Lund University
Lund Institute of Technology

SCHENKER
Stinnes Logistics

Master Thesis:

Schenker's Box Handling Processes for Dell Computers at a Cross-Docking Centre in Copenhagen.

A Simulation Study

2002-05-27

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Abstract

The 17th September 2001 the distributor Schenker started to cooperate with the computer systems manufacturer Dell to deliver Dell's products to the Nordic market. In the beginning of a new cooperation new processes are formed and they are often developed to solve the local, immediate problems without considering the overall picture.

In the distribution network from Dell's plants in Ireland and Holland to the Nordic customers, the cross-docking centre in Copenhagen is a central part as a hub in the network. Almost all boxes are distributed through this hub in order to be sorted to one of the nine split point destinations located in Norway, Denmark, Sweden or Finland.

In order to improve the packet handling and the effectiveness at the cross docking centre in Copenhagen different scenarios have been developed with the simulation tool AutoMod[1] within the boundaries of this master thesis. On the basis of the simulation models various changes and how they affect the flow have been studied in order to find a packet handling that improves the effectiveness at the cross-docking centre.

Eight different models have been studied. One original model that shows how the material flow is working today, three basic models that include one alteration each in comparison to the original model and four models that include all possible combinations of the basic models. Today the cross-docking process is divided in three sub processes, one for each of the box sizes; small, medium and large. Only the medium sized boxes can use the sorting conveyor while the small and large boxes are scanned, sorted and transported manually. The basic models are:

- The Värnamo model, which, via an extra conveyor, enables a faster cross-docking of the boxes that are going to the split-point in Värnamo, Sweden.
- The Single Process model, where *all boxes* are sorted by the conveyor.
- The RFID[2] model, where all scanning of the boxes is made automatically.

The flow of Dell's computers from Ireland to the Nordic market has been studied but only the cross-docking centre in Copenhagen has been modelled in Automod. That means that the manufacturing sites and the transport ways have not been included in the model. The different models' cross-docking time and need of resources have been compared, but no thorough comparisons between the costs of the different packet handling strategies have been made.

The *Original model* is somewhat optimized to the basic conditions that are equal for all the models. Therefore the original model handles the competition from the other models well in terms of cross-docking time. On the other hand several of the new models require less resources and by that holds potential to enhance their performance.

In a short-term point of view it is realistic to implement the *Single Process model* if it is possible to increase the velocity of the conveyor and do a complete identification of the new bottlenecks that will arise. The model uses four resources less than the original model but gives a longer cross-docking time due to that only one truck is unloaded at a time. A great advantage by loading all boxes on the conveyor is that the cross-docking process is equal for all box sizes.

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[1] See Section 3.1.2 for a presentation of the software Automod

[2] Radio Frequency Identification.

The *RFID model* has the best performance of all simulation models and uses five resources less than the original model. Today the technology for RFID is too expensive and the performance is not good enough, but when the day comes that the price and performance on RFID is at a realistic level, the organisation and the technologies should be prepared for the RFID technology.

In a long-term point of view the *RFID-Single Process combination* is the future for the cross-docking centre. One process for all box sizes and automatic radio frequency scanning ensures that the human errors will decrease dramatically. The potential in increasing the velocity on the conveyor and reducing the cross-docking time even more seems to be good.

The *Värnamo model* uses one more resource and has the same cross-docking time as the Original model. All combinations involving the Värnamo concept can therefore be discarded. The adding of an extra conveyor cost money and does not result in higher capacity.

Acknowledgements

This Master thesis is an obligatory final examination at the Master of Science in Mechanical Engineering at the Lund Institute of Technology in Sweden.

Our Master Thesis is a simulation study at Schenker's cross-docking centre in Copenhagen. Eight simulation models have been developed, tested and analysed to evaluate future box handling strategies.

This study could not have been done without the help of the employees at Schenker, our fellow students and the employees at Lund Institute of Technology. We would especially like to thank consultant Andy Grumbt, Dell Department Manager Martin Carlsen at Schenker A/S, Hub Manager Peter Skermer at Schenker A/S, IT Associate Mattias Olofsson at Schenker AG and PhD Student Daniel Hellström at Lund Institute of Technology.

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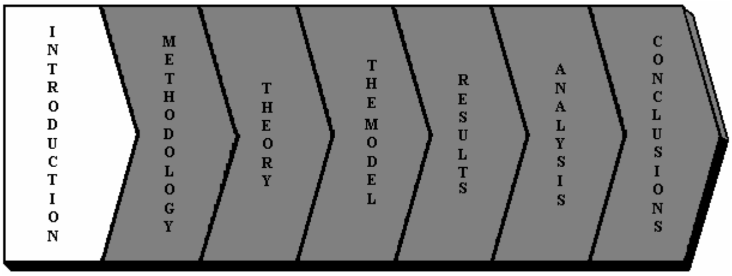

Of a good beginning cometh a good end.

John Heywood (1497–1580)

1 Introduction

In this introduction chapter the background and the basic conditions for the report are explained. The studied companies, the problem statement, the objectives, the limitations and the outline of the report are presented.

1.1 Background

The 17th September 2001 Schenker started the cooperation with Dell to deliver their products to the Nordic market. In the beginning of a new cooperation there are always problems to overcome. It is of immense importance that both companies are certain about what their responsibilities are in the cooperation. New processes are formed and they are often developed to solve the local, immediate problems without considering the overall picture

In the distribution network from Dell's plants to the Nordic customers the cross-docking centre in Copenhagen is a central part as a hub in the network. Almost all boxes are distributed through this hub in order to be sorted to one of the nine split point destinations situated in Norway, Denmark, Sweden or Finland.

Dell manufactures the computers (CPU:s) in Limerick, Ireland. Other computer components, like the screen and keyboard, are bought from suppliers. The CPU:s are loaded on a transport vehicle which then travels to a warehouse in Limerick where other components are loaded on the truck. Collies with the components are then sent to Schenker's cross-docking centre in Copenhagen. There the collies will be consolidated into complete orders, deliveries that are to be sent to split points in Värnamo (Sweden), Helsingborg (Sweden), Helsinki (Finland), Glostrup (Denmark) and Oslo (Norway). See *Figure 1.1*.

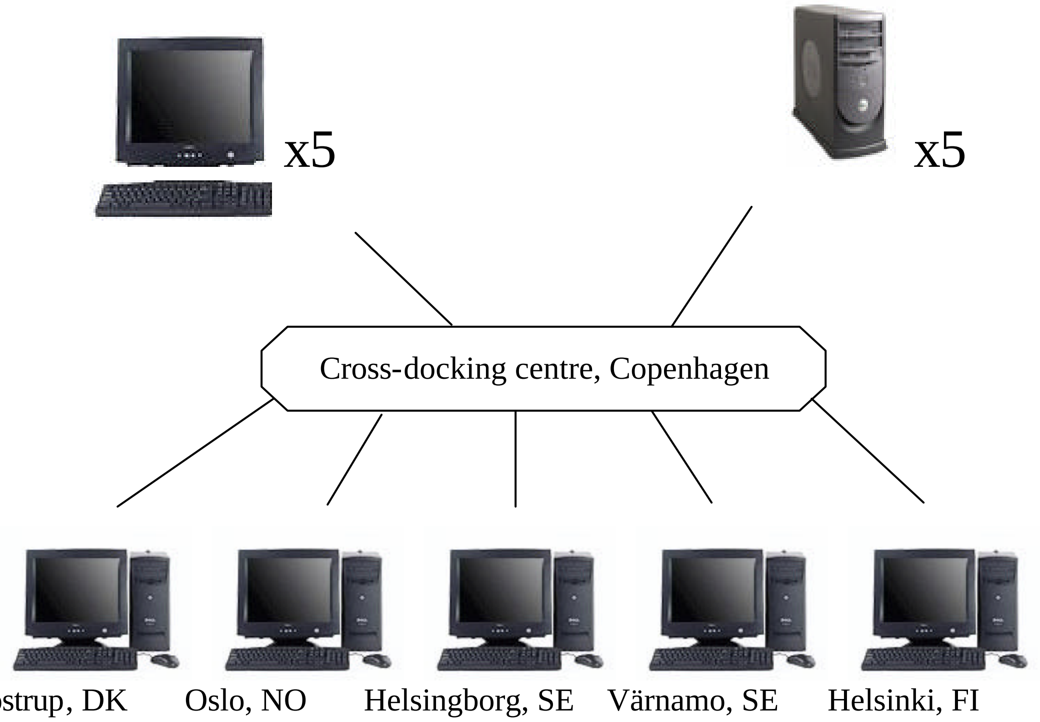

Figure 1.1 The Flow of Computer Components from Ireland and Holland to the Nordic Market.

In reality the consolidation is not always performed immediately in Copenhagen. If the production of, for example, the CPU:s is lagging the production of the other components, those components will be stored in Copenhagen to await the CPU:s. This causes an increased need of storage room, decreased effectiveness and decreased flexibility. The purpose of a cross-docking centre is to sort incoming goods and, as fast as possible, send it on to next hub in the supply chain. It is not a warehouse and no goods should stay in the centre longer than necessary. The shorter cross-docking time in the cross-docking centre, the better conditions for a shorter total lead time in the supply chain.

Simulation can be introduced to test processes and develop them to make them faster, more predictable, easier and cheaper. A simulation software makes it possible to forecast and study scenarios when changes are introduced in existing activities. This will reduce uncertainty and can also be a tool for optimizing future changes in activities or implementing new technologies.

This study is focused on Schenker's cross-docking centre in Copenhagen and uses the simulation software AutoMod[3] to simulate the impact of developed processes and new technology.

1.2 Company Introduction

1.2.1 Dell Computer Corporation

Dell Computer Corporation is headquartered in Austin, Texas and has approximately 40,000 employees around the world. The company was founded by Michael Dell in 1984 and is now No. 2 worldwide in market share among computer systems companies. Dell's concept is to sell personal computer systems *(see Figure 1.2)* directly to customers without retailers. Instead the customers place their order on the Internet or by phone and get their computer delivered to their door. The computers are produced one at a time, as ordered, at facilities in USA, Brazil, Ireland, Malaysia and China.[4] Dell does not manufacture computer components, instead they use components that are available on the market. This reduces their need of research and development and owning assets. Dell's so called direct business model reduces the cost of inventory and the reselling expenses greatly. Another benefit is that they deal directly with the customer and therefore receive valuable information about customer behaviour.[5]

Figure 1.2 A Computer System from Dell[6]

[3] See Section 3.1.2 for a presentation of the software AutoMod
[4] www.dell.com, 2002-02-04
[5] Designing and Managing the Supply Chain, 2000.
[6] www.dell.com, 2002-02-04

1.2.2 Schenker

Schenker was founded in Vienna almost 130 years ago and is now a leading international provider of integrated logistics services. The company has nearly 32 000 employees at 1000 locations all over the globe and specialise in land transport (*see Figure 1.3*) but also provide worldwide air and sea freight, and all the associated logistics services. Schenker is a part of the logistics enterprise Stinnes AG.[7] In the year 2000 Stinnes achieved sales of approximately 6 billion euro, of which 3.2 billion were generated by the European land transports unit. Schenker and their main competitor Danzas both have a market share of 2.3 percent of the land transport market in Europe and by that they share the first place. The number three on the list, Geodis only has a 1.4 percent market share.[8]

Schenker-Sweden is with its 4000 employees Sweden's largest transport and logistics provider. Along with its Norwegian and Danish equivalents Schenker-BTL AB constitutes the region Northern Europe within the Schenker group. Schenker-BTL AB's main customers are industrial and trade companies of large or medium size.[9]

Figure 1.3 A Land Transport vehicle from Schenker[10]

[7] www.schenker.com, 2002-02-04
[8] LOGISTICS - The Stinnes magazine
[9] Nova, Schenkers Intranet, 2002-02-01
[10] Nova, Schenkers Intranet, 2002-02-01

1.3 Problem Statement

Approximately one million boxes per year are handled at the cross-docking centre in Copenhagen. The large amount of boxes means that only a small reduction of the cross-docking time can results in great savings. It is therefore of great importance to study what different packet handling strategies will entail.

The packet handling and the effectiveness at the cross docking centre in Copenhagen must continuously be improved. In order to do so different scenarios will be developed with the simulation tool AutoMod within the boundaries of this master thesis. On the basis of the simulation models various changes and how they affect the flow and the cost will be studied.

1.4 Limitations

The flow of Dell's computers from Ireland to the Nordic market will be studied but only the cross-docking centre in Copenhagen will be modelled in Automod. The manufacturing sites and the transport ways will not be included in the model.

The different models' cross-docking time and need of resources will be compared, but no thorough comparisons between the costs of the different packet handling strategies will be made. Schenker can later estimate which investment, if any, that is the most efficient for the processes.

1.5 Objectives

This master thesis' objective is to find a packet handling that improves the effectiveness at the cross-docking centre in Copenhagen. The packet handling will be visualised with the simulation software Automod in order to demonstrate the software for Schenker and improve the understanding of the packet handling process.

1.6 Outline

This report can be divided into four major parts, first an introduction chapter where the background of the report is explained. The second part is a frame of reference, where the report's methodology and theory is described. Two empirical chapters follow the frame of reference. Here our model and the results of the simulations are shown. The last part of this report analyses the result and conclusions are drawn. *See Figure 1.4.*

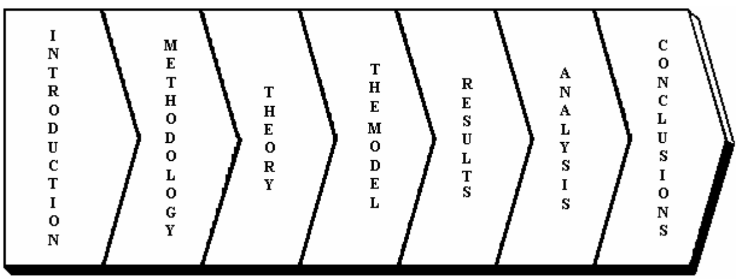

Figure 1.4 The outline of the report

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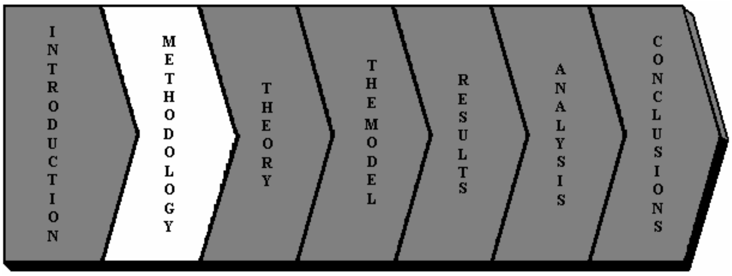

Methodology gives those with no ideas something to do.

Mason Cooley (b. 1927), U.S. aphorist

2 Methodology

In this methodology chapter different research approaches are described followed by an explanation to why we have chosen the respective approaches. The chapter is concluded with a description of the proceeding of this report.

2.1 Research Traditions - Positivism, Hermeneutics and Systems Theory

A main characteristic within **positivism** is the believe in scientific rationality. All knowledge must be empirically tested and judgements and estimates must be replaced by measurements. If the knowledge cannot be tested empirically, like feelings or values, then it is not scientific knowledge. Explanations to, for example, the behaviour of a model is made in terms of *action* and *reaction*. According to positivism the collected data must be tested so that it is valid and reliable. Read more about the terms valid and reliable in chapter 2.5.[11]

Positivism does not consider feelings and values to be scientific knowledge. But sometimes knowledge that is not empirically testable has to be studied and then the **hermeneutic** approach is useful. Here the *meaning* of texts, symbols and actions is interpreted and analysed, often with psychological theories.[12]

A system is a group of object that interact to accomplish a purpose.[13] The system as a whole has other properties than what you would find in the parts. **Systems theory** is used to study and understand, but also to plan for change, in complex connections as organising and planning of activities.[14] Since the system's environment often affects the system it is important to define the systems limits and structure.[15] [16] The interaction between the parts of the system is also an important segment to study.[17]

Systems theory and positivism have a lot in common. Both focus on empirical studies but where positivism focus on *action and reaction*, systems theory focus on the *interaction* between objects.[18]

In this report we will mainly use systems theory and a positivistic approach. In order to be simulated all actions must be quantified and measured and therefore these approaches suit us best.

[11] Vetenskapsteori och forskningsmetodik, 1996
[12] Vetenskapsteori och forskningsmetodik, 1996
[13] Discrete-Event System Simulation, 1996
[14] Vetenskapsteori och forskningsmetodik, 1996
[15] Discrete-Event System Simulation, 1996
[16] Vetenskapsteori och forskningsmetodik, 1996
[17] Vetenskapsteori och forskningsmetodik, 1996
[18] Vetenskapsteori och forskningsmetodik, 1996

2.2 Quantitative and Qualitative Methods

Quantitative studies, and their conclusions, are based on data that can be quantified. Qualitative studies are based on data that cannot be quantified, such as attitudes, values and feelings.[19]

In quantitative studies you use *systematic* observations and focus on what is *common and representative* to describe and *explain* phenomenon. In qualitative studies you use *unstructured* observations and focus on what is *unique and deviant* to describe and *understand* phenomenon.[20]

To choose between a quantitative or qualitative method you study the problem statement. Often a combination between the methods is a preferred choice. This can result in a more balanced picture and a more complete theory but it can also result in the opposite.[21]

Since this report use "hard data" and is not interested in feelings we will use a qualitative approach. Data will be collected and made general by statistic methods that will eliminate deviant data.

2.3 Models

A model is an intentional simplification of a phenomenon in order to examine and explain this phenomenon. Since a model is a simplification and an idealisation it is also always theoretical.[22] It can be practical to use *a model* of a system instead of the *actual* system for experiments, since experimenting with the system itself is not always possible. The system that is going to be evaluated may not yet exist or experimenting with it can be impractical in other ways.[23]

Simulation models are classified as mathematical models and can be further classified as static or dynamic, deterministic or stochastic and discrete or continuous. A *static* simulation model is a "snapshot" of a system at a specific time while a *dynamic* model simulates a changing system. A *deterministic* model contains no random variables and since the input is not random the output is always the same no matter how many times you run the model. A *stochastic* model, on the other hand, has random input and will therefore result in random output. Since the output is random all result must also be considered as estimates of the real system characteristics. In a *discrete* model the variables change at a discrete set of points in time while in a *continuous* model the variables change continuously.[24]

A dynamic, stochastic and discrete model will represent the system studied in this report.

A high-quality model should be systematic, effective, valid and under some conditions general.[25] The term valid will be further explained in chapter 2.5.

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[19] Utredningsmetodik för samhällsvetare och ekonomer, 1999
[20] Forskningsmetodik, 1997
[21] Forskningsmetodik, 1997
[22] Vetenskapsteori och forskningsmetodik, 1996
[23] Discrete-Event System Simulation, 1996
[24] Discrete-Event System Simulation, 1996
[25] Vetenskapsteori och forskningsmetodik, 1996

2.4 Data Collection

Data collection is an essential, and difficult, part of a simulation. If the input data is of low quality then no model, no matter how well structured and valid the model is, can produce high quality output. The basic computer science rule "SISO" applies. Shit In generates Shit Out.[26]

To build our model we have to primarily rely on secondary data. The data will be received via Schenker's internal data system, COS. When needed secondary data is not directly available primary data will be collected trough direct observation.

When an observer is present in a certain situation his presence may influence the behaviour of the people being studied so that they do not act as they normally would. When collecting data through direct observation the ideal is therefore to achieve a situation where the observer is hidden and do not disturb the observed persons. But it is not always practically possible to reach this ideal and also moral and ethic objections can be made against the ideal situation.[27]

2.5 Validity and Reliability

A model is *valid* when it does not contain any *systematic* errors i.e. that it studies what it is supposed to study.[28] The model must have relevant variables and relations shall be correctly displayed.[29] In chapter 3.3.2 we will describe how to validate a model.

A model is *reliable* when it does not contain any *random* errors i.e. that it gives the same result if the model is run a second time.[30] The result does not depend on who did the study or under which circumstances the study was made. Reliability is a basic condition for validity because a perfect model is worthless if it is used incorrectly.[31] The relation between validity and reliability is described in *Figure 2.1*.

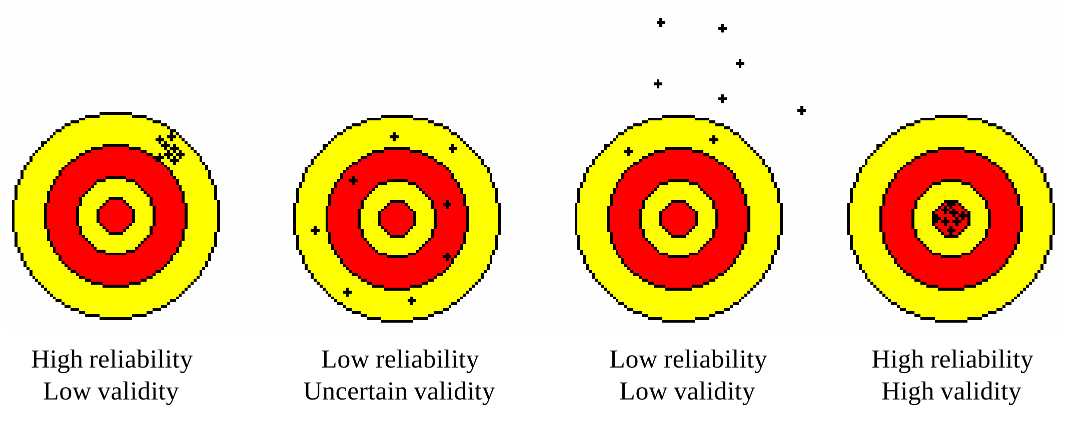


Figure 2.1 The relation between reliability and validity[32]

[26] Discrete-Event System Simulation, 1996
[27] Utredningsmetodik för samhällsvetare och ekonomer, 1999
[28] Utredningsmetodik för samhällsvetare och ekonomer, 1999
[29] Vetenskapsteori och forskningsmetodik, 1996
[30] Vetenskapsteori och forskningsmetodik, 1996
[31] Utredningsmetodik för samhällsvetare och ekonomer, 1999
[32] Utredningsmetodik för samhällsvetare och ekonomer, 1999

2.6 Steps in a Simulation Study[33]

See Figure 2.2. The first step in a simulation study is to define the **problem formulation**. There is a great difference if those who have the problem set the statement of the problem or if a simulation analyst sets it. In both cases the persons involved must be sure that the *real* problem is defined.

