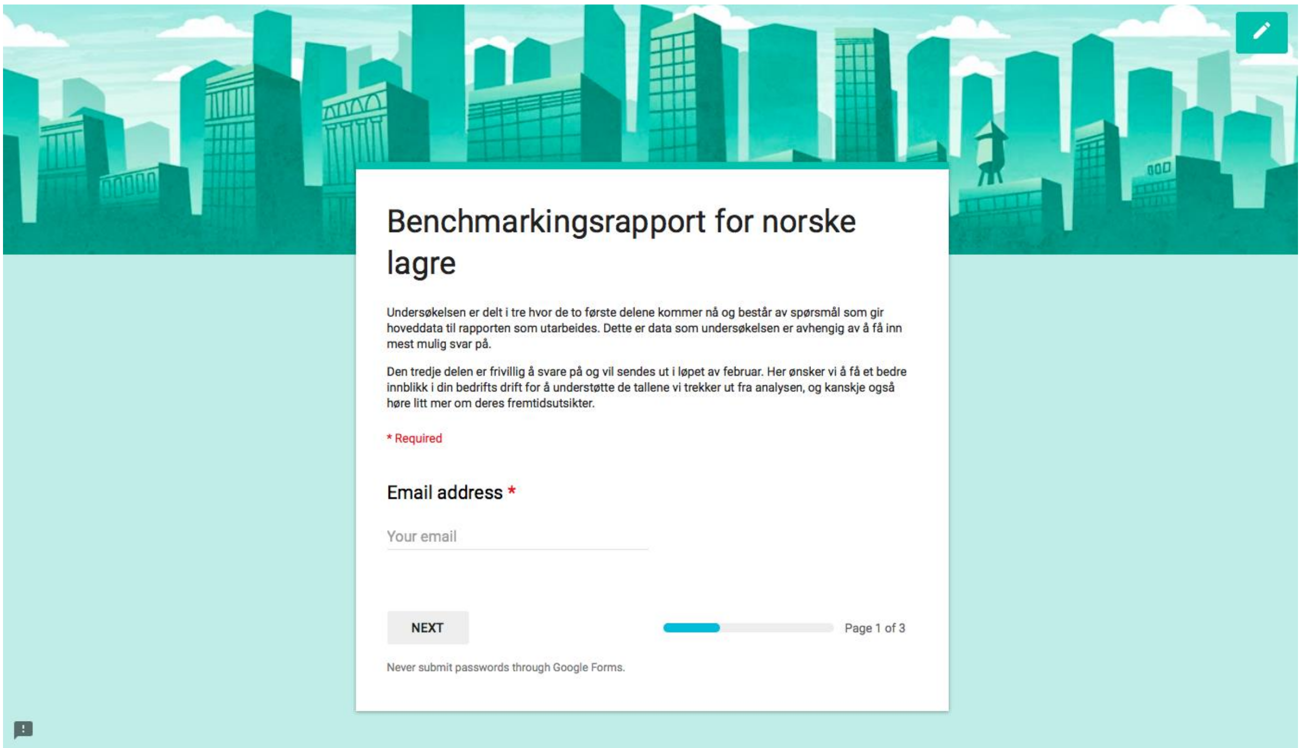
6.2 Further Research

Since this is the first year of the report, 15 companies are actually a quite good response. This thesis uses the NACE-code in order to separate the companies by sectors. Hopefully, the report is seen as a success and contribution for the companies, so that they will be eager to participate in the years to come. They will be able to compare themselves year by year as well as against competitors. In addition, new companies might show their interest. Then the report will grow in size of population as well as receive a good reputation in order to be sustainable for several years. In the following years, the aim is to have as many companies as possible, in order to be able to benchmark within the sector. Then each company could be divided into separate groups and benchmarked within the appropriate group.