The collecting of **data,** the building of the **model** and the **coding** are essentially performed at the same time. This part of a simulation study is not a linear process. The model builders will in an iterative mode collect new data and revise the model while coding. Initially a basic model is built and is then gradually developed until a model of appropriate complexity is created.

Verification is needed to determine whether the operational model is performing in the way it is supposed to do. Further information about verification is given in chapter 3.1.3.

Through **validation** the conceptual model is controlled so that it is an accurate representation of the real system, if there is a real system to compare with. Read more about validation in chapter 3.1.3.

Which length of the simulation run? How many runs are necessary? Those issues are considered in the **experimental design**.

Model runs and analysis are used to estimate relevant measures of performance for the scenarios that are to be studied.

Documentation is necessary for further work with the simulation model and must also be complete so that the client understands how the simulation model operates.

If the simulation study is correctly done it will ensure a smooth **implementation** and foremost that it is a suitable solution of the problem.

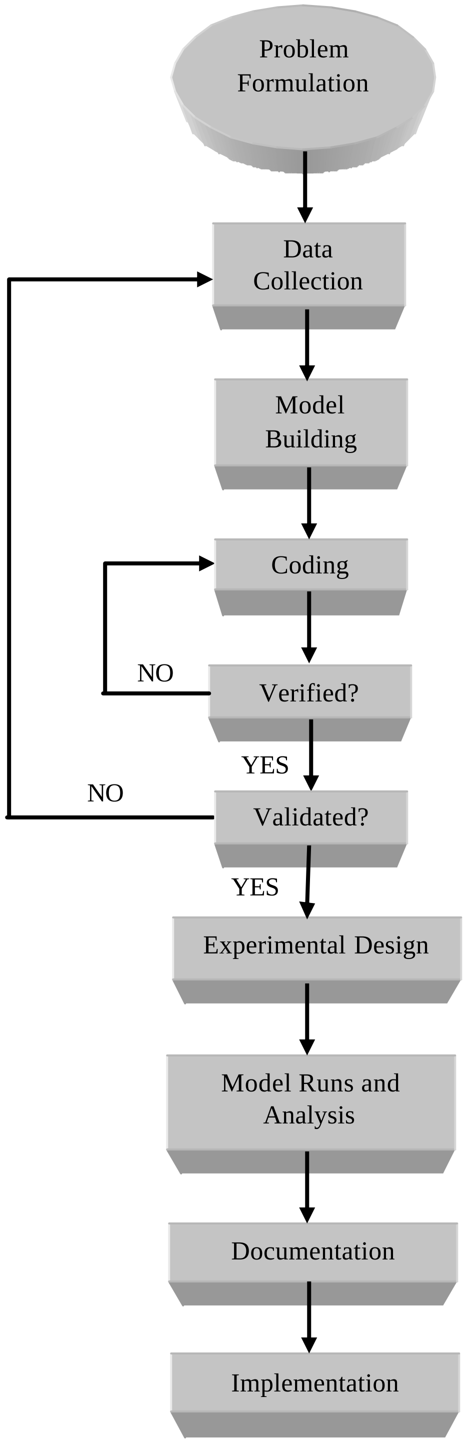


Figure 2.2 Steps in the Simulation Process.[34]

[33] Discrete-Event System Simulation, 1996
[34] Getting Started with AutoMod, 2000

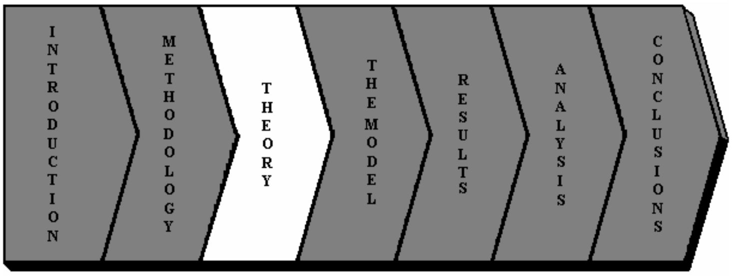
2.7 Method

Initially the flow of components, from Ireland and the Netherlands to the split points, was mapped out. Then a model based on how the flow works today was produced in the simulation software Automod. This original model is based on registered data, interviews, timing and measuring. The arriving trucks with boxes from Dell were first analysed through compiling registered data from Schenker's data system COS and notes from the cross-docking centre. This gave insight to what kind of boxes a truck usually is loaded with. Timing was done for scanning processes, box handling, forklift processes and wrapping of pallets. Measuring of the premises was primarily done for velocity calculations and for a natural reshaping of the cross-docking-centre in the models. Interviews with the personnel gave the possibility to check the reliability and validity of the input data.

Developed simulation models were constructed and compared with the original model. Three alternative basic models and combinations of them were built and analysed. These models are based on the original model's performance but are also redone in the processes and/or the physical structure in the cross-docking centre.

The input data in the models are how many trucks that will arrive to the cross-docking centre. In the comparing process between the models there will be two, four and six trucks arriving to the centre. Output data received are how much time the models require to be finished with all boxes at one shift i.e. the total cross-docking time. The models have been compared on two different aspects, the time and amount of resources required.

III



No theory is good except on condition that one use it to go on beyond.

André Gide (1869–1951), French author

3 Theory

This theory chapter explains various aspects of simulation, statistics and logistics used later in the empirical and analytical chapters of this report.

3.1 Simulation Theory

3.1.1 Computer Simulation

Computer simulation is the imitation of a real-world process or system, often over time, to conduct numerical experiments. The simulation is done to create a better understanding of the behaviour of the imitated system for a given set of conditions. Simulation is often the preferred method to study the system because of the possibility to simulate complex systems. Other methods can require stronger simplifications, which can bring the validity of the model into question. If you oversimplify a complex reality into a simplistic model it will not be valid and you will get nice and simple answers to the wrong questions.[35,36]

3.1.2 The Software

To build the model and to simulate the flow of components the software Automod is used. Automod has a powerful material-handling simulator that is combined with general purpose programming features. To analyse the results of the simulation the software Autostat can be used. Autostat is integrated with Automod and provide general statistical features such as confidence interval generation and simulation warm-up capability. A company called AutoSimulations, Inc develops Automod and Autostat.[37]

The simulation structure that is employed when you are using the simulation software Automod is called the process-interaction method. In this method the software imitates the flow of objects through a system. The objects travel in the system until they are delayed; enter an activity or exits from the system. When the objects' movement is stopped temporarily, the clock advances to the time of the next movement of any object. The simulation thereby describes, in sequence, all of the states that the objects can reach in the system.[38]

3.1.3 Evaluation of the model

To ensure that the model is an accurate representation of the simulated system the model has to be evaluated. This can be done by verification and validation.

To determine that the model is performing *as designed*, that it has been built right, verification is made.[39]

The verification is facilitated if the logic file of the simulation model is well structured. Before coding it is therefore useful to do a top-down designed detailed plan of the simulation model and break down the simulation model into sub-models. It is of great importance that a detailed flowchart of the macro activities is visualised, especially when the problem is of a large and complicated nature. When reading the coded logic file it must be possible for anyone (that is familiar with the simulation software) to understand the function, without any other help than what is written in the file.

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[35] Simulation with Arena, 1998
[36] Getting Started with AutoMod, 2000
[37] Discrete-Event System Simulation, 1996
[38] Getting Started with AutoMod, 2000
[39] Discrete-Event System Simulation, 1996

Several persons should check the model code. Both *software techniques and code inspection* can be used. There are a couple of different software techniques that can review code in the simulation model. Code inspection means that a team (the modeller, the designer etc.) reviews the design and the model line by line.

Studying the input and output can also verify the model. Is the input data being used correctly? If input data is in minutes, and the model is using seconds, the model is inaccurate. The output data must also be controlled and questioned. For example if there are 140 loads queuing and it is believed to be around 20 loads there *could* be something wrong.[40]

Finally, illogical actions in the model can be detected simply trough watching the model. This is called sanity checking.[41]

To determine if the simulation model can *substitute the real system*, in order to make experiments, a **validation** is performed.[42] While verification was concerned with *building the model right*, validation is concerned with *building the right model*.[43]

A straightforward way to validate the simulation model is to let a person who is knowledgeable about the real system study the model. He can identify deficiencies and by eliminating these, the credibility of the model is enhanced.[44] This is one of the advantages with a model that is an animated computerised representation of the real system.[45]

Validation trough sensitivity-analysis is also a useful way to test the model. If the input is changed then the output should change in a predictable manner. If it does not, the model is inaccurate. A kind of sensitivity-analysis that can be used is to test the model under extreme conditions. How does it behave if the input data is at its extremes? Does the output reflect these extremes?[46]

3.1.4 Statistics

If enough data is collected, it usually shows some kind of statistical distribution. Statistical software, i.e. Matlab, is a useful tool to know which distribution that is suitable for a data quantity. One of the most well known distributions is the normal distribution (*Figure 3.1*). *Figure 3.1* also illustrates how the standard deviation affects the normal distribution. The standard deviation shows how irregular the analysed data are. A higher standard deviation results in a larger span and means that the values are more uncertain.

[40] Getting started with Automod, 2000
[41] www.autosim.com, Discrete Event, vol 12, nr 1, 2000
[42] Getting started with Automod, 2000
[43] Discrete-Event System Simulation, 1996
[44] Getting started with Automod, 2000
[45] Discrete-Event System Simulation, 1996
[46] Getting started with Automod, 2000

The normal density function $f_X(x)$ is:

$$f_X(x) = \frac{1}{s\sqrt{2p}} e^{-(\frac{(x-m)^2}{2s^2})}$$

(-8 < x < 8)

s = Standard Deviation
m = Mean Value

95 % of the samples are ±1.96*s from the mean value. [47]

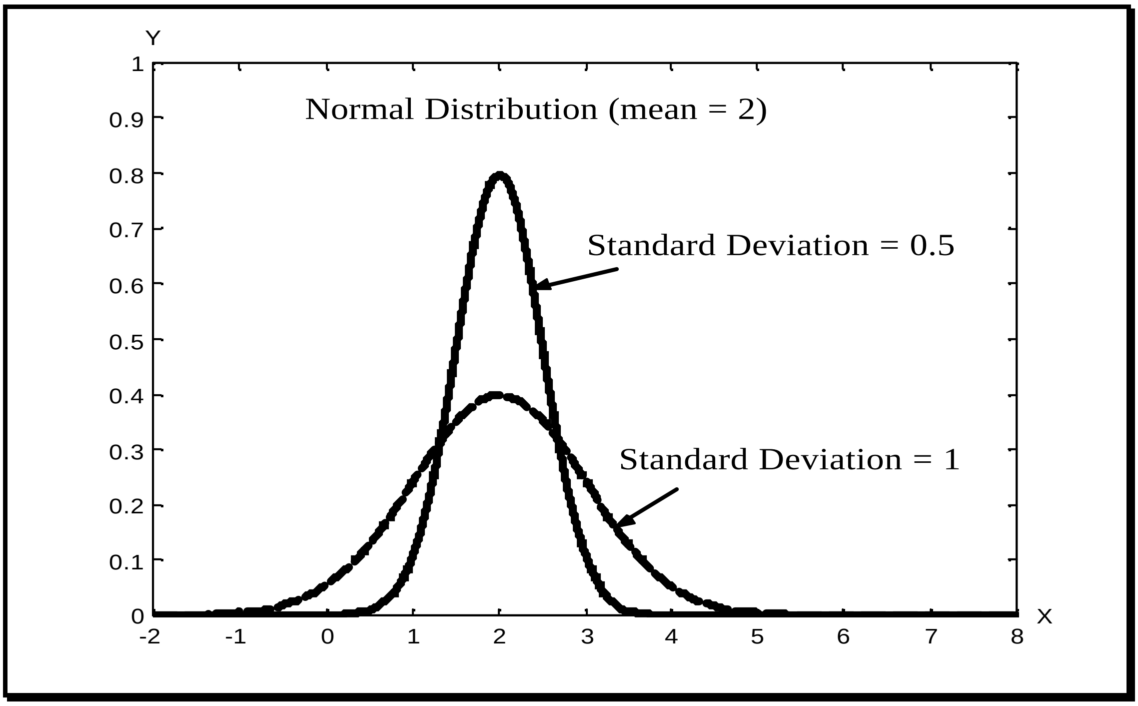

Figure 3.1 Different Types of Normal Distributions

The exponential distribution (*Figure 3.2*) is often used to simulate the time it takes for a human to perform a task like, for example, serving a customer. Often a combination of two exponential distributions is used for this purpose since the task that is to be performed often requires a minimum time. If, for example the mean of a serving time is two minutes the best way to simulate the distribution of it is to set it to two exponential distributions with the mean of one added to each other. [48]

[47] Sannolikhetsteori och statistisk teori med tillämpningar, 1989
[48] Georg Lindgren, University Professor of Mathematical Statistics at Lund Institute of Technology, 2000-09-28

The exponential density function is for the general case:

$$f_X(x) = \frac{1}{m} e^{-x/m}$$

If x = 0 and μ = mean value

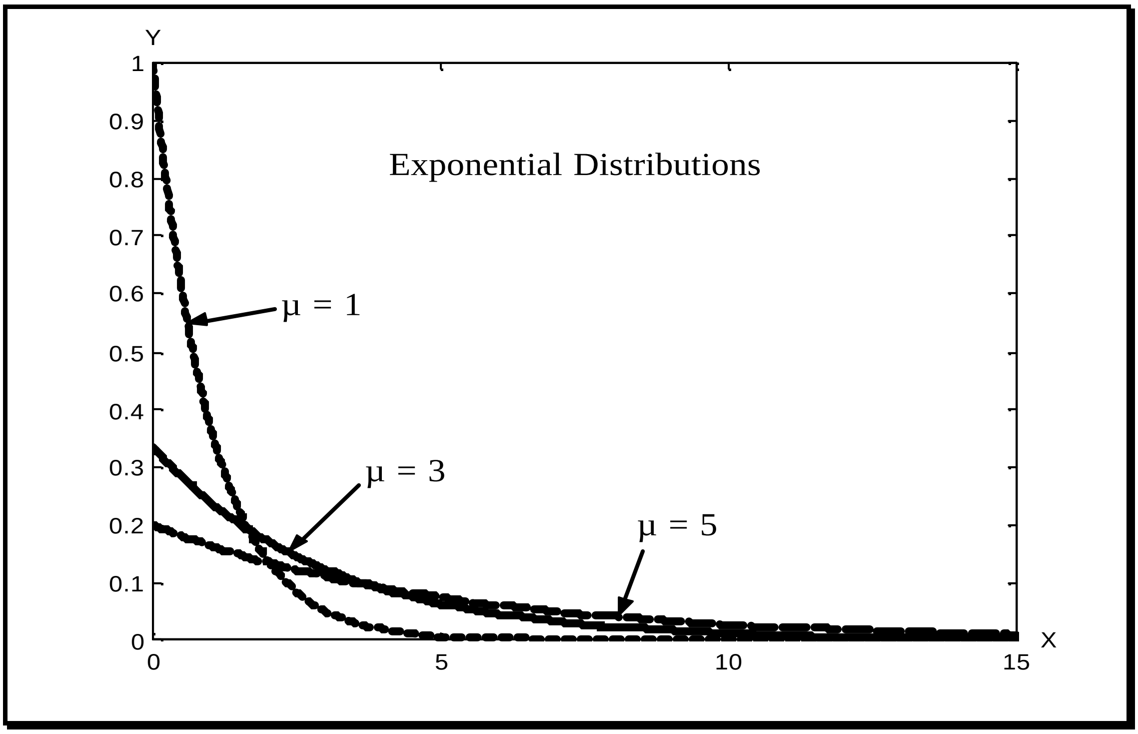

Figure 3.2 Exponential Distributions with Different Mean Values, μ.

Another distribution is the weibull distribution (*Figure 3.3*). The weibull density function, $f_X(x)$ is[49]:

$$f_X(x) = \frac{b}{a} (x/a)^{b-1} e^{-(x/a)^b}$$

If x = 0

When the constant b is 1 the weibull distribution becomes exactly like the exponential distribution. Note that the values can not be negative in the weibull distribution.[50]

[49] Sannolikhetsteori och statistisk teori med tillämpningar, 1989
[50] Sannolikhetsteori och statistisk teori med tillämpningar, 1989

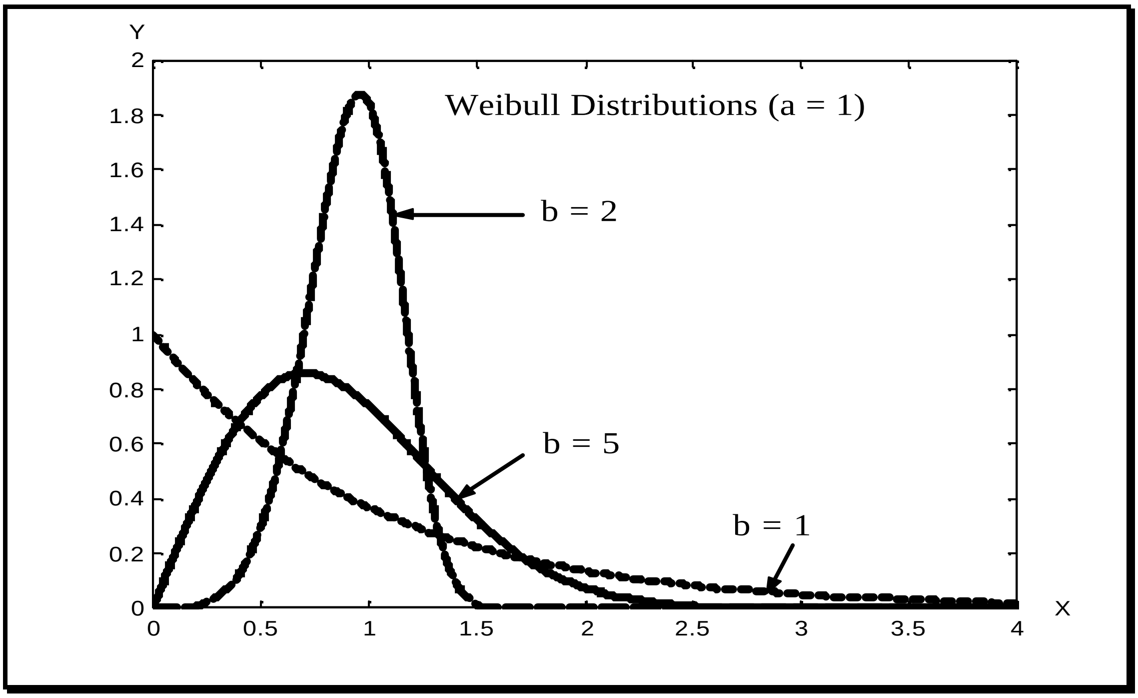

Figure 3.3 Different Types of Weibull Distributions

If the data selection is small, then a triangular distribution can bee a good approximation (*Figure 3.4*). It requires estimates of the minimum (L), maximum (U) and mean (μ) values. (D) in *Figure 3.4* is the most common value. [51]

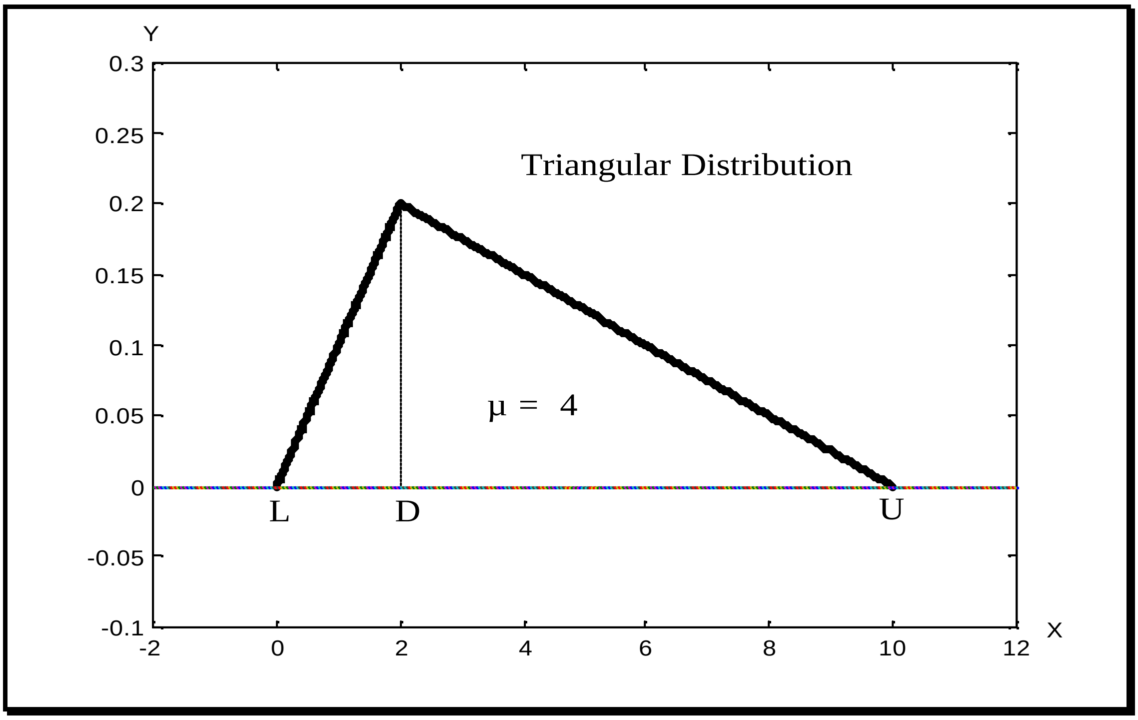

Figure 3.4 Triangular Distribution with Mean Value, μ = 4.