Appendix 1- Webpage for the Questionnaire

Link to the web-questionnaire:

https://docs.google.com/forms/d/e/1FAIpQLSdgC_ldEUWYFGaYYPuLNsYlqr5cBqqk7-t32sN5qI5qjZiA-Q/viewform



Benchmarkingsrapport for norske lagre

Undersøkelsen er delt i tre hvor de to første delene kommer nå og består av spørsmål som gir hoveddata til rapporten som utarbeides. Dette er data som undersøkelsen er avhengig av å få inn mest mulig svar på.

Den tredje delen er frivillig å svare på og vil sendes ut i løpet av februar. Her ønsker vi å få et bedre innblikk i din bedrifts drift for å understøtte de tallene vi trekker ut fra analysen, og kanskje også høre litt mer om deres fremtidsutsikter.

* Required

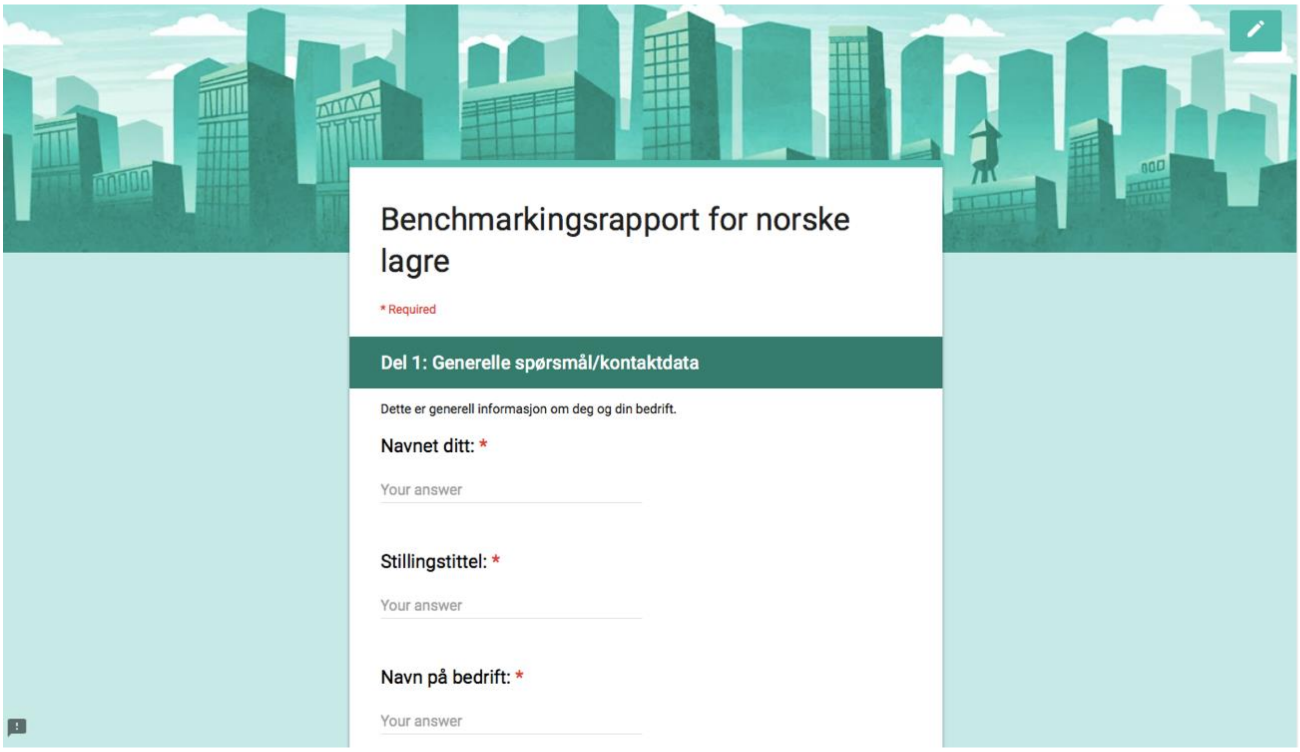
Email address *

Your email

NEXT

Page 1 of 3

Never submit passwords through Google Forms.