[51] Getting started with Automod, 2000

3.2 Logistics Theory

3.2.1 Cross-Docking

There are, typically, three different outbound distribution strategies. The first and most straightforward strategy is direct shipment; where items are shipped directly from the supplier to the retailer, see *Figure 3.5a*. In the second strategy, warehousing, the supplier uses warehouses to keep stock and provide customers with the required goods, see *Figure 3.5b*. Finally, the third strategy is called cross-docking, see *Figure 3.5c*. In this system, goods are distributed from the suppliers via warehouses, or cross-docking centres, to the customers. The warehouses works as an inventory co-ordination point rather than as inventory storage point and the goods often spend less than twelve hours in it. By decreasing the storage time the strategy limits inventory cost and decreases lead times[52].

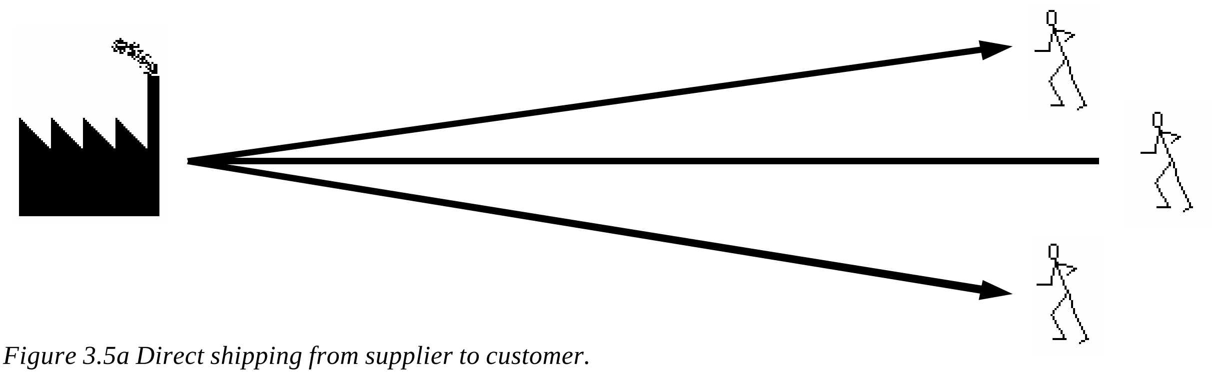

Figure 3.5a Direct shipping from supplier to customer.

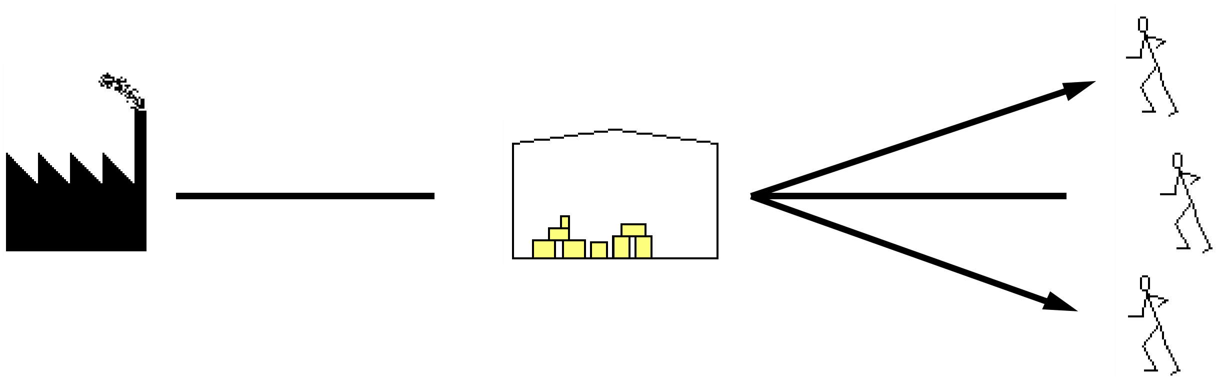

Figure 3.5b Warehousing. The goods is kept stock in a warehouse.

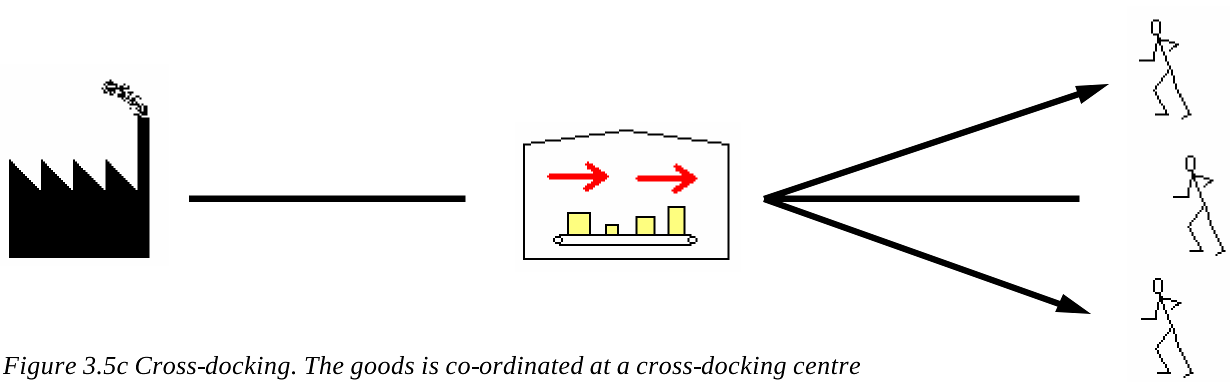

Figure 3.5c Cross-docking. The goods is co-ordinated at a cross-docking centre

[52] Designing and Managing the Supply Chain, 2000

In order to achieve an effective cross-docking operation more or less advanced equipment is needed, equipment like conveyor systems, barcodes, automatic barcode reading, systems for track-and-trace etc. It is fundamental that the information system is properly constructed and well functioning so that it can provide information about[53]:

- What is arriving to the cross-docking centre?
- How does it get there?
- When does it arrive?
- At what quantity?
- How is it identified?
- Where is it going after the cross docking?
- When is it sent on?
- What is the final destination and who is the customer?
- Is it fragile?

3.2.2 Postponement

In practice the concept of postponement can be traced back to the 1920's, but in the literature it was first proposed by Alderson in 1950. The idea with postponement is to reduce or eliminate the risk, cost and uncertainty that differentiation (form, place and time) represents. This is done through postponing of manufacturing and logistics operations until the final costumer commitments are recognized[54].

There are two types of postponement. The first is *geographic* postponement, which means that the *movement* of the product is postponed. This means that no unnecessary transports are done. The benefits are reduced levels of stocks and the negative effects are usually that costs for transports, information systems and production capacity increase. The second kind of postponement is that of the value added activities. In practise this means that *the finishing of the product is postponed*[55]. The final value added actions often starts after that the customer has decided which model it want to buy. A good example is Benetton Corporation that manufactures wool sweaters where the dyeing of the yarn is postponed. The dyeing is done after the sweater is completely assembled which enables a faster change to the market of the colours as the fashion is changing[56]. *See Figure 3.6.*

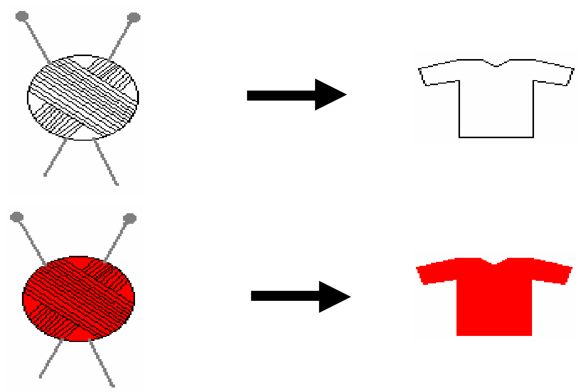

Figure 3.6a Sweater manufacturing without postponement.

[53] Logistikens grunder, 1998
[54] Journal of Businesses Logistics vol.19, No.2, 1998
[55] Logistik för konkurrenskraft, 1998
[56] Designing and Managing the Supply Chain, 2000

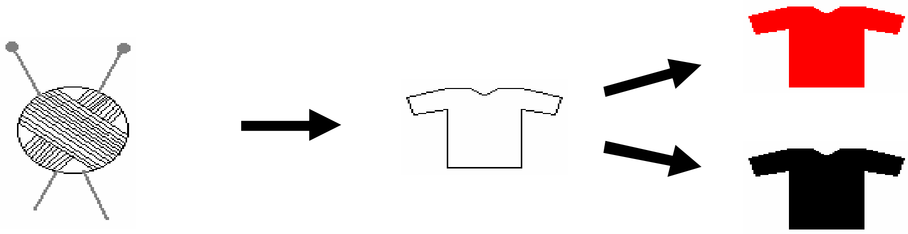

Figure 3.6b The Benetton manufacturing method with postponement.

3.2.3 Third Party Logistics

Until the 1990's most companies ran their own fleet of trucks and had plenty of storage capacity. Constantly well-filled warehouses enabled a steady supply of materials to the production lines. To reduce the quantity of cost intensive warehouses that tied up capital resources the companies had to redesign their production processes so that they reacted more rapidly to change. The companies' supply chain often did not fit the new strategy so many companies decided to outsource their logistics processes.[57]

Third Party Logistics means that companies, except from the ordinary transports, buy external services to accomplish logistic activities, for example warehousing, pricing, order handling etc. These services are characterised by a daily and intensive cooperation, which is supposed to be a winning concept for all parts involved. The third party logistic company take over some of the costumer's logistic activities or entire processes in the supply chain, that earlier were within the costumer's company. This means that the third party logistic provider owns these processes, but not the product. [58] [59]

The main reason why the costumer company's logistic activities are outsourced are that the company want to concentrate on their core activity. The advantages that will occur are shorter lead times and more consumer adapted and flexible service. This solution is most suitable for companies with a global supply chain, which have a high degree of complexity. Some other advantages for the costumer are the third party logistic provider's knowledge, recourses, new technologies and scale advantages that don't exist in the costumer company. Fixed costs are transformed to flexible costs and the need of employees and costs for logistics are decreased. Income can increase and the company is given the opportunity to mobilise capital when the need of investing is decreasing. [60] [61] [62]

The disadvantages in outsourcing the logistics are, among others, that the company loose the contact with its costumers; the risk of being depending on the third party logistic provider increase and the control of some processes within the company is lost. In some cases when the logistics is outsourced the transportation costs increases, but it often results in a higher degree of service. Initially the logistic co-operation can lead to increased costs because of the new situation for the employees and duplicated resources. [63]

[57] LOGISTICS – The Stinnes magazine 3/2001 Volume 11
[58] Tredjepartslogistik i svensk industri – En kartläggning, 1999
[59] Third Party Logistics – Outsourcing Logistics in Partnerships, 1997
[60] Third Party Logistics – Outsourcing Logistics in Partnerships, 1997
[61] Tredjepartslogistik i svensk industri – En kartläggning, 1999
[62] Third-Party Logistics: Is there a future?, 1999
[63] Third Party Logistics – Outsourcing Logistics in Partnerships, 1997

3.2.4 Information Systems

It is of great importance for the distribution system that the transfer of information is working in a correct way. The information can be seen as the "blood" in the logistic system[64].

Practical use of information system can be divided into five different areas[65]:

- **Infrastructure**, which consists of hardware as PCs, servers and barcode readers.
- **Information system**, the system for stocks, planning and reservations.
- **Networks and communications**, that connects the company with their costumers, partners and others in the world. Examples are GSM, GPS, Internet and EDI.
- **Knowledge,** is needed to be able to use information technology in a proper way.
- **Services,** is based on knowledge and technology, for example cross-docking, third party logistics.

The goal with an information system is to connect the information flow in the supply chain (*Figure 3.7*). Anyone that needs a certain real-time data in the supply chain should have access to it. This will allow planning, tracking and estimating lead times.[66] Instead of doing forecasts of, for example, the demand of a product, the information that others in the supply chain already know can be used.[67]

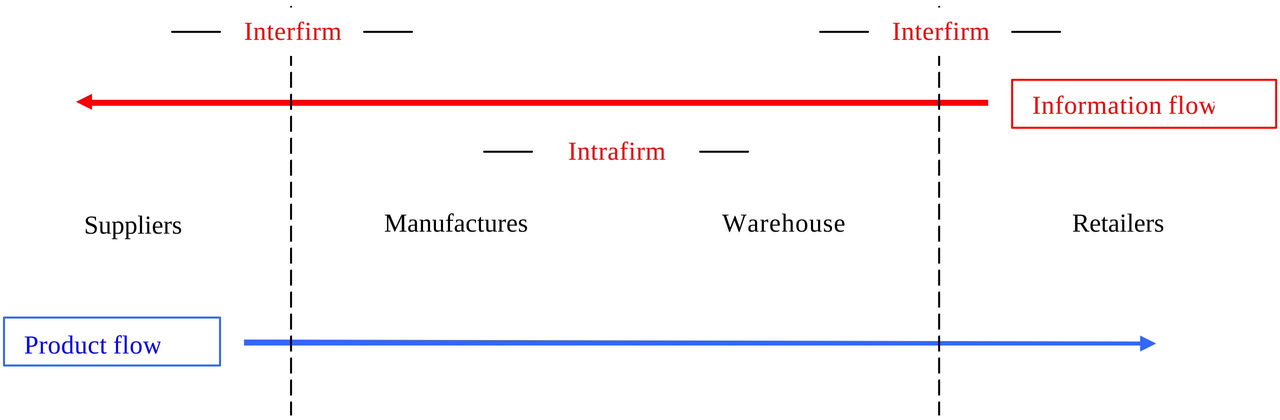

Figure 3.7 The flow of information and products in the supply chain.[68]

[64] The Handbook of Logistics and Distribution Management, 2000
[65] Effektivare logistik med hjälp av IT, 1999.
[66] Designing and Managing the Supply Chain, 2000
[67] 21st Century Logistics: Making Supply Chain Integration a Reality, 1999
[68] Designing and Managing the Supply Chain, 2000

3.2.5 Identification Systems

Identification systems are used to automatically identify goods. If a person dials a code via a keyboard he makes approximately one mistake per 300 digits. By choosing an appropriate automatic system the error frequency can be reduced about 1 000 – 10 000 times. Different types of systems are discussed in the following sections.[69]

The **barcodes** has been on the market for 40 years and is developed to different standards in different industries. One type of barcode is one dimensional.[70] It exists in many different variants; one example can be seen in *Figure 3.8*. EAN stands for European Article Numbering.[71]

7 310120 344278

Figure 3.8 One dimensional barcode standard EAN 13[72].

Radio Frequency Identification, RFID, can be a substitute to the barcode technology that is used today. As the name implies it is a system based around radio or electromagnetic communication. The RFID system has the ability to read a tag that is not visible. Different frequencies of the radio system result in different reading ranges and properties of the system. *Figure 3.8* shows the basic function for a RFID system where the RFID tag could be placed on a box.[73]

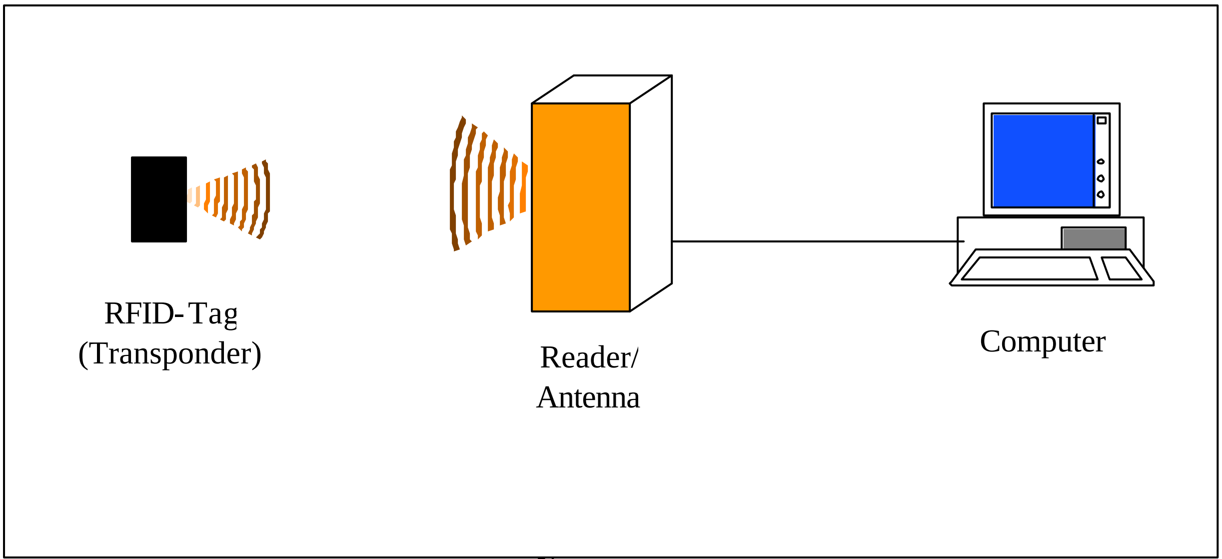

Figure 3.9 The Basic Function of a RFID System. [74]

[69] ABC om streckkoder, 1996
[70] ABC om streckkoder, 1996
[71] www.ise.se., 2002-05-23
[72] www.ise.se., 2002-05-23
[73] http://transpondernews.com/, 2002-05-07
[74] Advantage with RFID Application in B2B Logistics, 2001

A RFID tag can be read-only or read-and-write.[75] If it is read-only no new information can be added to the tag. Transponders in this form can be made more cheaply than read-and-write transponders and the tags do not need power to retain their identity, i.e. no battery is required.[76] The read-only transponders are effective where the identity of an object is required and can be used with a computer database to indirectly contain variable information.[77] Read-and-write tags, on the other hand, find application particularly in the more expensive transponder market, such as with toll roads[78].

Commonly available tags have an operating frequency in the range from 60 kHz to 5.8 GHz[79]. Usually existing standard frequencies are 125 kHz, 13.56 MHz and 2.45 GHz. A low operating frequency results in high penetration through water, high resistance to surface but also higher dimension of the antenna. With a high operating frequency the benefits are higher reading range, temperature resistance and storage capacity[80].

Currently the RFID-technology is too expensive to implement, but it is not only the cost that is a problem.[81] Another significant issue to address is the many different standards on the market. This makes it difficult for a participant on the market like Schenker since they have many different customers and their supposedly various standards to take into account.[82]

Even though there are some problems to solve by developing improved RFID components the possibilities are a driving force. With an effective RFID system the possibilities are[83]:

- Eliminate human errors
- No contact required
- Performs in harsh environments
- Improved delivery quality
- Increased productivity
- Increased flexibility

3.2.6 Bottlenecks

The definition of a bottleneck is that it is a resource with less capacity than the existing demand. If an hour is lost in a bottleneck it is lost in the whole system.[84]

A bottleneck analysis visualises the whole flow as a tube where the thinnest part of the tube affects all other parts of the flow. Often it is only some part of the flow that has to be more efficient. This will improve the whole system. If the flow is increased in wrong sections of the tube it could create even more problems.[85]

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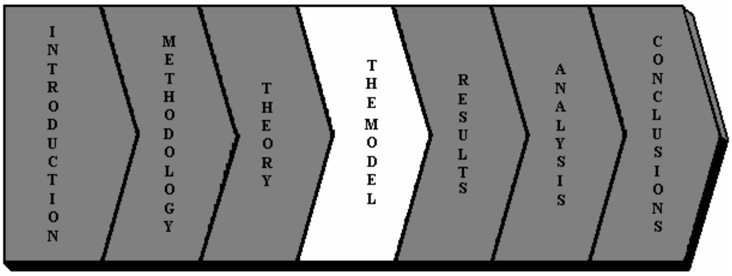
[75] Gert Klargaard, IT Development Manager, Schenker, 2002-03-08
[76] http://transpondernews.com/, 2002-05-07
[77] Kenth Lumsden, University Professor of Logistics at Chalmers Institute of Technology, 2002-04-30
[78] http://transpondernews.com/, 2002-05-07
[79] http://transpondernews.com/, 2002-05-07
[80] Advantage with RFID Application in B2B Logistics, 2001
[81] Gert Klargaard, IT Development Manager, Schenker, 2002-03-08
[82] Kenth Lumsden, University Professor of Logistics at Chalmers Institute of Technology, 2002-04-30
[83] Advantage with RFID Application in B2B Logistics, 2001
[84] Logistik för konkurrenskraft, 1998
[85] Processbaserad verksamhetsutveckling, 2001

IV



Sie ist eine Model und sie sieht gut aus.

Kraftwerk

4 The Model

In this chapter we describe the material flow of Dell computers. How it worked before, how it works today and the different future scenarios that have been tested. The last part of this chapter presents how we processed the input data that we used in the models.

4.1 The Flow – Earlier

Dell's deliveries from Limerick in Ireland to the Nordic market where earlier managed by the Irish company IEC. The IEC, in turn, hired DFDS to ship the goods from Ireland to Gothenburg in Sweden. In Gothenburg IEC took care of the goods and let ASG deliver the computers to the Nordic market.[86]The problems associated with this earlier organisation where among others that the total shipping time was about 24 hours longer than it is today and that the many transfers between shippers lead to mistakes. The goods were unaccompanied during the shipment between Ireland and Sweden, which lead to security problems such as theft and damages on the computers.[87]

4.2 The Flow Since Schenker Took Over (Figure 4.1)

Nowadays a production plant in Limerick (I) called EMF 3 (European Manufacturing Facility nr 3) produces the computers and then sends them on via a local distributor to IEC who consolidate the computers with accessories. Schenker picks them up at IEC and handles the delivery to Copenhagen. The trailers travel for 41 hours from Limerick to Copenhagen (DK) via Dublin (I), Holyhead (UK), Harwich (UK), Hook (NL), Puttgarten (D) and Rödby (DK).[88] Additional accessories are kept stock in Tilburg (NL) and the trucks from this warehouse leave Tilburg so that they arrive simultaneously with the Limerick-trucks in Copenhagen.[89]

Figure 4.1 The Flow Since Schenker Took over.[90]

[86] Andy Grumbt, Consultant, 2002-01-22
[87] Andy Grumbt, Consultant, 2002-01-22
[88] Andy Grumbt, Consultant, 2002-01-22
[89] Martin Carlsen, Dell Department Manager, Schenker, 2002-04-25
[90] www.stadskartan.se, 2002-04-01

4.3 The Original Model

4.3.1 The Flow

See Figure 4.2 and 4.3. When the trailers reach Copenhagen (A) the personnel first unload the large boxes that are on pallets at dock 1 (B, C) and then the medium and small boxes at dock 2 (D). The unloading of large boxes is done at a regular ramp and the other boxes are unloaded at a ramp with a telescope conveyor. When the pallets have been unloaded they are transported by truck to the scanning area to be scanned (E). Each bar-coded box on the pallet is scanned individually by hand. After the scanning the pallets are transported to the sorting area to be sorted (F). The boxes, which weigh at least 21 kg, are carried individually to their respective split-point pallet at the conveyor (M).

The telescope conveyor mentioned earlier enables direct loading (J) of medium sized boxes onto the main sorting conveyor. Goods are scanned in (K) and sorted (L) automatically and then loaded manually onto pallets at the rear of the conveyor by ten different criteria.

- Business customers in Norway, split point Oslo.
- Private customers in Norway, split point Oslo.
- Business customers in Finland, split point Helsinki.
- Private customers in Finland, split point Helsinki.
- Business consumers in Denmark, split point Glostrup.
- Private consumers in Denmark, split point Glostrup.
- Private customers in Stockholm.
- All goods with destination Värnamo in Sweden serving the Stockholm area.
- All goods with destination Helsingborg in Sweden serving the Swedish market except the Stockholm area.
- The goods that are to be put on hold because it is part of an incomplete order (OH).

The small and large boxes are of course sorted by the same criteria as the medium sized boxes.

Small sized boxes are put in a cage / wire box (G) in the truck and when the cage is full it is sent on to the scanning area. The boxes are scanned individually (H) and transported to the sorting area where they are placed on pallets (I) corresponding to the destination split point.

When the split-point pallets (M) are filled with small, medium and large pallets they are either sent to the plastic-wrapping area (O) or to the out scanning area (N) depending on if the boxes to the current split-point are to be loaded on pallets or loose on the truck respectively. At the plastic wrapping area the boxes are first scanned out before they are wrapped.

When the boxes have been scanned out they are loaded on the waiting trucks (P). The wrapped pallets on the other hand are stored until a suitable transport to their destination can be arranged.

Note that there are in practice three parallel processes, one process for each box size. The handling of the medium sized boxes is semiautomatic while the processes for large and small boxes are completely manual.

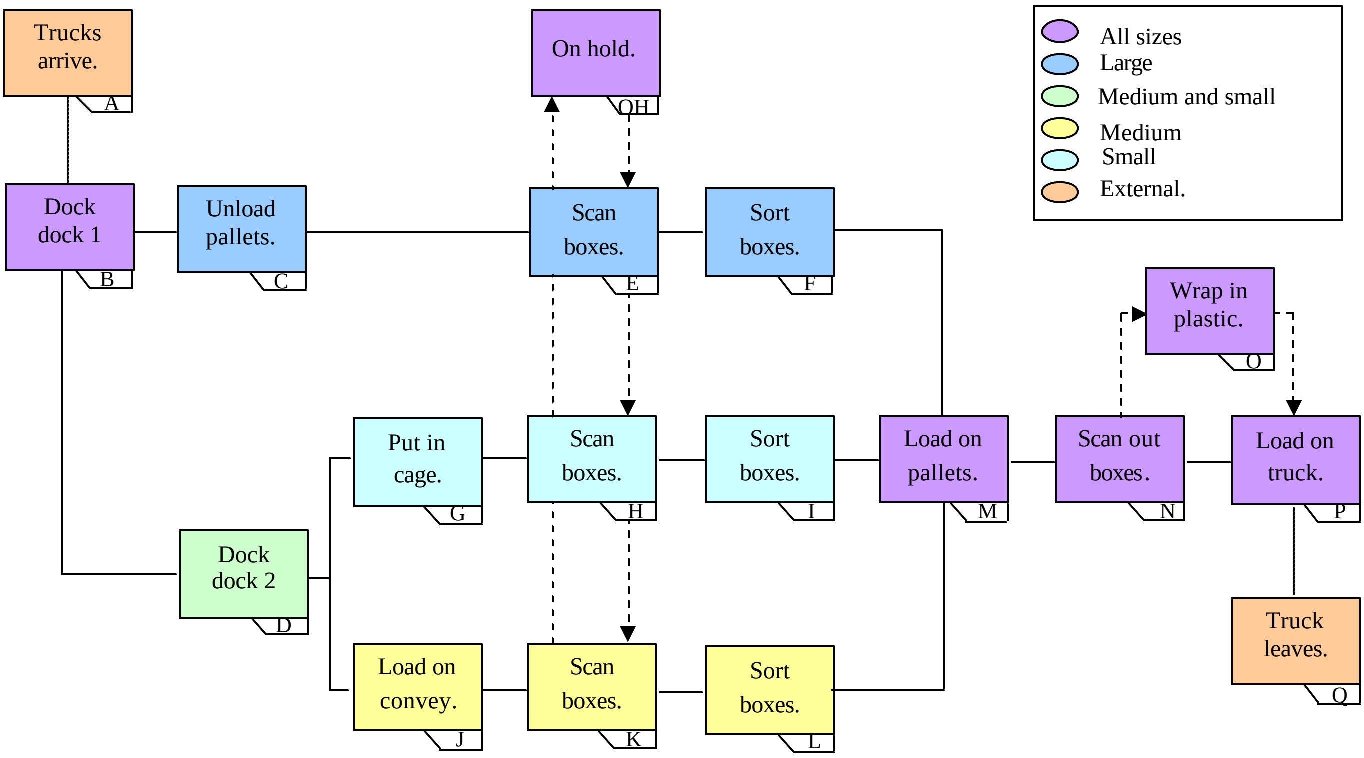


Figure 4.2 Chart over the Current Material Flow

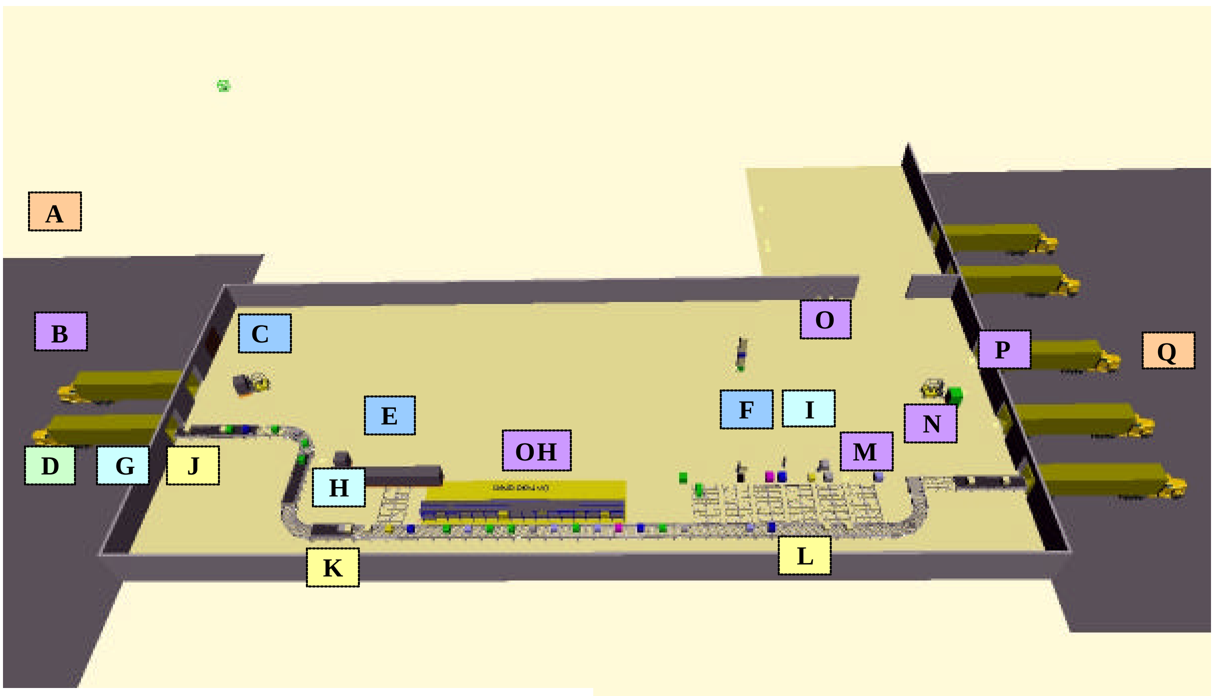


Figure 4.3 Overview – The Original Model

The amount of time each internal process is taking up is summarised in *Table 4.1*. The processes that are not in the table depend on how fast a forklift or a human travel, the distance travelled and the traffic. The time has therefore in these cases been estimated by measuring the speed and the distance for these units. Since the distances travelled depend on to which split-point the boxes are going it is not meaningful to set up an average time in the table.

Action	Level	Min time	Mean time	Max time
Docking dock 1 (B)	Vehicle		5 min (estimated)	
Docking dock 2 (D)	Vehicle		3 min (estimated)	
Scan one large box manually(E)	Box	8 sec	14 sec	23 sec
Load one medium box on conveyor (G)	Box		5 sec (estimated)	
Scan one medium box automatically(H)	Box		3 sec	
Put one small box in cage (J)	Box		5 sec (estimated)	
Scan one small box manually (K)	Box	7.3 sec	9.2 sec	12 sec
Sort one small box (L)	Box		3 sec (estimated)	
Load one medium box on pallet (M)	Box	5 sec	7.5 sec	10 sec
Scan one box manually (N)	Box	8 sec	14 sec	23 sec
Wrap one pallet (O)	Pallet		80 sec	
Load boxes from one pallet to truck (P)	Pallet	192 sec	287.2 sec	447 sec

Table 4.1 Measured and Estimated Action Times Used in the Model.

The flow for boxes, which destination is the split point in Helsingborg, differs a bit from the other box flows. See the bottom right corner in *Figure 4.3*. Since a telescope conveyor is stationed at the Helsingborg dock the medium sized boxes can travel directly from the incoming truck to the outgoing. This presupposes that an employee is unloading the boxes from the conveyor to the truck.

On an average shift (day *or* night) the cross-docking crew is 14 persons:[91]

- Two persons drive forklift trucks that unload goods on pallet from the arriving trucks and transport the goods between different stations in the cross-docking centre.
- One person scans the incoming large boxes.
- One person unloads the medium sized boxes from the incoming truck onto the conveyor and loads small boxes into the wire box.
- One person scans the incoming small boxes.
- Three persons sort the boxes onto pallets corresponding to the different split points.
- One person scans out all Helsingborg boxes.
- Two persons scan out all other boxes.
- One person scans out and plastic wrap pallets that require so.
- One person loads all boxes from the Helsingborg telescope conveyor onto the truck.
- One person loads all other boxes which are loaded on pallets to respective leaving truck.

These employees are in reality not *always* on the stations listed above. They *can* for instance move from a station with low intensity to a station with high intensity at a certain occasion. In our model, for programming reasons, the employees do not have that opportunity.

[91] Peter Skermer, Hub Manager, Schenker, 2002-02-04

4.3.2 On Hold Activities

Since Schenker took over the Dell contract they have in periods experienced substantial problems with incomplete orders. If Schenker receive components from Dell that are not part of a complete order, Schenker can not send the components on to the next split point. That would only increase the problems in those split points. Schenker instead has to put the component on rack until all the components in the complete order have arrived. The "on hold" rack is displayed in *Figure 4.4.*

A similar problem occurs when the boxes have not been properly scanned out in Ireland. Then the personnel in Copenhagen does not know what goods that are on the truck and therefore cannot sort the goods in a proper way and instead has to put the boxes on rack. Since the cross-docking centre in Copenhagen is built for cross docking and not storage, incomplete orders causes this problems in Copenhagen.[92] There can be as much as 15 tons [93] (two full trucks) of incomplete orders on hold in Copenhagen. Needless to say, these components are in the way of the cross docking process.[94] In the model we will not simulate "the on hold" phenomenon since the extent of it varies a great deal. Our model is instead based on an ideal situation where nothing is put "on hold" and no boxes are taken from the "on hold" rack. In the model the "on hold" rack and the main "on hold" area are marked out. The area is $5 \times 20 = 100\ m^2$. In periods when a lot of boxes are put "on hold" an additional "on hold" area, just as large as the first, is used. This additional area is not stationed in the main cross-docking hall and is therefore not marked out in the model.

Figure 4.4 The "on hold" rack in Copenhagen.

[92] Erik Madsen, National Department Manager, Schenker, 2002-01-23
[93] Peter Skermer, Hub Manager, Schenker, 2002-01-28
[94] Erik Madsen, National Department Manager, Schenker, 2002-01-23

4.4 The Värnamo Model

This model's flow is essentially the same as in the original model. The flowchart in *Figure 4.2* is therefore accurate also for this model. The models only differ in the sense that a telescope conveyor is placed also at the Värnamo dock. *See Figure 4.5 and compare with Figure 4.3*. Since there was already a telescope conveyor at the Helsingborg dock this enables that approximately 55 % of all medium sized boxes can travel directly from the incoming trucks to the outgoing.

This model requires one extra employee in comparison with the original model since an extra person has to unload all Värnamo boxes from the telescope conveyor onto the truck with destination Värnamo. The work load for the three persons sorting the boxes onto pallets will on the other hand decrease.

To be considered is also the improved working environment for the employees when more than 50 % of the medium sized boxes do not require the loading of boxes from the conveyor onto pallets at station M in *Figure 4.3*.

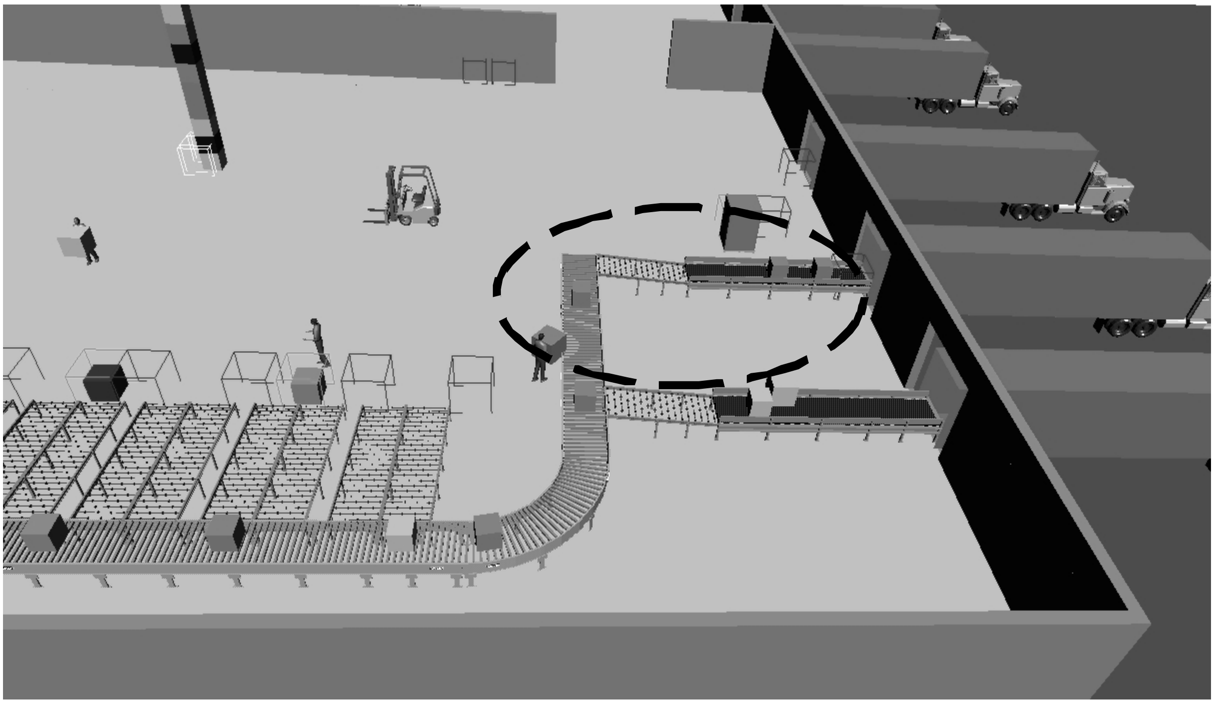


Figure 4.5 The Värnamo Model – Alterations to the Original Model. The marked out extra telescope conveyor is not installed today.

4.5 The Single Process Model

See Figure 4.6 and 4.7. In this model the incoming truck (A) directly docks dock 2 (B) without docking dock 1 first. All boxes (*see Figure 4.8*), including the large ones, are loaded (C) onto the main sorting conveyor. The in scanning process is now completely automatic since all boxes are scanned at (D). No personnel are required to sort the large and small boxes since the sorting is performed by the conveyor (E). Presumably one person loads boxes from the conveyor onto pallets (F). The out scanning (G), the plastic wrapping (H) and the loading on trucks is performed in the same manner as in the original model. This results in a model that only requires ten employees as oppose to 14 in the original model. Note that only one arriving truck can be unloaded as oppose to two in the original model. To be considered is also the improved working environment for the employees when all boxes are sorted by the conveyor instead of manually. The on hold (OH) activities are supposedly performed the same way as in the Original model but they are not simulated.

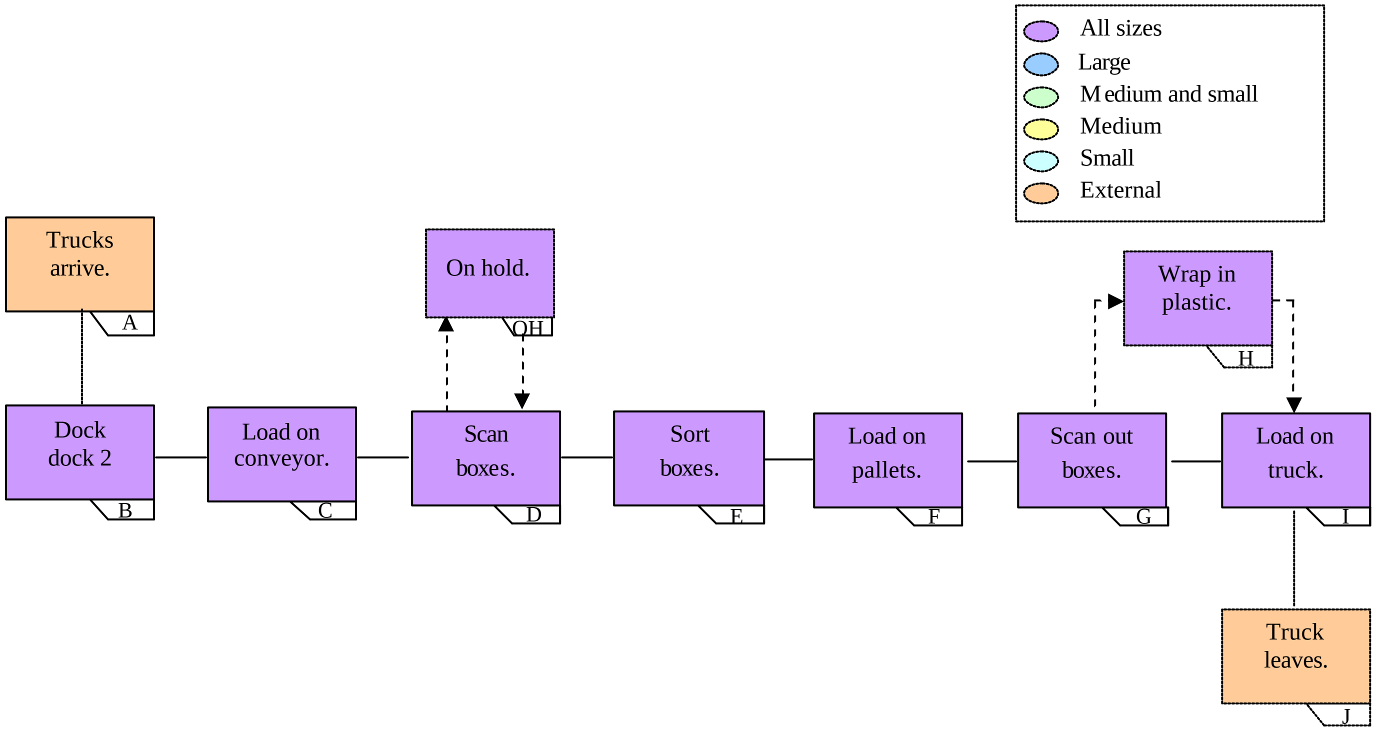


Figure 4.6 Chart Over the Material Flow When All Boxes Are Loaded On the Conveyor.