Benchmarkingsrapport for norske lagre

* Required

Del 1: Generelle spørsmål/kontaktdata

Dette er generell informasjon om deg og din bedrift.

Navnet ditt: *

Your answer

Stillingstittel: *

Your answer

Navn på bedrift: *

Your answer

Organisasjonsnummer: *

Your answer

Årlig omsetning: *

Your answer

B2B / B2C (kryss av hva som passer din bedrift): *

- ◯ Vi er en ren B2B-bedrift
- ◯ Vi er en ren B2C-bedrift
- ◯ Vi jobber med både B2B & B2C

Har dere nettbutikk?

- ◯ Ja
- ◯ Nei
- ◯ Blir lansert i løpet av 2018
- ◯ Other:

Antall faste ansatte på lageret:

Your answer

Har du lagerstyring i dag?

- ◯ Ja
- ◯ Nei

Har du noen kommentarer til spørsmål / svar?

Your answer

Konfidensialitet

All data vil behandles konfidensielt. Du har sammen med denne rapporten mottatt et eget skriv som informerer om håndteringen og bruken av dataen som blir delt. Disse dokumentene må signeres og returneres til steffen.larvoll@lis.no

Egen graf med data?

Jeg ønsker egen graf med data som viser hvordan vår bedrift gjør det opp i mot resten av bransjen og gir masterstudentene tillatelse til å koble våre data opp i mot de beste i bransjen.

- ◯ Ja
- ◯ Nei
- ◯ Vi ønsker mer info om hva dette innebærer

Tillatelse for bruk av logo

Vi ønsker å tillate bruk av vår logo i forbindelse med informasjons- og markedsføring av rapporten. (Nettsider, informasjonsskriv, annonser etc).

- ◯ Ja
- ◯ Nei
- ◯ Vi ønsker mer info om hva logoen skal benyttes til

Benchmarkingsrapport for norske lagre

Del 2: Spørsmål til Rapporten

Spørsmålene i del 2 er de spørsmålene som utgjør selve rapporten. Disse er viktige at fylles ut, kom gjerne med kommentarer ved behov.

1. Effektivitet plukk: Hvor mange ordrelinjer plukket pr. time pr. Operatør

Med dette mener vi antall betalte timer og ikke arbeidede timer. Prosessen begynner ved arbeidsdagens start, hvor forberedelse er en del av effektiviteten. Inluderer det å hente selve produktet i orderen og pakke det. MERK: Hopp over hvis du ikke har tall.

Your answer

Har du noen kommentarer til spørsmål/svar?

Your answer

2. Effektivitet varemottak: Hvor mange ordrelinjer er mottatt og lagt på plass pr. time pr. operatør

Med dette mener vi antall betalte timer og ikke arbeidede timer. Prosessen begynner ved arbeidsdagens start, hvor forberedelse er en del av effektiviteten. MERK: Hopp over hvis du ikke har tall.

Your answer

Har du noen kommentarer til spørsmål/svar?

Your answer

3. Leveringspresisjon:

Hvor stor % av ordrelinjer som er sendt i henhold til servicenivå/SLA (Service Level Agreement) MERK: Hopp over hvis du ikke har tall.

Your answer

Hvilket servicenivå har dere valgt?

Your answer

Har du noen kommentarer til spørsmål/svar?

Your answer

4. Intern ordrehåndteringstid:
Hva er gjennomsnittlig tid fra ordren bestilles fra kunden til varen sendes fra lageret? MERK: Hopp over hvis du ikke har tall.

Your answer

Har du noen kommentarer til spørsmål/svar?

Your answer

5. Total ordrehåndteringstid:
Hva er gjennomsnittlig tid fra ordren bestilles fra kunden til varen har kommet frem til kunden. MERK: Hopp over hvis du ikke har tall.

Your answer

Har du noen kommentarer til spørsmål/svar?