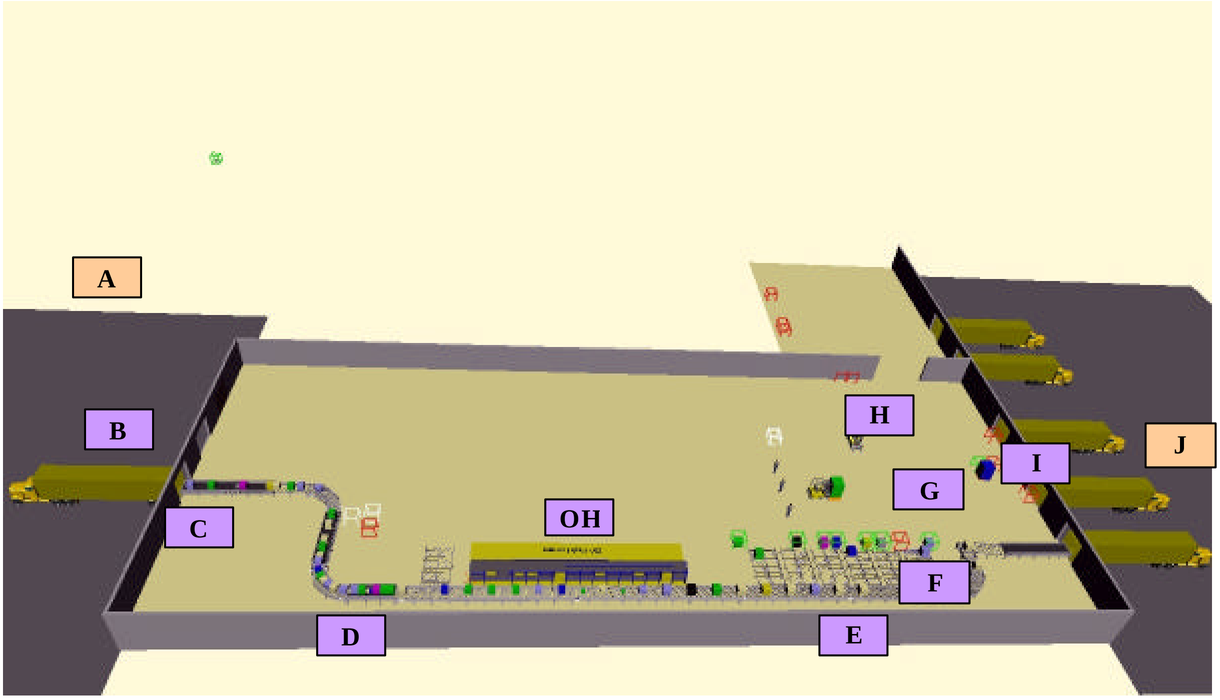


Figure 4.7 Overview – The Single Process Model

Figure 4.8 Boxes of Different Sizes On the Conveyor

4.6 The RFID Model

This model's material flow is also essentially the same as in the original model. The flowchart in *Figure 4.2* is therefore accurate also for this model. The models differ in the in and out scanning processes since when RFID is used no manual scanning is needed and the automatic scanning is done in a split second while the goods is on the move. Scanning of the boxes is practically completed, for example, by driving the goods on a pallet trough a RF receiver gate. The model does not require any in scanning or out scanning personnel and thereby only employ 9 persons. The downside of RFID is that it requires large investments in hardware, software and implementation.

4.7 The Combinations

When the three different basic models have been tested the four possible combinations of them will also be tested and analysed. The four combinations are:

- Single Process – Värnamo. Crew: 11 persons.
- Single Process – RFID. Crew: 7 persons.
- RFID – Värnamo. Crew: 10 persons.
- RFID – Värnamo – Single Process. Crew: 8 persons.

The combinations behaviour and appearance follow logically from their name and the names of the corresponding basic models. The Single Process – Värnamo combination, for example, displays the flow through the cross-docking centre as it would appear if the Single Process model were combined with the Värnamo model. All boxes are loaded on the conveyor and an extra telescope conveyor is placed at the Värnamo dock enabling direct transport of Värnamo boxes from the incoming truck to the outgoing Värnamo truck.

4.8 Data Used for the Model

4.8.1 Primary Data

The primary collection of data has been done mostly on the processes that are related to human work. This includes loading into trucks, unloading from trucks, hand scanning, forklift driving, wrapping a pallet with plastic and packet handling. Data collection for box transportation on the conveyer system and measurement of the building has also been done. Data collections have been done on several different days to get a better quality of the primary data.

A full truck loaded with pallets has a load weight at 6.5 tons and a truck loaded with boxes that are not on pallet has a load weight at 8 tons.[95] The load volume for a truck is 60 m^3 and if it is only loaded with pallets there will be approximately 25 pallets on the truck.[96] This data sets the average load volume on a pallet to 2.4 m^3. In the model the load volume on a pallet is estimated to 2 m^3 since observations show that the pallets often are not full when goods are transported inside the cross-docking centre.

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[95] Michael Strandby, Nordic Traffic / Department Manager, Schenker, 2002-01-23
[96] Peter Skermer, Hub Manager, Schenker, 2002-02-04

4.8.2 Secondary Data

Secondary data was collected from the period 2002-01-23 to 2002-02-03. The data are taken from Schenker's internal data system COS and complemented with registered data direct from Schenker's Dell department in Copenhagen. The total number of Dell boxes that have arrived to Copenhagen within this period are 42745 and they have arrived with 63 trucks, see *Figure 4.9*.

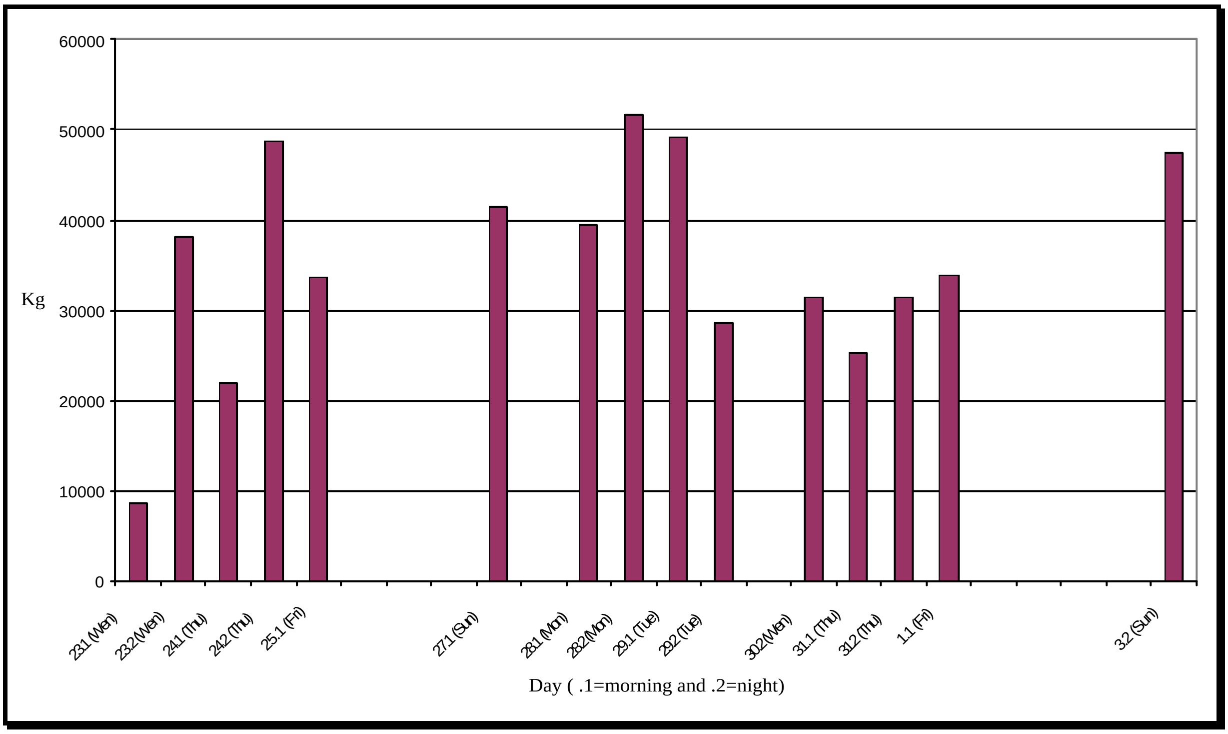


Figure 4.9 Weight and Arrival Time for Truck Loads During the Examined Period.

The shares of the boxes split point destination after being sorted in Copenhagen is illustrated in *Figure 4.10*.

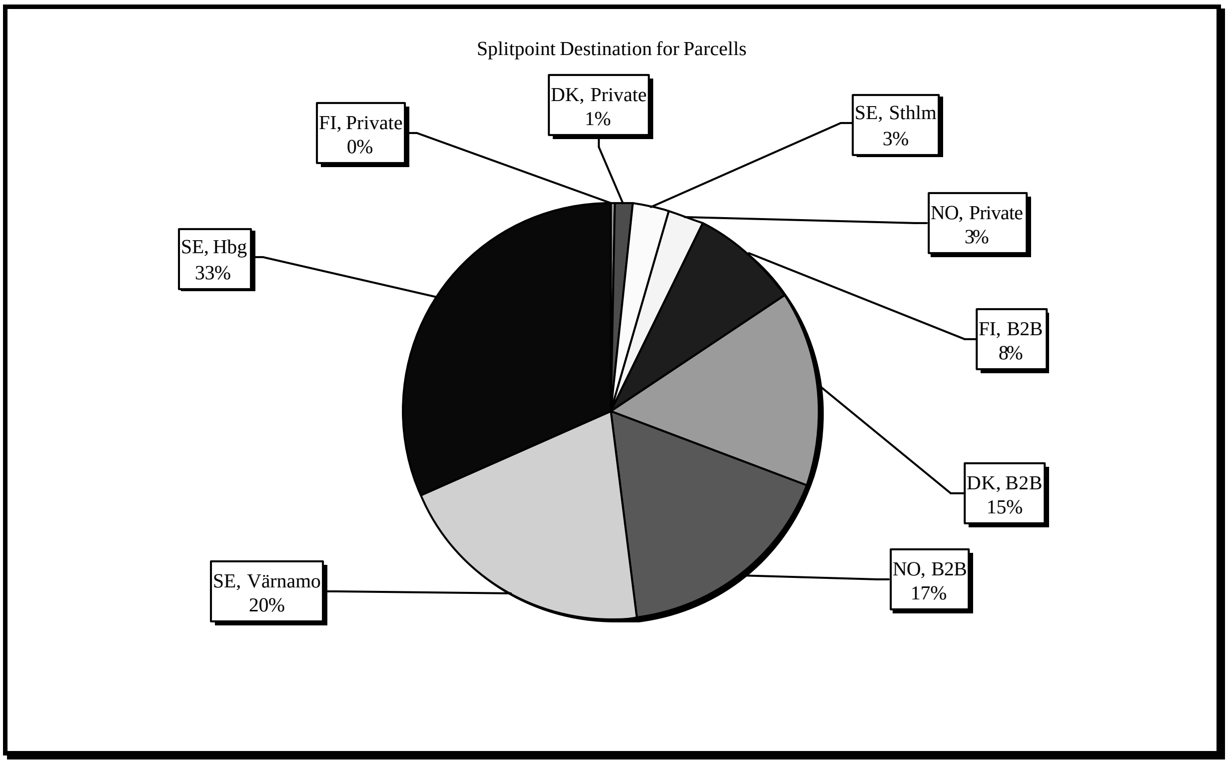


Figure 4.10 Splitpoint Destination for Boxes.

A problem with the original data, *see Figure 4.11*, was the large share of boxes (over 50 %) that did not have any weight and volume information in the COS system. The reason is that Schenker do not have that information available from Dell. [97]

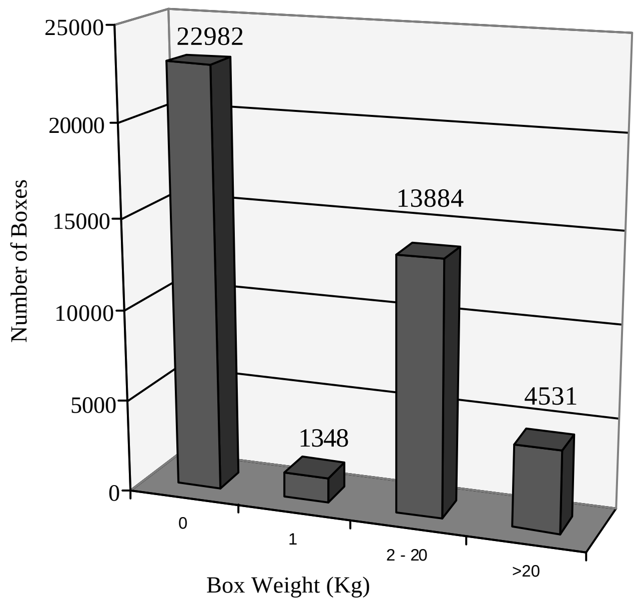


Figure 4.11 Original Data of Box Weights (from COS).

In COS there is also information about the total weight and volume data on each order, which normally consists of several boxes. This weight and volume for the whole order are very reliable. Through combining small (0 kg) boxes and orders with only one box the mysteriously weightless boxes, see *Figure 4.12,* can be analysed with the help of weight and volume of the order. This information gives the possibility to compensate all the 22982 boxes that do not have any weight information. The boxes in *Figure 4.12* also give the opportunity to analyse the mean weight and volume of the average box in each of the box groups.

[97] Martin Jensen, Key Account Manager , Schenker, 2002-03-10

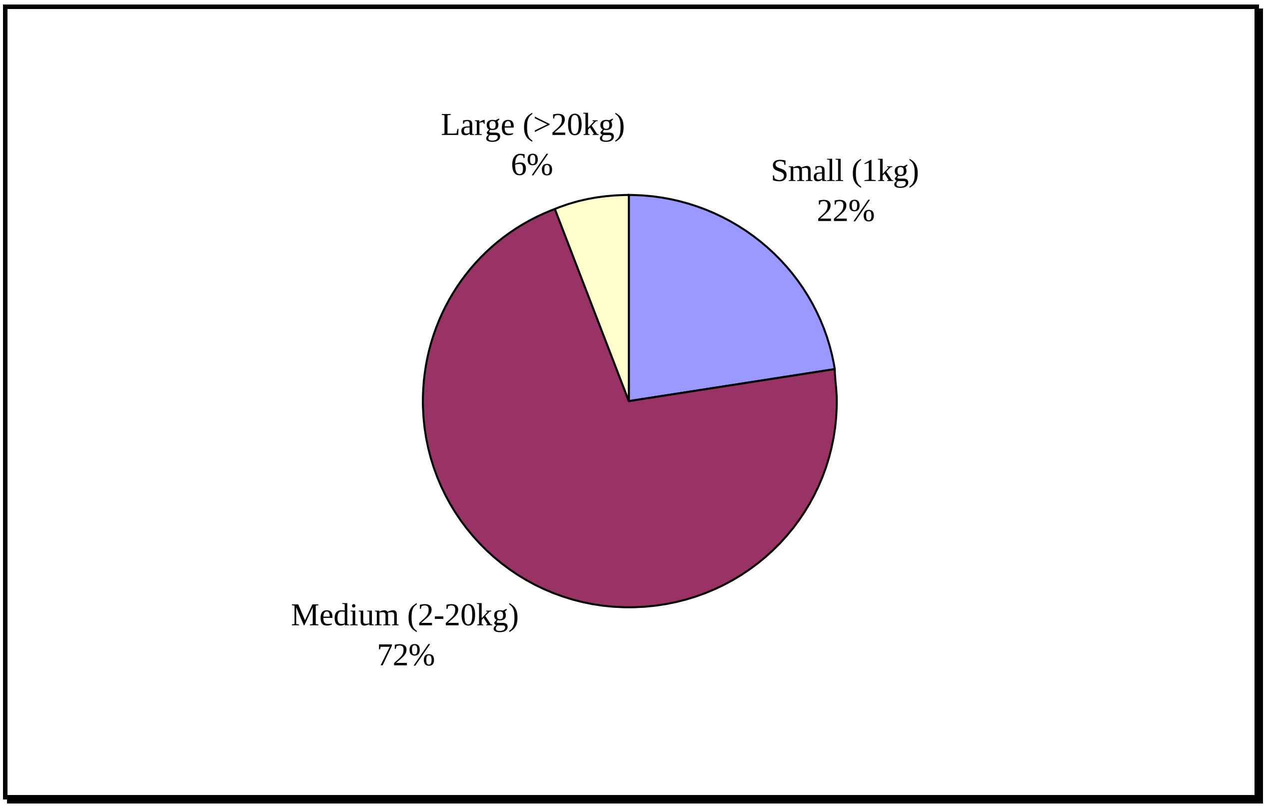


Figure 4.12 Share of number of boxes when order consists of one box and box weight is zero (total 4145 boxes).

When the boxes with no weight in COS are analysed they are included to one of the three box groups. The box groups will then look like in *Figure 4.13*.

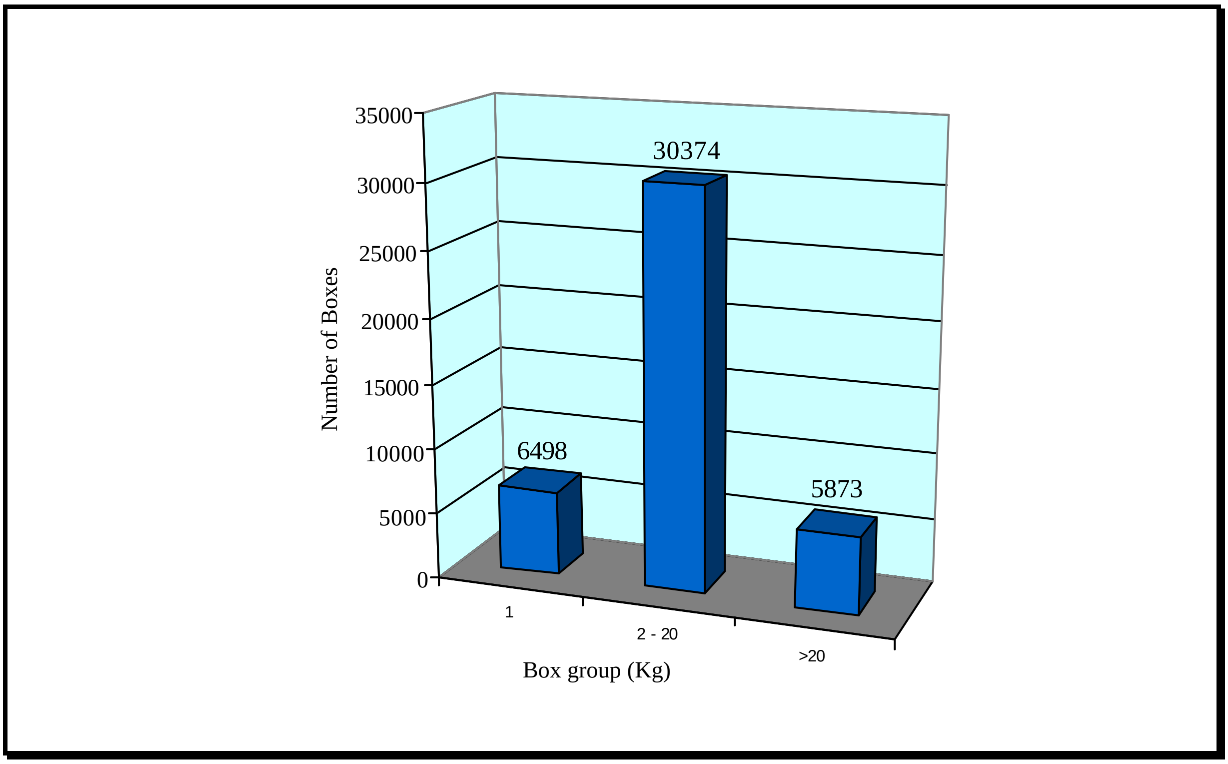


Figure 4.13 Number of Boxes in each Box Group after Compensation.

This also gives the possibility to calculate the mean volume and weight for the average box in all of the three box groups, see *Figure 4.14* and *Figure 4.15*.