Your answer

6. Plukkpresisjon: Dette måler nøyaktigheten hos ordreplukkeren. Hva er andel feilplukk (%).
Med dette mener vi feilplukk som følge av a) feil vare eller b) feil antall av riktige varer. Tallet vi er ute etter er de feil som ikke oppdages i huset, det vil si basert på kundetilbakemeldinger eller andre måter å oppdage dette på. MERK: Hopp over hvis du ikke har tall.

Your answer

Har du noen kommentarer til spørsmål/svar?

Your answer

7. Andel hasteordre: En ordre som behandles avvikende i forhold til en vanlig ordre.
Hvor stor % er andel ordre som er avvikende i forhold til vanlige ordre. Med dette mener vi antall hasteordre (i prosent) i forhold til totalen av ordre. MERK: Hopp over hvis du ikke har tall.

Your answer

Har du noen kommentarer til spørsmål/svar?

Your answer

8. Returgrad: Hva er %-andel av ordre som kommer i retur.
Her skiller vi ikke mellom årsaker til returen. MERK: Hopp over hvis du ikke har tall.

Your answer

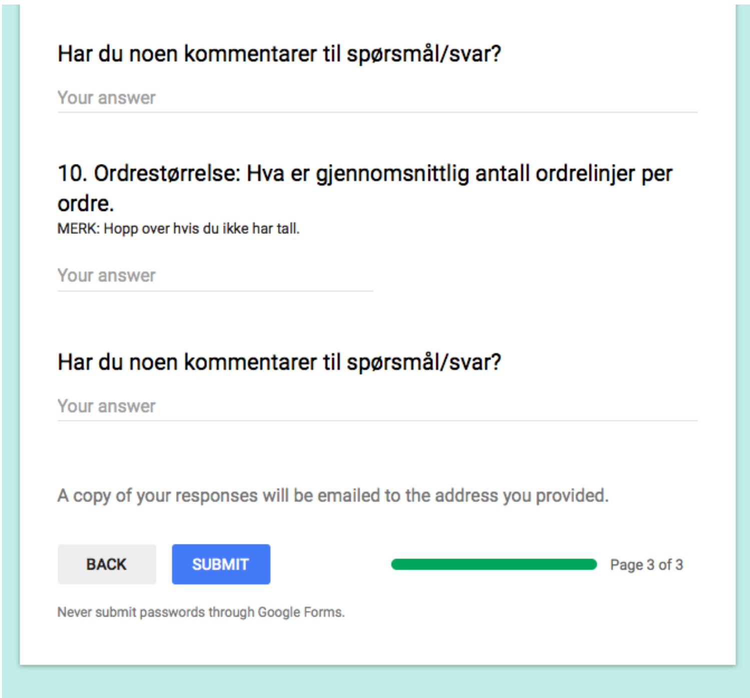
Har du noen kommentarer til spørsmål/svar?

Your answer

9. Fyllingsgrad: Hva er %-andel av total kapasitet som er benyttet på lageret.
Med dette mener vi antall tilgjengelige lagerplasser målt mot antall lagerplasser med varer i. Her skiller vi ikke mellom plukkplasser og bufferplasser, da vi er ute etter den totale fyllingsgraden. MERK: Hopp over hvis du ikke har tall.

Your answer

Har du noen kommentarer til spørsmål/svar?


Har du noen kommentarer til spørsmål/svar?

Your answer

10. Ordrestørrelse: Hva er gjennomsnittlig antall ordrelinjer per ordre.

MERK: Hopp over hvis du ikke har tall.

Your answer

Har du noen kommentarer til spørsmål/svar?

Your answer

A copy of your responses will be emailed to the address you provided.

BACK SUBMIT Page 3 of 3

Never submit passwords through Google Forms.

List of References

Avital, Oded. 2015. "Effectiveness, efficiency, and productivity - what do they mean? ." Last Modified 4th of September 2015, accessed 4th of September. https://www.knowmail.me/blog/effectiveness-efficiency-and-productivity-what-do-they-really-mean/.