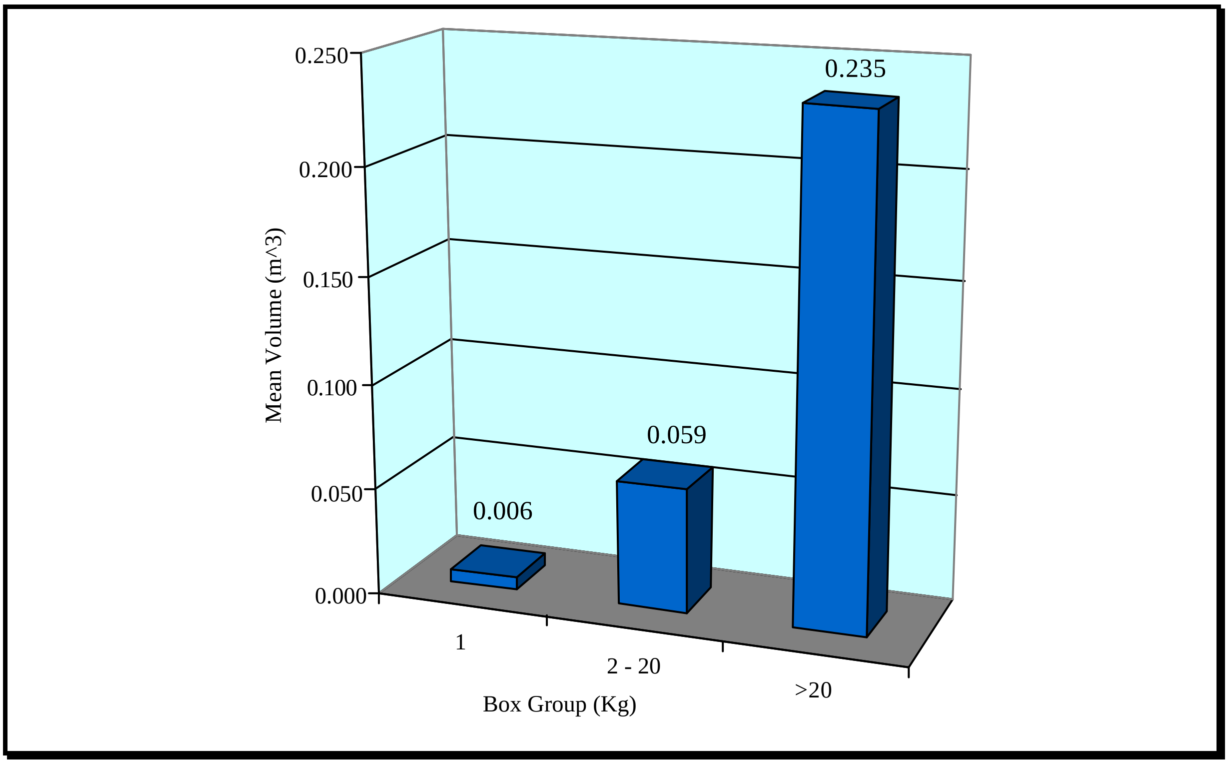


Figure 4.14 Mean Box Volumes.

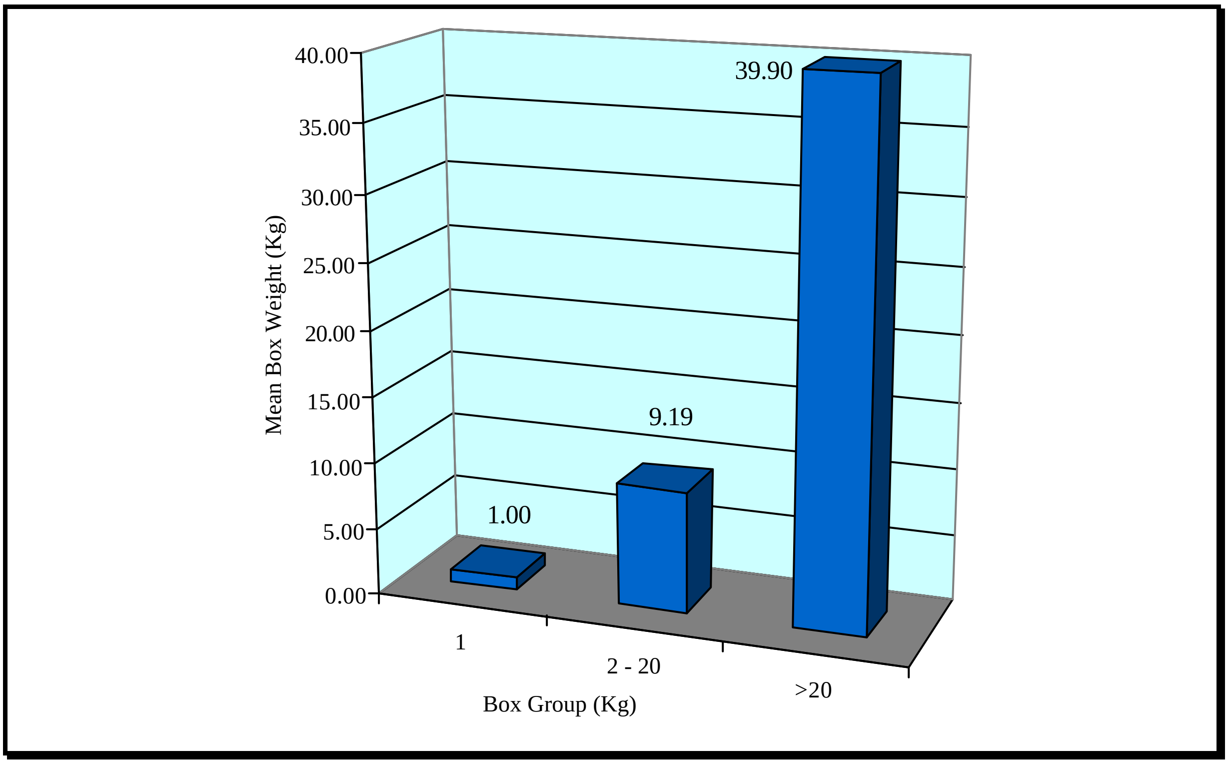


Figure 4.15 Mean Box Weight.

An arriving truck to Copenhagen has a number of boxes that is small, medium or large. The shares of the different box group's volume are different from time to time. The shares do have some patterns. An analysis of the 63 trucks gives the distribution of the shares for the three size groups. For the medium and large boxes a normal distribution is suitable. This has been analysed in MATLAB and can be seen in *Figure 4.16 and Figure 4.17.* These probability plots from MATLAB show how well the data can be estimated with a certain distribution. If all the values are close to the line in the plot then the distribution is a good estimation of the data.

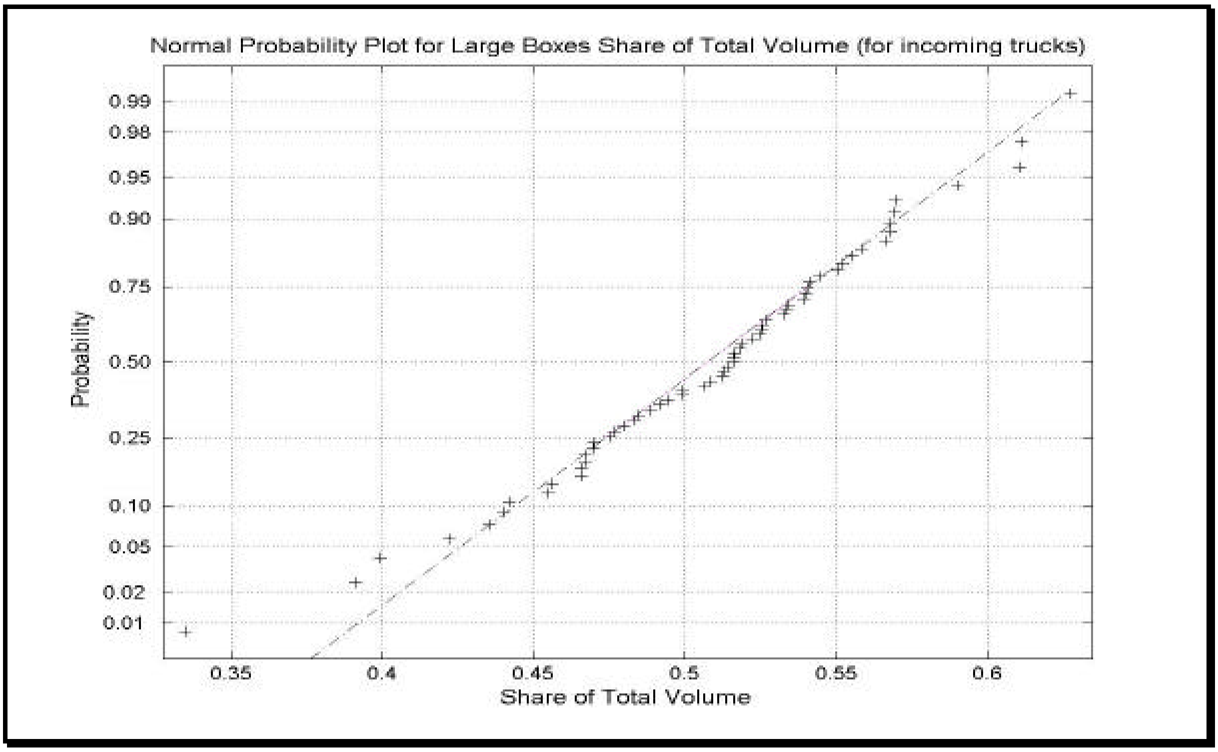


Figure 4.16 Normal Probability Plot for Volume Share of Large Boxes.

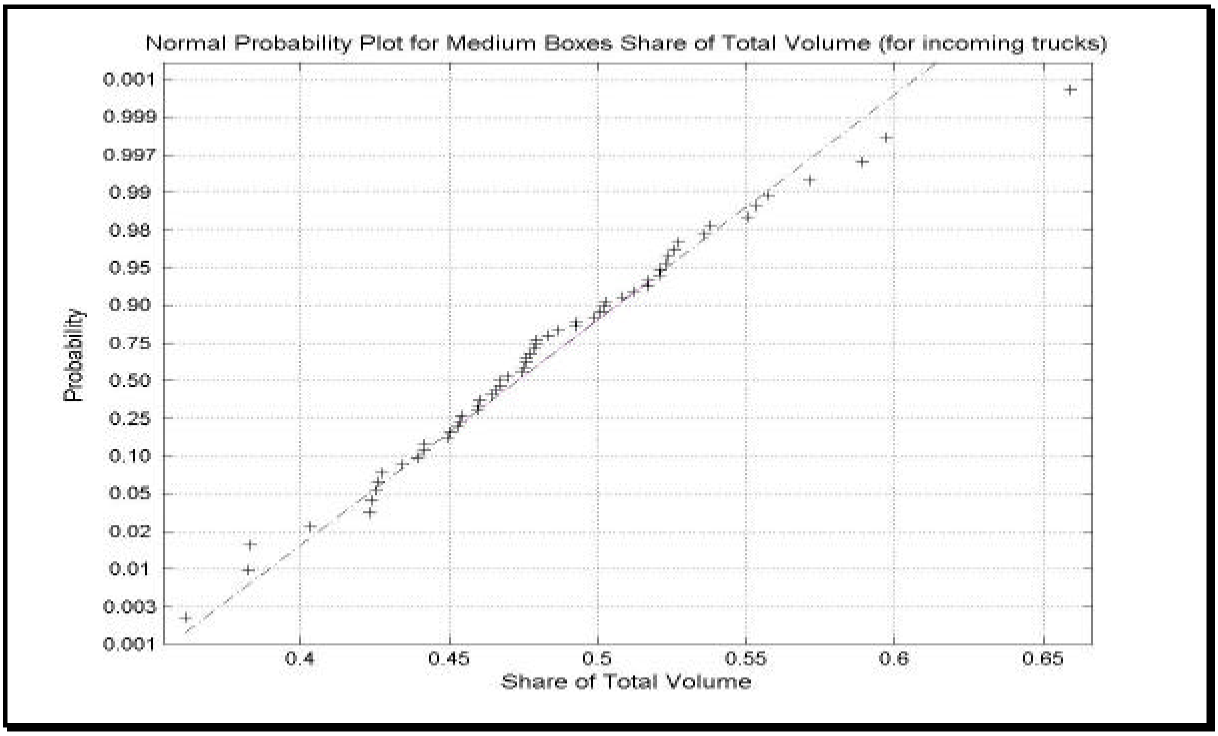


Figure 4.17 Normal Probability Plot for Volume Share of Medium Boxes.

For the small boxes a weibull distribution is the best way to describe the volume share, *see Figure 4.18*. The formula in Matlab for the weibull distribution is:

$$F_{(X)} = 1 - e^{-ax^{b}}$$ For x > 0, a and b are constants

$$F_{(X)} = 0$$ For x <= 0

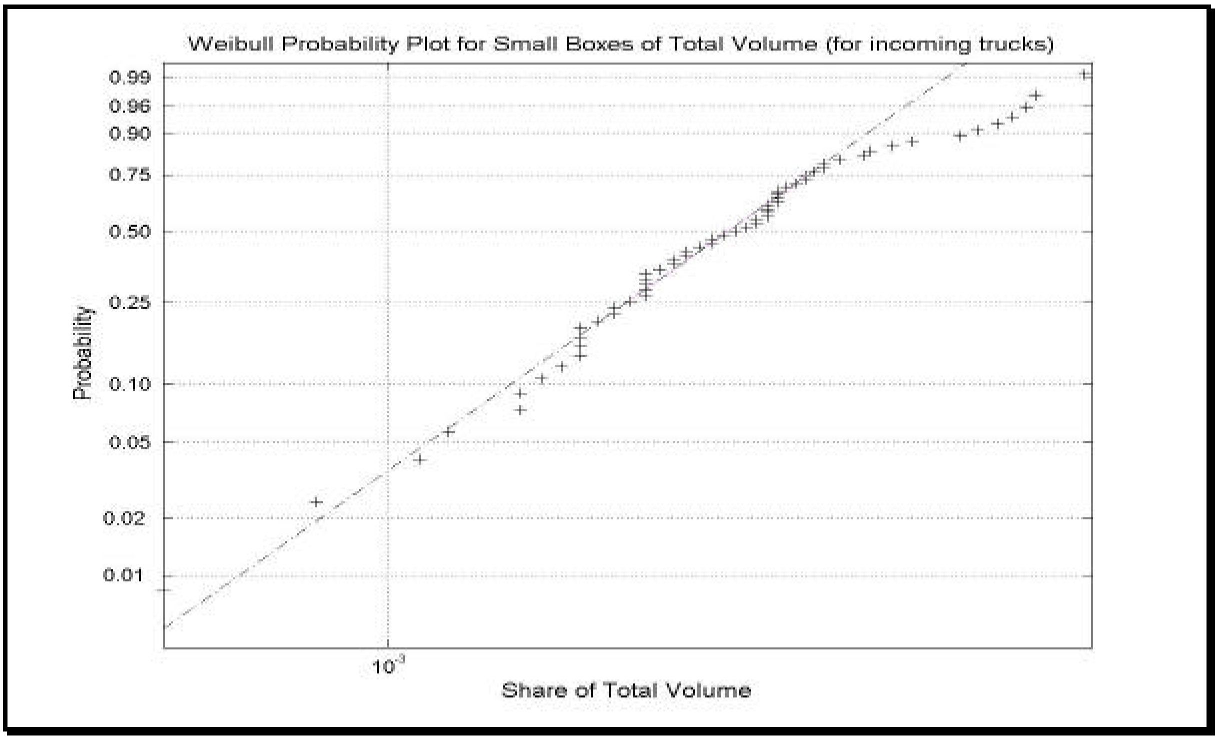


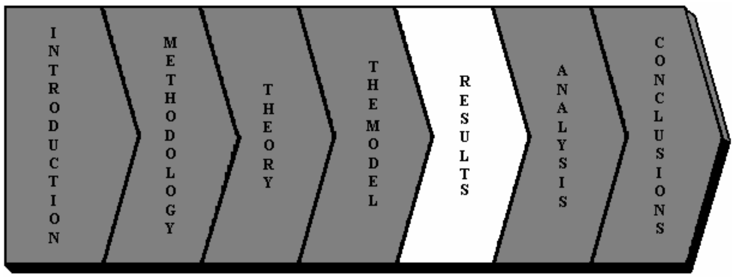
Figure 4.18 Weibull Probability Plot for Volume Share of Small Boxes.

The resulting distributions for the volume shares of the three box groups can be seen in *Table 4.2*.

Box Group	Distribution for Volume Shares
Small	Weibull (a = 0.003585, b = 2.05061)
Medium	Normal (mean = 0.4838, std = 0.0537)
Large	Normal (mean = 0.5085, std = 0.0541)

Table 4.2 The Resulting Distributions

V



A thought which does not result in an action is nothing much,
and an action which does not proceed from a thought is nothing at all.

5 Results

In this chapter the different models' cross-docking time and throughput are presented with associated standard deviations. Sources of error are discussed at the end of the chapter.

5.1 The Simulation Approach

All the models have been simulated when two, four or six trucks arrive at one shift. Cross-docking time is defined as the time between when the first box arrives, from the first truck, until the last box, in the last truck, has left the cross-docking centre. Average number of boxes per hour is all the number of boxes during a shift divided with the cross-docking time. All models have been executed for 20 runs. This is the reason for the appearance of the standard deviation.

5.2 The Original Model

The Original model displays the flow through the cross-docking centre as it is today (see Chapter 4.3). Results for the original model simulations can be seen in *Table 5.1* and *5.2*.

Arriving Trucks	Cross-docking Time (min)	Standard Deviation
2	154.51	10.24
4	244.85	9.93
6	343.67	13.44

Table 5.1 Mean Cross-docking Time for the Original Model

Arriving Trucks	Boxes per Hour	Standard Deviation
2	493.03	17.13
4	613.73	20.76
6	659.84	15.16

Table 5.2 Average Number of Boxes per Hour for the Original Model

5.3 The Värnamo Model

The Värnamo model displays the flow through the cross-docking centre as it would appear if an additional telescope conveyor were placed at the Värnamo dock for outgoing boxes (see Chapter 4.4). Results for the Värnamo model simulations can be seen in *Table 5.3* and *5.4*.

Arriving Trucks	Cross-docking Time (min)	Standard Deviation
2	155.00	11.85
4	245.86	10.29
6	342.05	12.88

Table 5.3 Mean Cross-docking Time for the Värnamo Model

Arriving Trucks	Boxes per Hour	Standard Deviation
2	492.14	22.52
4	611.63	17.02
6	658.52	15.19

Table 5.4 Average Number of Boxes per Hour for the Värnamo Model

5.4 The Single Process Model

The Single Process model displays the flow through the cross-docking centre as it would appear if all boxes (large, medium and small) were loaded on the conveyor (see Chapter 4.5). Results for the Single Process model simulations can be seen in *Table 5.5* and *5.6*.

Arriving Trucks	Cross-docking Time (min)	Standard Deviation
2	154.88	7.53
4	271.02	7.67
6	389.53	10.07

Table 5.5 Mean Cross-docking Time for the Single Process Model

Arriving Trucks	Boxes per Hour	Standard Deviation
2	491.52	13.04
4	558.50	10.62
6	580.95	8.92

Table 5.6 Average Number of Boxes per Hour for the Single Process Model

5.5 The RFID Model

The RFID model displays the flow through the cross-docking centre as it would appear if the in and out scanning of the boxes did not take up any time (see Chapter 4.6). Results for the RFID model simulations can be seen in *Table 5.7* and *5.8*.

Arriving Trucks	Cross-docking Time (min)	Standard Deviation
2	125.92	6.32
4	219.35	6.30
6	313.75	7.64

Table 5.7 Mean Cross-docking Time for the RFID Model

Arriving Trucks	Boxes per Hour	Standard Deviation
2	604.38	11.45
4	688.70	8.62
6	724.00	8.92

Table 5.8 Average Number of Boxes per Hour for the RFID Model

5.6 The Single Process-Värnamo Combination

As the name of the model implies the Single Process-Värnamo model displays the flow through the cross-docking centre as it would appear if the Single Process model were combined with the Värnamo model (see Chapter 4.7). The results for the Single Process-Värnamo model simulations can be seen in *Table 5.9* and *5.10*.

Arriving Trucks	Cross-docking Time (min)	Standard Deviation
2	154.41	6.00
4	272.20	8.89
6	391.80	11.45

Table 5.9 Mean Cross-docking Time for the Single Process Värnamo Model

Arriving Trucks	Boxes per Hour	Standard Deviation
2	492.68	11.56
4	554.81	10.55
6	576.71	6.44

Table 5.10 Average Number of Boxes per Hour for the Single Process Värnamo Model

5.7 The Single Process-RFID Combination

The Single Process-RFID model displays the flow through the cross-docking centre as it would appear if the Single Process model were combined with the RFID model (see Chapter 4.8). Results for the Single Process-RFID model simulations can be seen in *Table 5.11* and *5.12*.

Arriving Trucks	Cross-docking Time (min)	Standard Deviation
2	137.32	5.26
4	252.20	6.99
6	368.78	6.45

Table 5.11 Mean Cross-docking Time for the Single Process-RFID Model

Arriving Trucks	Boxes per Hour	Standard Deviation
2	553.96	12.23
4	595.12	7.62
6	609.74	6.70

Table 5.12 Average Number of Boxes per Hour for the Single Process-RFID Model

5.8 The RFID-Värnamo Combination

The RFID-Värnamo model displays the flow through the cross-docking centre as it would appear if the Värnamo model were combined with the RFID model (see Chapter 4.9). Results for the RFID-Värnamo model simulations can be seen in *Table 5.13* and *5.14*.

Arriving Trucks	Cross-docking Time (min)	Standard Deviation
2	138.19	7.75
4	228.61	6.91
6	326.91	9.69

Table 5.13 Mean Cross-docking Time for the RFID-Värnamo Model

Arriving Trucks	Boxes per Hour	Standard Deviation
2	551.05	17.74
4	660.93	14.67
6	695.75	10.22

Table 5.14 Average Number of Boxes per Hour for the RFID-Värnamo Model

5.9 The RFID–Värnamo-Single Process Combination

As the name of the model implies the RFID-Värnamo-Single Process model displays the flow through the cross-docking centre as it would appear if the Single Process model were combined with the RFID model *and* the Värnamo model (see Chapter 4.10). The results for the RFID-Värnamo-Single Process model simulations can be seen in *Table 5.15* and *5.16*.

Arriving Trucks	Cross-docking Time (min)	Standard Deviation
2	134.43	5.60
4	250.43	7.71
6	368.45	9.30

Table 5.15 Mean Cross-docking Time for the RFID-Värnamo-Single Process Model

Arriving Trucks	Boxes per Hour	Standard Deviation
2	565.89	10.57
4	601.41	8.87
6	614.00	7.17

Table 5.16 Average Number of Boxes per Hour for the RFID-Värnamo-Single Process Model

5.10 Compilation of Results

5.10.1 Mean Cross-Docking Time

A compilation of the resulting cross-docking times for the models with the different number of arriving trucks are displayed in *Figures 5.1, 5.2 and 5.3.* The model with the lowest (best) cross-docking time is placed at the far left and the model with the highest (worst) cross-docking time is placed at the far right.

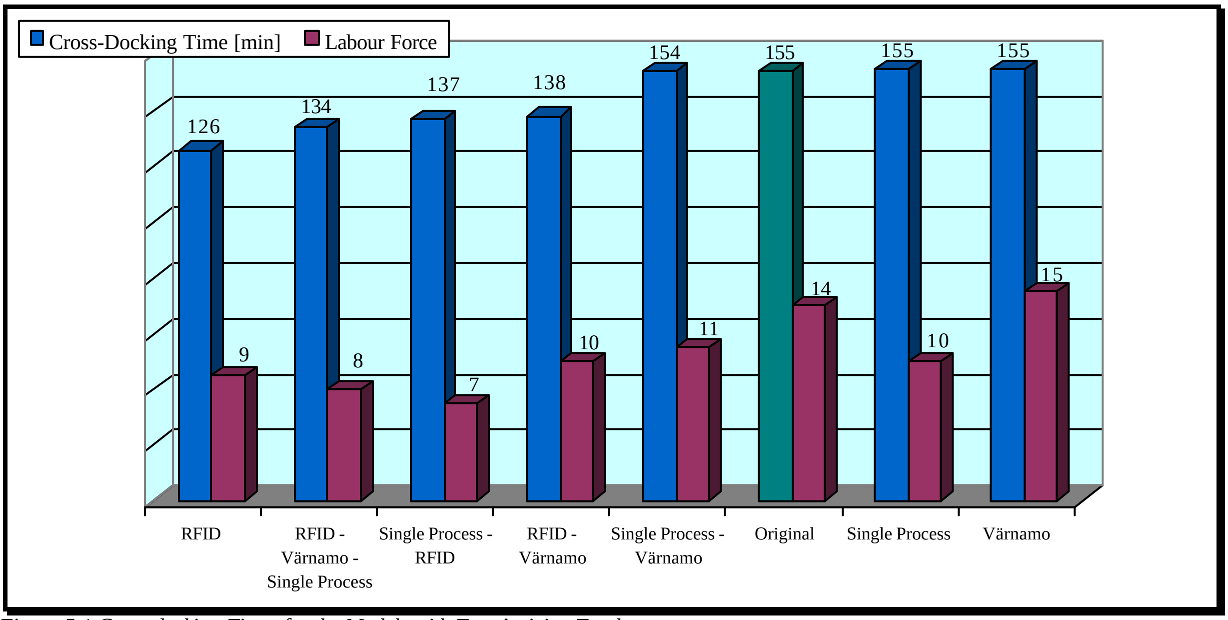


Figure 5.1 Cross-docking Times for the Models with Two Arriving Trucks

In *Figure 5.1* you can see that the RFID model results in the lowest cross-docking time and that the alternatives of the Single Process model, the Värnamo model and the combination of the two give approximately the same result as the Original model. Keep in mind that the models which are based on that all boxes are loaded on the conveyor require a fewer number of resources. The difference in cross-docking time between the RFID-model and the Original model is approximately 29 minutes.

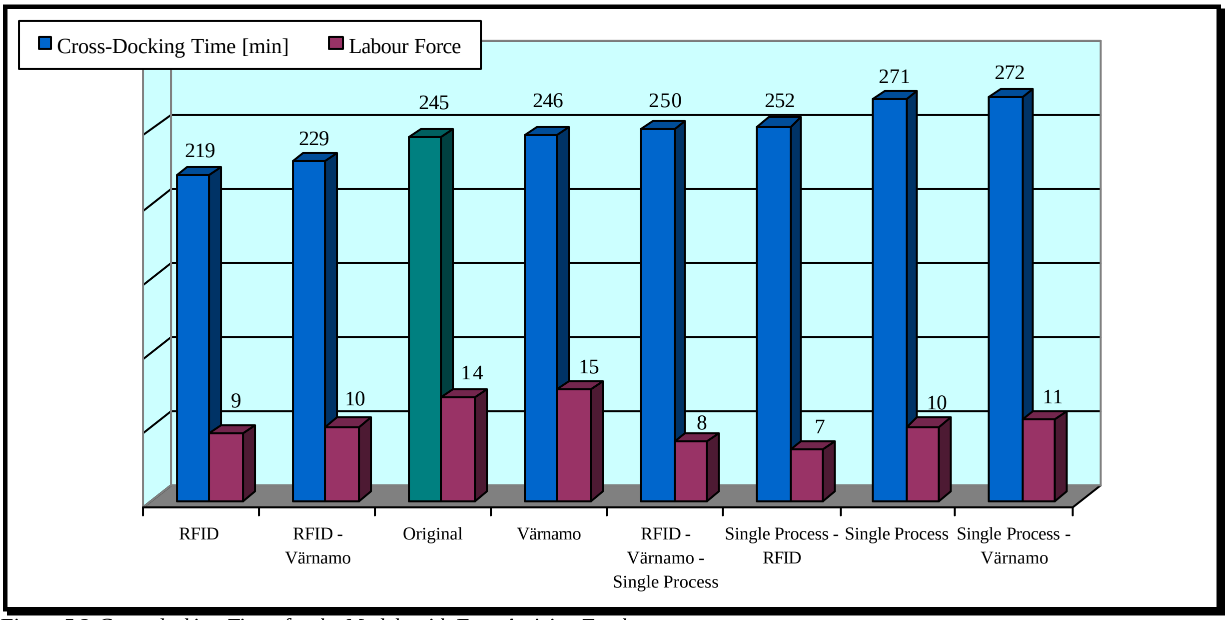


Figure 5.2 Cross-docking Times for the Models with Four Arriving Trucks

In Figure 5.2 you can see that the RFID model results in the lowest cross-docking time also with four arriving trucks. The models that are based on that all boxes are loaded on the conveyor result in the highest cross-docking times. The Original model is more competitive against the other models here than compared with the tests with two arriving trucks. The difference in cross-docking time between the RFID-model and the Original model is approximately 26 minutes.

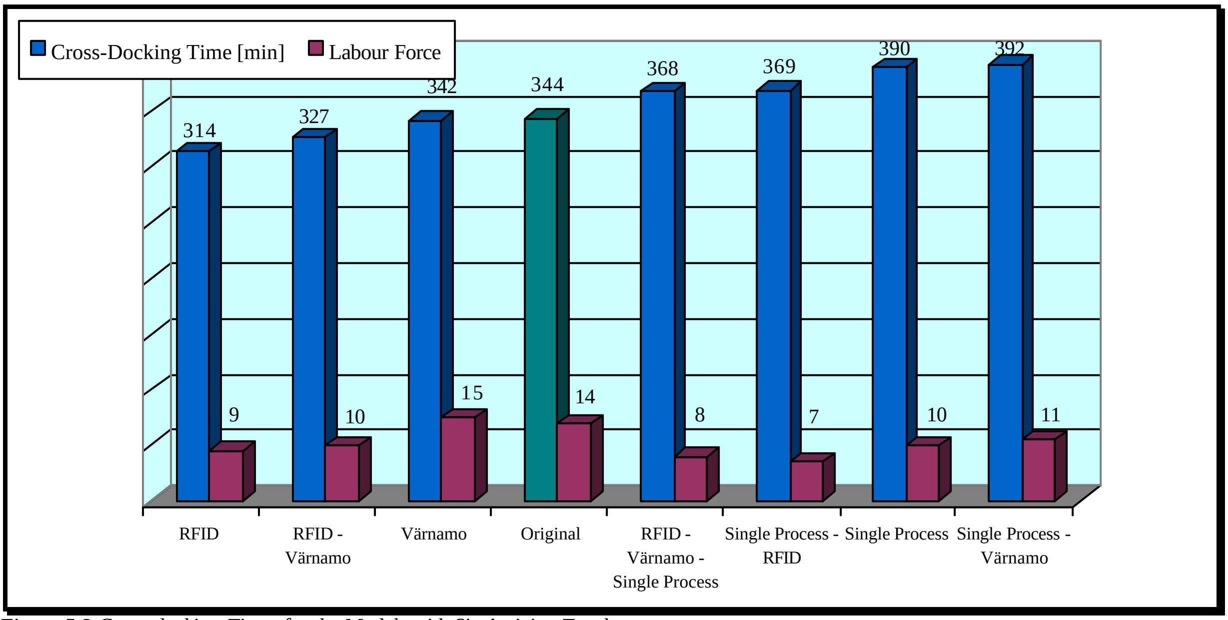


Figure 5.3 Cross-docking Times for the Models with Six Arriving Trucks

When the number of incoming trucks is increased to six the result is similar to the tests with four arriving trucks, *see Figure 5.3*. Once again the RFID model gives the lowest cross-docking time and the Single Process models gives the highest. The difference in cross-docking time between the RFID-model and the Original model is approximately 30 minutes.

5.10.2 Average Number of Boxes per Hour

A compilation of the resulting average number of boxes per hour for the models with the different number of arriving trucks are displayed in *Figures 5.4, 5.5 and 5.6.* The model with the highest (best) throughput is placed at the far left and the model with the lowest (worst) throughput is placed at the far right. The number of boxes per hour is, of course, related to the cross-docking time. If the cross-docking time is low the number of boxes per hour is likely to be high and vice versa. Therefore, it is also likely that the resulting rank in the *Figures 5.4, 5.5 and 5.6* is similar to the ranking in *Figures 5.1, 5.2 and 5.3.*

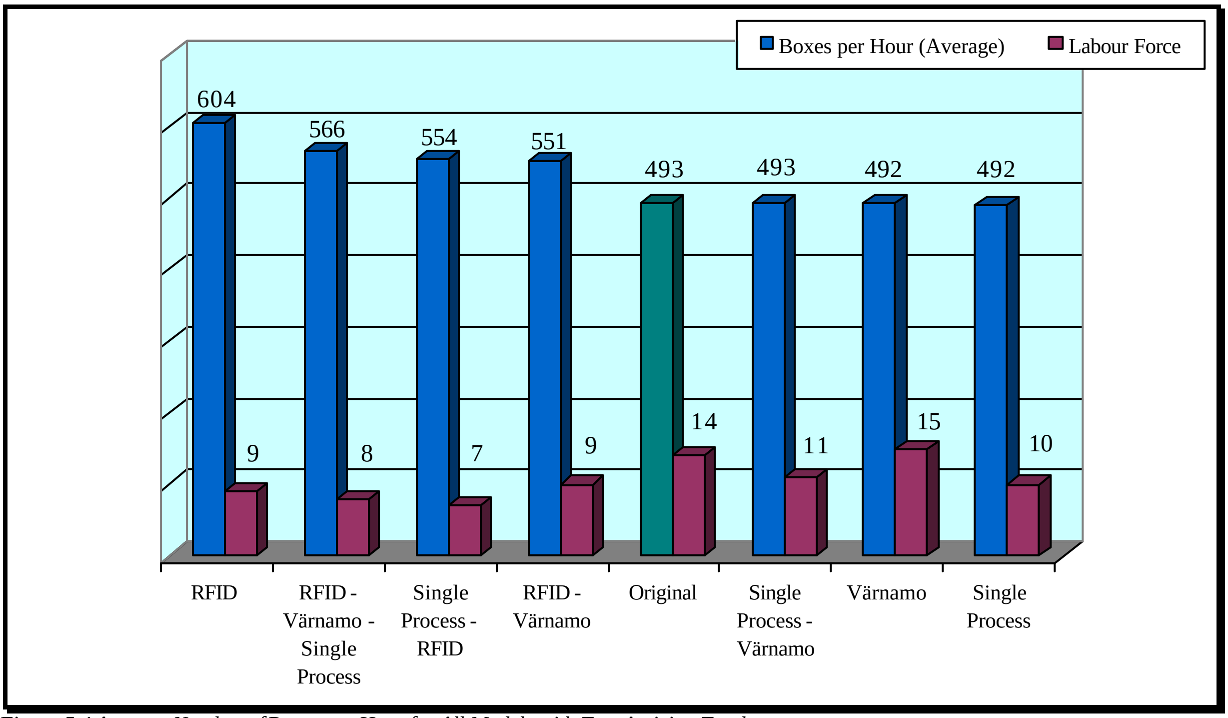


Figure 5.4 Average Number of Boxes per Hour for All Models with Two Arriving Trucks.

In *Figure 5.4* you can see that the RFID model results in the highest throughput and that the alternatives of the Single Process model, the Värnamo model and the combination of the two models give approximately the same result as the Original model. Keep in mind that the models which are based on that all boxes are loaded on the conveyor require a fewer number of resources. The difference in throughput between the RFID-model and the Original model is approximately 111 boxes per hour.

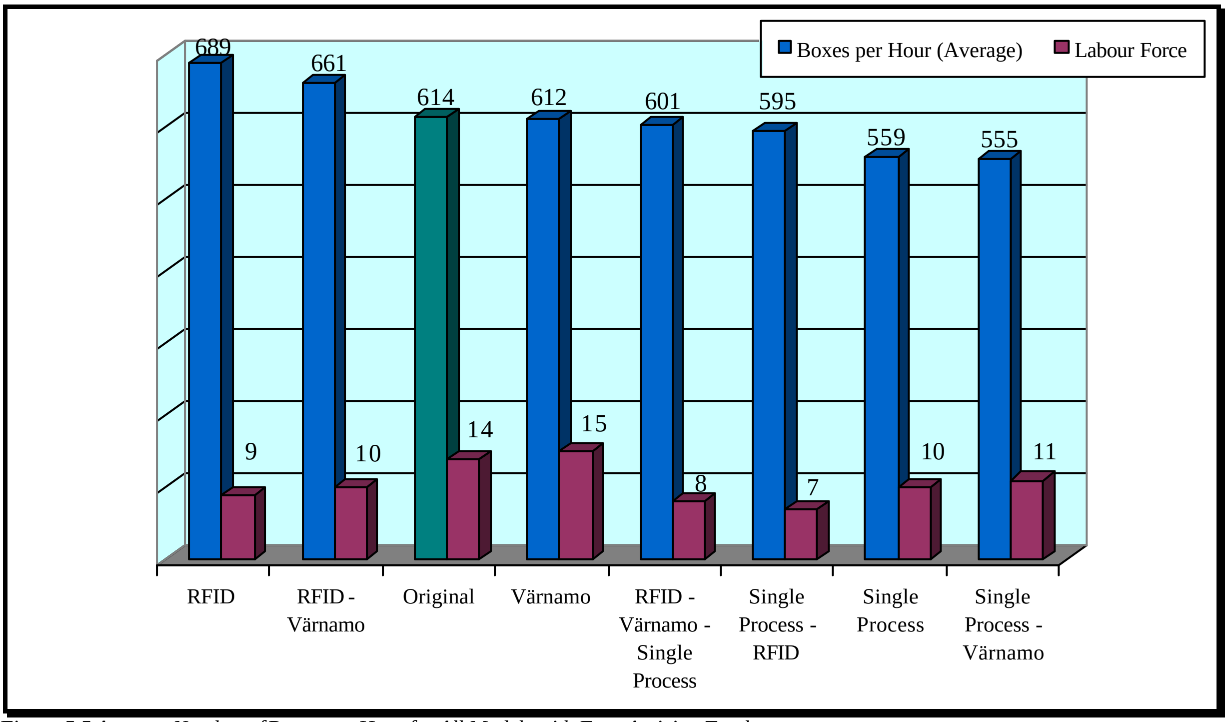


Figure 5.5 Average Number of Boxes per Hour for All Models with Four Arriving Trucks.

In *Figure 5.5* you can see that the RFID model again results in the highest throughput. As seen before the Single Process-based models results are worse than the other models. The difference in throughput between the RFID-model and the Original model is approximately 75 boxes per hour.

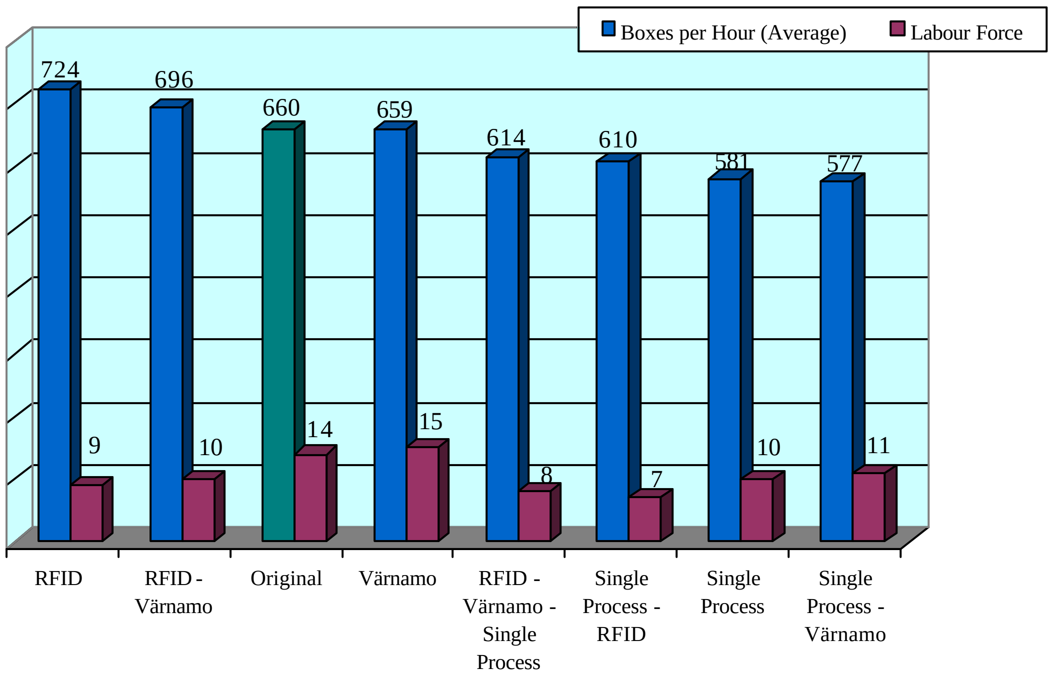


Figure 5.6 Average Number of Boxes per Hour for All Models with Six Arriving Trucks.

When the number of incoming trucks is increased to six the result is similar to the tests with four arriving trucks, *see Figure 5.6*. Once again the RFID model gives the highest throughput and the Single Process models give the lowest. The difference in throughput between the RFID-model and the Original model is approximately 64 boxes per hour.

5.11 Sources of error

A simulation is by definition always a simplification. Resource times, mean velocity estimations and statistical distributions in the models are based on primary and secondary data. If more samples were collected a better estimation of these times, velocities and distributions would be possible to get.

The *day* of the data collection will affect the outcome. For example: For a shift where there are only two arriving trucks the personnel are not pressured to work fast because there is a lot of time to get finished before the shift is over. The opposite case occurs when many trucks arrive and the personnel must work faster to get finished on time. The data that this study is based on are collected from different days which should equalize this problem and give a mean value that is representative.

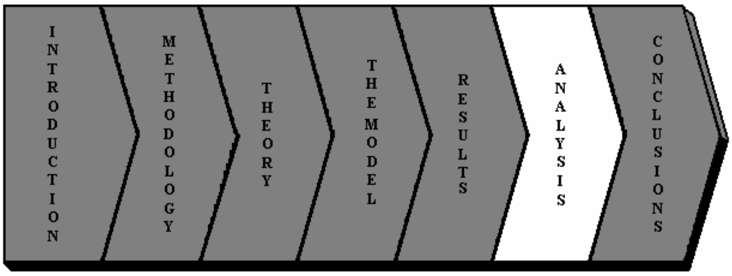
In the models there are no on hold activities. In reality, however, on hold activities do exist. The on hold handling is of course taking resources from the organisation. Since the simulation models are compared to each other and the reason for on hold activities origins from outside the cross-docking centre, this should not influence the results.

In reality the scanning has some errors that are not included in the models. The errors often depend on low quality on the barcode so that the scanner can not read it. In those models where the barcode is changed to RFID tags the errors is supposed to decrease radically. If this theory is true then the results will not improve for the models *with* RFID in comparison with the models *without* RFID since no errors are included in any of the models.

When activities are timed it is obvious that the activity time is depending on which personnel that is working. The primary data that is used in this study are timed on different employees and should therefore be an acceptable mean value of the activity.

In the models there are no resources that can be flexible and move to places that need more help. In reality all resources should be flexible which would display one of the best qualities that human labour stands for.

VI



Oh Lord. See to it that we are always right, for we cannot change our minds.

Scottish saying from the 14th century

6 Analysis

This chapter discuss the results in the previous chapter. Various aspects of the results are high lightened.

6.1 Underlying Reasons for the On Hold Problems in Copenhagen

The initial agreement between Schenker and Dell stated that Dell only should deliver complete orders. This is clearly not the case but Dell refuses to admit that they are in fact shipping incomplete orders.[98] A reason for Dell to send incomplete orders could be that their business is quarterly driven.[99] The Dell share is listed on the US Stock exchange and if their coming report not seems to meet the expectations of the market they are likely to try to improve their result. The computers are prepaid but Dell probably cannot count the orders as sold until they are delivered, or at least part of them is. This causes Dell to ship incomplete orders.[100]

When a customer orders a package from Dell he prepays the computer and is normally promised a delivery time of five days. But since the computer is prepaid Dell does not loose money on late deliveries, not until the customer cancels the order. The incitement for Dell to deliver on time is probably therefore lesser than if they had a large stock of components that they themselves had to pay for. At the moment it is essentially the customers that have to pay for the late arrival of their computer since computers loose approximately ten percent[101] of their sales value in a month. When an order is delayed it is common that the customer re-order the goods in attempt to get an earlier delivery date. Say, for instance, that a customer receives a message that his computer is delayed and will be delivered in twenty days. If he contacts Dell and orders the computer a second time, he is promised a delivery time of five days and is likely to receive the order earlier than the first. Regardless of which of the orders he receives first he can always return the second one to Dell. This reversed logistic process is of course very expensive to Dell.