Banker, R.D., A. Charnes, and W.W Cooper. 1984. "Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis " *Management Science* 30 (9):1078-1092.

Benicio, Juliana, and Joâo Carlos Soares de Mello. 2015. "Productivity Analysis and Variable Returns of Scale: DEA Efficiency Frontier Interpretation " *Science Direct* Procedia Computer Science 55:341-349.

Berg, J. P. van den, and W. H. M. Zijm. 1999. "Models for warehouse management: Classification and examples." *International Journal of Production Economics* 59 (1):519-528. doi: https://doi.org/10.1016/S0925-5273(98)00114-5.

Charnes, A, W W Cooper, and E Rhodes. 1978. "Measuring the Efficiency of Decision Making Units " *European Journal of Operational Research* 2 (6):429.

Cooper, W.W ; , L.M ; Seiford, and K Tone. 2007. "The Basic CCR Model " In *Data Envelopment Analysis A Comprehensive Text with Models Applications, References and DEA-Solver Software*, 22. Springer US.

Cooper, William W., Lawrence M. Seiford, and Joe Zhu. 1962. "Handbook on Data Envelopment Analysis " In, ed William W.Cooper, Lawrence M. Seiford and Joe Zhu. Springer New York Dordrecht Heidelberg London Springer. International Series in Operations Research & Management Science https://books.google.no/books?id=fBbrAjpSpLYC&pg=PA41&lpg=PA41&dq=Cooper,+W.+W.,+Seiford,+L.+M.,+%26+Zhu,+J.+(2011).+Handbook+on+data+envelopment+analysis+(Vol.+164):+Springer+Science+%26+Business+Media.&source=bl&ots=vbgx9pJB3T&sig=nrgfOpkEoOjChEsfHQ9YLlcqZIM&hl=no&sa=X&ved=0ahUKEwjlpOTbn8HaAhWU0aYKHWUbAx8Q6AEINzAC#v=onepage&q=Cooper%2C%20W.%20W.%2C%20Seiford%2C%20L.%20M.%2C%20%26%20Zhu%2C%20J.%20(2011).%20Handbook%20on%20data%20envelopment%20analysis%20(Vol.%20164)%3A%20Springer%20Science%20%26%20Business%20Media.&f=false.

Davis, Peter S, and Timothy L. Pett. 2002. "Measuring Organizational Efficiency and Effectiveness,." *Journal of Management Research* 2 (2):87-97.

Ekse, Steinar. 2013. "Næringskoder i enhetsregisteret ". Registerenheten i Brønnoysund http://hotell.difi.no/?dataset=brreg/naeringskode.

Emrouznejad, Ali, and Guo-liang Yang. 2018. "A survey and analysis of the first 40 years of scholarly literature in DEA: 1978–2016." *Socio-Economic Planning Sciences* 61:4-8. doi: https://doi.org/10.1016/j.seps.2017.01.008.

Farrell, M.J. 1957. "The Measurement of Productive Efficiency." *Journal of the Royal Statistical Society. Series A (General)* 120 (3):253-290.

Ford, Jeffrey D, and Deborah A Schellenberg. 1982. "Conceptual Issues of Linkage in the Assessment of Organizational Performance." *Academy of Management. Academy of Management Review* 7 (000001):49.

Forvalt, Proff. "Utvidet firma- og regnskapsinformasjon ". Proff Forvalt https://www.forvalt.no/foretaksindex2/Default.aspx

Fugate, Brian S;, John T; Mentzer, and Theodore P Stank. 2010. "Logistics Performance: Efficiency Effectiveness, and Differntiation." *Journal of Business Logistics; Hoboken* 31 (1):43-VII.

Gaither, Norman, and Greg Frazier. 2002. "Supply Chain Management and E-Business." In *Operations Management* edited by Jr Charles McCormick, 241. United States of America South-Western, Thomson Learning
Gergova, Iva. 2010. "Warehouse improvement with Lean 5S - A Case study of Ulstein Verft AS." Master Master, Logistics Molde University Brage.bibsys.
Griffis, Stanley E, Martha Cooper, Thomas Goldsby, and DAvid J Closs. 2004. "Performance Measurement: Measure SElection Based Upon Firm Goals and Information Reporting Needs." *Journal of Business Logistics; Hoboken* 25 (2):95-118.
Gu, Jinxiang, Marc Goetschalckx, and Leon F. McGinnis. 2010. "Research on warehouse design and performance evaluation: A comprehensive review." *European Journal of Operational Research* 203 (3):539-549. doi: https://doi.org/10.1016/j.ejor.2009.07.031.
Hackman, Steven T, Edward H. Frazelle, Paul M. Griffin, Susan O. Griffin, and Dimitra A. Vlasta. 2001. " Benchmarking Warehousing and Distribution Operations: An Input- Output Approach." *Journal of Productivity Analysis* 16 (1):79-100.
Hamdan, Amer, and K. J. Rogers. 2008. "Evaluating the efficiency of 3PL logistics operations." *International Journal of Production Economics* 113 (1):235-244. doi: https://doi.org/10.1016/j.ijpe.2007.05.019.
Hox, J.J , and H.R Boeije. 2005. "Data collection, primary versus secondary " In *Encyclopaedia of Social Measurement* 593-599. San Diego Acadeic Press Original edition, Elsevier
Ishizaka, Alessio, and Philippe Nemery. 2013. Multi-Criteria DEcision Analysis: Methods and Software EbookCentral ProQuest: John Wiley & Sons, Incorportaed.
Ji, Y. , and C Lee. 2010. "Data Envelopment Analysis." *The Stata Journal* 10 (2):267-280.
Johnson, Andy, Wen-Chih Chen, and Leon F. McGinnis. 2010. "Large-scale Internet benchmarking: Technology and application in warehousing operations." *Computers in Industry* 61 (3):280-286. doi: https://doi.org/10.1016/j.compind.2009.10.006.
Kotler, Philip, and Kevin Lane Keller. 2016. "Markedsføringsledelse." In *Marketing Management* 55-56 Perason Education i-nc. .
Mahoney, Thomas A. 1988. "Productivity Defined: The Relativity of Efficiency, Effectiveness, and Change " In *Productivity in organizations*, 13-39 United States of America: Jossey-Bass Publishers.
Mentzer, John T., and Brenda Ponsford Konrad. 1991. "An Efficiency/Effectiveness Approach to Logistics Performance Analysis " *Jounral of Business Logistics* 12 (1):33-62.
More, Ms. Sneha Vishnu. 2016. "The study of Efficiency and Effectiveness of Warehouse Management in the context of Supply Chain Management." *International Journal of Engineering Technology, Managment and Applied Sciences* 4 (8):160-169.
Network, Global Benchmarking. "Types of Benchmarking ". http://www.globalbenchmarking.org/benchmarking/types-of-benchmarking/.
Ostroff, Cheri, and Neal Schmitt. 1993. "Configurations of Organizational Effectiveness and Efficiency." *Academy of Management Journal* 36 (6):page 1345.
Richards, Gwynne. 2014. *Warehouse Management - A complete guide to improving efficiency and minimizing cost in the modern warehouse* Second Edition ed. Great Britain and the United States Kogan Page Limited
Ting, Ching-Jung, and Hsueh-Lin Fang. 2010. Using Data Envelopment Analysis to Evaluate the Performance of Third Party Distribution Centers.
Webster, Merriam. 2018 Benchmark In *Merriam Webster*.

Wong, Wai Peng , and Kuan Yeu Wong. 2008. "A review on benchmarking of supply chain performance measures " *Bradford* 15 (1):25-51. doi: http://dx.doi.org/10.1108/14635770810854335.