If Dell could be made to only send complete orders to Copenhagen the components that are part of an incomplete order would be kept stock in Ireland and Holland instead. This would clearly increase the flexibility for Dell since they then, for example, could combine two incomplete orders to *one complete* and *one incomplete*. If one order lacks a keyboard and another order lacks a monitor the order lacking a keyboard could be completed with the keyboard in the second order. By applying this strategy only one of the orders is delayed and the total amount of storing area needed will decrease. Another benefit is that the orders that *are* complete will be delivered faster and more accurately since the supply chain after the Limerick facility not will be overloaded by incomplete orders. If the customers get their goods on time they will not re-order their goods a second time in attempt to speed up their delivery time and the cost for reversed logistic processes will decrease.

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[98] Anja Buus, Logistics Administration Front Office Dell, Schenker, 2002-01-23
[99] Andy Grumbt, Consultant, 2002-01-22
[100] Allan T Malm, University Professor of Corporate Strategy, Department of Business Administration at Lund University, 2002-01-31
[101] Andy Grumbt, Consultant, 2002-01-22

6.2 The Models in General

When valuating which models that is the best various aspects has to be considered. This study is focused at the cross-docking centre in Copenhagen so the impact the different solutions will have *outside* the centre is therefore difficult to estimate. If Schenker and Dell, for instance, decide to implement RFID the overall information base will increase, both in quantity and in quality. The success of the implementation will thereafter be decided by *how* Schenker and Dell *use* the new information.

Even when only the factors inside the cross-docking centre are considered it is difficult to valuate which model that is the best. Which is best, fewer resources or lower cross-docking time? How do you decide between better working environment versus higher throughput?

See Table 6.1 and 6.2. Note that the resulting throughput corresponds well with the resulting cross-docking time. A low cross-docking time corresponds, as expected, to a high throughput.

Model	Resources	2 Trucks	4 Trucks	6 Trucks
Original	**14**	**155**	**245**	**344**
Värnamo	15 (+1)	155 (±0)	246 (+1)	342 (-2)
Single Process	10 (-4)	155 (±0)	271 (+26)	390 (+46)
RFID	9 (-5)	126 (-29)	219 (-26)	314 (-30)
Single Process – Värnamo	13 (-1)	154 (-1)	272 (+27)	392 (+48)
Single Process – RFID	7 (-7)	137 (-18)	252 (+7)	369 (+25)
RFID - Värnamo	10 (-4)	138 (-17)	229 (-16)	327 (-17)
RFID – Värnamo - Single Process	8 (-6)	134 (-21)	250 (+5)	368 (+24)

Table 6.1 Compilation: Differences in Cross-docking Times[min] and Resources Required.

Model	Resources	2 Trucks	4 Trucks	6 Trucks
Original	**14**	**493**	**614**	**660**
Värnamo	15 (+1)	492 (-1)	612 (-2)	659 (-1)
Single Process	10 (-4)	492 (-1)	559 (-55)	581 (-79)
RFID	9 (-5)	604 (+111)	689 (+75)	724 (+64)
Single Process – Värnamo	13 (-1)	493 (±0)	555 (-59)	577 (-83)
Single Process – RFID	7 (-7)	554 (+61)	595 (-19)	610 (-50)
RFID - Värnamo	10 (-4)	551 (+58)	661 (+47)	696 (+36)
RFID – Värnamo - Single Process	8 (-6)	566 (+74)	601 (-13)	614 (-46)

Table 6.2 Compilation: Differences in Throughput and Resources Required.

A possible disadvantage with the Original model and the Värnamo model is the, in comparison, large standard deviation of the cross-docking time. This could indicate a more unstable process which would result in larger difficulties planning the personnel needed for these models. But since the input data is the same for all models it can be argued that the models should be equally stable. The explanation to the difference in standard deviation could then be a bottleneck interfering with the flow. If the variation of the incoming flow is approximately the same and the variation of the outgoing flow is lower for some models it can be an indication that a bottleneck has stabilised the flow in these models, *see Figure 6.1*. If that is the case a larger throughput can be achieved in the bottleneck models by directing resources to that bottleneck and thereby removing it. A bottleneck is essentially an unwanted queue and queues are often used to stabilise the flow through a production facility.[102] By this logic a lower standard deviation would indicate a higher potential in throughput.

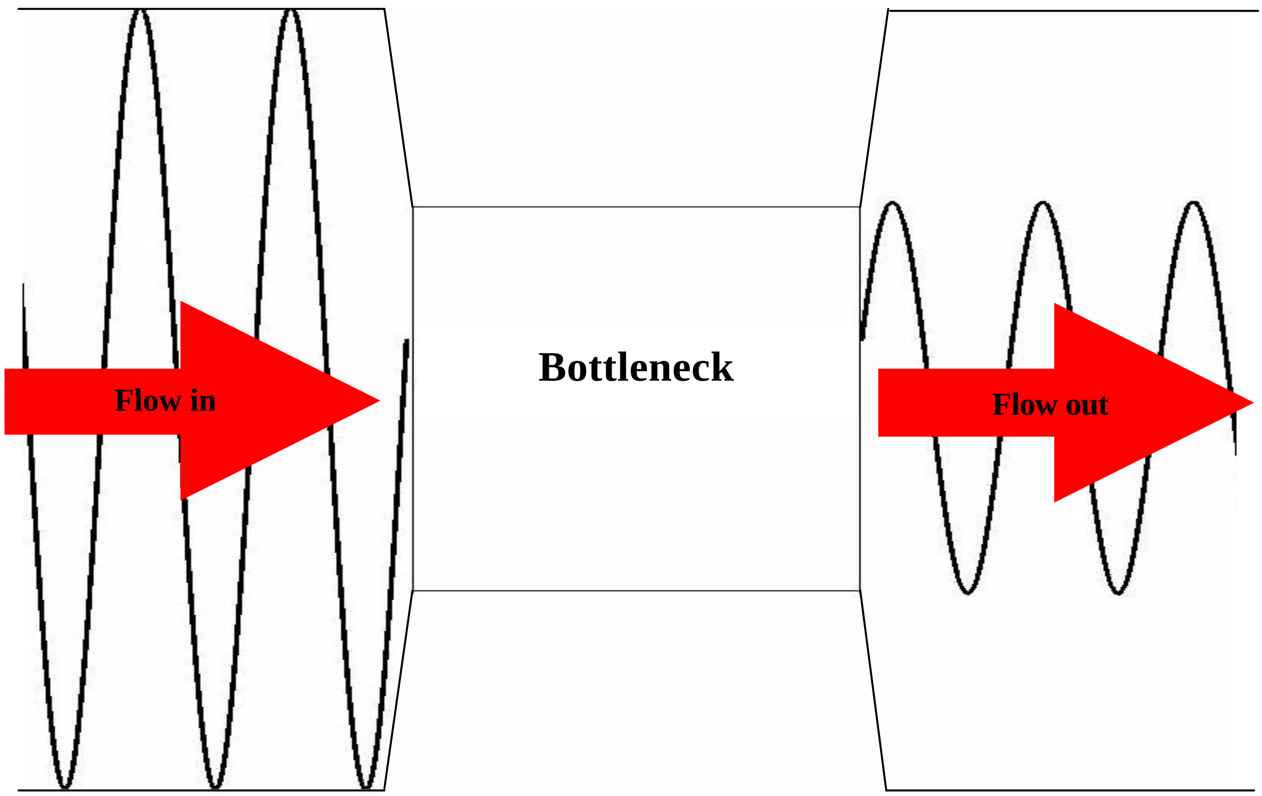


Figure 6.1: The Stabilising Effect of a Bottleneck.

6.3 The Original Model

The original model handles the competition from the other models well. It is in many cases faster than the other ones. This can be explained by the lesser amount of resources required in most of the new models and the fact that the original model can be considered somewhat optimized to the basic conditions in the models. The other models result would probably be improved if it was possible to alter the basic conditions, for example by moving resources to where they are needed or to speed up the conveyor. A disadvantage with this model is that it requires one process per box size. Three parallel processes make it more difficult to overview the total process and the handling of boxes is not standardised. This makes it a source for human errors.

[102] Peter Bergling, PhD Student of Production Management at Lund Institute of Technology, 2002-05-21

6.4 The Värnamo Model

The point of adding an extra telescope conveyor must be seriously questioned. All combinations involving the Värnamo model have a resulting cross-docking time that are, at best, approximately the same as it would be if the extra telescope conveyor had *not* been added. On top of this it also requires an extra resource.

The reason for the poor performance of this model is that the boxes, that do not travel on the conveyor from truck to truck, still take a lot of time to cross-dock. It does not matter that the boxes to Värnamo get to the truck faster since we measure the *total* cross-docking time. The total cross-docking time is defined as the time it takes for *all* boxes to cross-dock. The poor performance could therefore partly be a product of what we measure, but the benefits of a shorter lead time for a Värnamo box is difficult to benefit by anyway. If the last box out of the incoming truck is going to Värnamo, the shorter lead time for that box does not result in a shorter total cross-docking time.

The working environment for the employees is improved since most of the boxes do not require loading from conveyor to pallet, but the effect of this is probably not that big.

An implementation of the Värnamo model should be relatively simple and inexpensive but since the use of the model is questionable the advantage of an easy and inexpensive implementation is, of course, rather small.

6.5 The Single Process Model

If improving the working environment is a goal the models involving the Single Process approach must be considered. When all boxes are loaded on the conveyor the employees does not have to carry boxes that weigh above 20 kilos from one pallet to another. The Single Process model's cross-docking time and throughput is not as good as the Original model's but on the other hand only requires 10 resources.

The reason that this model has a longer cross-docking time than the Original one is that the Original can unload two trucks at a time. While one truck's large boxes are unloaded at dock 1 the other ones medium and small boxes are unloaded at dock 2. This is not possible for this model since there is only a conveyor at dock 2. However, if Schenker invests in an additional complete conveyor system and place it at dock 1 it should result in a very efficient cross-docking process.

The forklift truck traffic is substantially reduced since no transport of small and large boxes from the incoming truck to the sorting area is necessary. The forklift truck drivers are therefore available to do other tasks, at least at the beginning of each shift.

This model is based on one process, not three parallel ones as in the Original model. The Original model should reduce the human errors substantially since the in scanning of all boxes is made automatically. To make scanning errors can be very expensive since the box could end up in the wrong country or at the wrong customer. Not only is the reversed logistics expensive, it is not certain that the customer, that ordered a mouse and received a laptop, files a complaint.

The more trucks that arrive to the cross-docking centre, the worse the performance of this model gets in comparison with the original model. This could be an indication that the conveyor is a bottleneck and that it cannot handle the increased load. Speeding up the conveyor and adding personnel at strategic points such as at the unloading of the truck and at the unloading of the conveyor could therefore be a way to improve the performance.

If Schenker decides to implement the Single Process model they will have to adjust the conveyor in the following way:

- Reduce the distance between the rolls so that the small boxes do not get stuck.
- Enforce the conveyor so that it can handle heavier boxes.
- Tryout how much the conveyor speed can be increased. The new speed's impact on the performance can then be tested with a new simulation.

The cost of these alterations is difficult to estimate since it is uncertain whether the current conveyor can be adjusted and used or if a whole new conveyor system is needed. The total cost is in any case much lower than for implementing RFID.

6.6 The RFID Model

Introducing the RFID technology gives definitely the most positive impact on the cross-docking time and throughput. The RFID model not only has the lowest cross-docking time, it also only requires nine resources. The expensive scanning mistakes and the amount of resources needed are also reduced in comparison with models lacking RFID.

In Table 6.1 the difference in cross-docking time between the Original model and the RFID model is between 26 and 30 minutes no matter how many trucks are arriving. This indicates that a bottleneck is present in the process. The decrease in cross-docking time for this model is probably limited to the time saved at the in and out scanning processes, in between, the conveyor works as a bottleneck that is slowing down the process.

RFID is a relatively new technology and all of its advantages and disadvantages are not yet known. Since RFID is new there is not yet a common standard and the cost is still high. The receiver gates, the transponder tags and the implementation are likely to be very expensive but will on the other hand, as we have seen, result in higher capacity with fewer resources. Although a receiver gate is expensive, the cost is inexpensive in comparison with having a person scanning the boxes[103]. Introducing RFID will also impact factors outside the cross-docking centre impossible for us to evaluate.

The cross-docking centre in Copenhagen takes the costs for implementing RFID but it is likely that the greatest benefits occurs outside the centre. RFID enables a more accurate track-and-trace, but the benefit of that is small if the deviation report is not working properly. It is important to compare where the box *is* with where the box *should be*. In the general case: The earlier a deviation is discovered, the cheaper a correction can be made.

[103] Sten Wandel, University Professor of Logistics at Lund Institute of Technology, 2002-05-21

An example: If the staff in Copenhagen knew what should be on the outgoing trucks a device could be installed in the trucks so that the trucks' loading doors cannot be closed before the right boxes are on the right trucks, or the reason for the deviation is known. This way a box that is going to Oslo is discovered on the Helsinki truck in Copenhagen and not when it has already arrived to the Helsinki split point. Instead of sending the incorrectly delivered box from Helsinki via Copenhagen to Oslo the staff just has to retrieve the box in the Helsinki truck and put it in the Oslo truck. The economical advantage of this is of course great.[104]

The RFID technology will cheapen once the production volumes of the components increase. But if everybody waits for the price to decrease the production volumes will not increase. It could therefore be an alternative to implement the RFID solution on the cross-docking centre in Copenhagen and consider it a pilot project. This way the full scope of possibilities for the new technologies will be easier to comprehend and evaluate. Benefits of this project can then be assimilated by the whole Schenker group.

To gain the most possible advantages of the RFID technology it is vital that as many as possible of the actors in the supply chain make use of it. A co-operation between Schenker, Dell, other customers to Schenker and other suppliers to Dell is therefore desirable.

The implementation also causes indirect costs. It will take up time from the employees working with it and during the trial period of the system the productivity is likely to decrease. Schenker should therefore plan the implementation so that it occurs during a period of lower demand, for example during the summer.

6.7 The Combinations

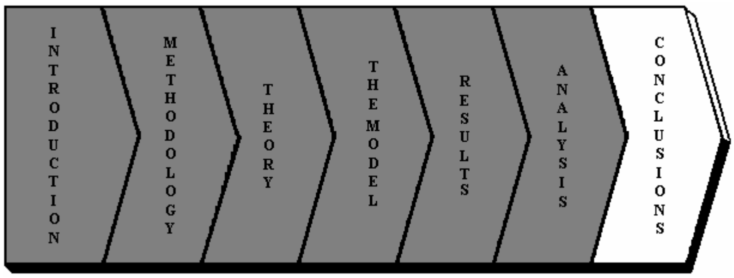
If the different model combinations are reviewed all combinations involving the Värnamo concept can be sorted out. The adding of an extra conveyor cost money but does not result in higher capacity.

Left among the combinations is then only the Single Process – RFID combination. This model has a longer cross-docking time than the original model but only require half the resources. The model is, since it requires RFID, very expensive. The investment in developing the conveyor so that boxes of all relevant sizes can be transported can in comparison with investing in RFID be considered insignificant.

This model can hold great potential and should be further investigated. The alterations suggested earlier for the Single Process model should be tested and evaluated.

[104] Sten Wandel, University Professor of Logistics at Lund Institute of Technology, 2002-05-21

VII



I think and think for months and years.
Ninety-nine times, the conclusion is false.
The hundredth time I am right.

Albert Einstein

7 Conclusions

This is the final chapter of the report and it concludes the results of the discussion in the previous chapter. Suggestions for further studies are also presented.

7.1 Conclusions

It is time to conclude what our study has resulted in. Though our conclusions are interesting to read it is your conclusions, as a reader, which really matters. So let *our* conclusions inspire you to draw your *own* conclusions.

The Original model is somewhat optimized to the basic conditions that are equal for all the models. Therefore the original model handles the competition from the other models well in terms of cross-docking time. On the other hand several of the new models require less resources and by that holds potential to enhance their performance. The original model requires one process per box size which makes it more likely to produce human errors.

In a short-term point of view it is realistic to implement the *Single Process model* if it is possible to increase the velocity of the conveyor and do a complete identification of the new bottlenecks that will arise. The model uses four resources less than the original model but gives a longer cross-docking time. In order to take full advantage of an increased conveyor velocity, part of the four residual resources can be required to counteract bottlenecks. A great advantage with loading all boxes on the conveyor is that the cross-docking process is equal for all box sizes. This results in an easier total process and decreases the probability for human errors.

The *RFID model* has the best performance of all simulation models and uses five resources less than the original model. There are signs that indicate some bottlenecks and therefore it should be studied and developed more before drawing any final conclusions. Today the technology for RFID is too expensive and the performance not good enough, but when the day comes that the price and performance on RFID is at a realistic level, the organisation and the technologies should be prepared for the new technology. A way to further study the potential of the RFID technology could be to implement it at the cross-docking centre in Copenhagen as a pilot project. This way the full scope of possibilities for the new technology will be easier to evaluate and the benefits of this project can be profited on by the whole enterprise.

In a long-term point of view the *RFID-Single Process model* is the future for the cross-docking centre. One process for all box sizes and automatic radio frequency scanning ensures that the human errors will decrease dramatically. Since the handling of the boxes gets more automated the working environment will be improved. The potential in increasing the velocity on the conveyor and reducing the cross-docking time seems to be good and should be further investigated.

One of the models does not give any changes in result and that is the *Värnamo model*. It uses one more resource and differs nothing in cross-docking time compared to the original model. All combinations involving the Värnamo concept can therefore be discarded. The adding of an extra conveyor cost money and does not result in higher capacity. The reason for the poor performance of this model is that the total cross-docking time does not decrease just because the lead time for one of the split points do.

The cross-docking centre in Copenhagen is, as the name implies, built for cross-docking operations. It is not a warehouse so no goods should be kept stock there. If incomplete orders are stored in Ireland and Tilburg instead;

- the flexibility for Dell will increase,
- the total amount of stored goods will decrease,
- the cross-docking time in Copenhagen will decrease,
- and the centre can be used as it is meant to.

This new strategy is not something that Schenker themselves can decide to implement. The cooperation with Dell is of course vital and the implementation depends on whether Dell, can / is willing to, store the goods in Ireland or not. The ideal case would of course be that no goods whatsoever had to be stored. If Dell followed their own strategy and only produced what they already had sold and did not produce half parts of orders they would, at least in theory, not need to keep a stock at all.

7.2 Suggestions for Further Studies

The objective with this master thesis is to find a packet handling that improves the effectiveness at the cross-docking centre in Copenhagen. However it is not our objective to *optimize* the new strategy we propose. The Single Process, RFID and the Single Process-RFID models seems to hold great potential. We therefore suggest that further analysis of these models should be performed in order to *find* and *remove* bottlenecks to gain the most benefits as possible from the new strategies.

The advantages and disadvantages of RFID have not been fully evaluated yet. What will an RFID implementation entail in terms of working environment and human errors? How is the radio frequency technology practically best used? These are subjects that a full investigation of the RFID technology should contain.

Table of models

The Original Model
The original model displays the flow through the cross-docking centre as it is today. The large boxes are unloaded at dock 1 and the small and medium sized boxes are unloaded at dock 2. There are three parallel flows, one for each box size (see Chapter 4.3).

The Värnamo Model
The Värnamo model displays the flow through the cross-docking centre as it would appear if an additional telescope conveyor were placed at the Värnamo dock for outgoing boxes. Except for the extra telescope conveyor the material flow the same as for the Original model (see Chapter 4.4).

The Single Process Model
The Single Process model displays the flow through the cross-docking centre as it would appear if the incoming trucks only docked dock 2 and all boxes (large, medium and small) were loaded on the conveyor (see Chapter 4.5).

The RFID Model
The RFID model displays the flow through the cross-docking centre as it would appear if the in and out scanning of the boxes were managed by RFID. This way the scanning processes do not take up any time since it is managed while the boxes are moving (see Chapter 4.6).

The Single Process-Värnamo Combination
As the name of the model implies the Single Process-Värnamo model displays the flow through the cross-docking centre as it would appear if the Single Process model were combined with the Värnamo model (see Chapter 4.7).

The Single Process-RFID Combination
The Single Process-RFID model displays the flow through the cross-docking centre as it would appear if the Single Process model were combined with the RFID model (see Chapter 4.8).

The RFID-Värnamo Combination
The RFID-Värnamo model displays the flow through the cross-docking centre as it would appear if the Värnamo model were combined with the RFID model (see Chapter 4.9)

The RFID–Värnamo-Single Process Combination
As the name of the model implies the RFID-Värnamo-Single Process model displays the flow through the cross-docking centre as it would appear if the Single Process model were combined with the RFID model *and* the Värnamo model (see Chapter 4.10).

References

Literature

Andersson D,*Third Party Logistics–Outsourcing Logistics in Partnerships*, Department of Management and Economics,Linköpings Institute of Technology,1997

Banks, J., Carson II, J.S., Nelson, B.L. *Discrete-Event System Simulation*, Prentice-Hall, Inc., 1996

Banks, J. *Getting Started with Automod*, AutoSimulations Inc., 2000

Berglund M, Laarhoven van P, Sharman G, Wandel S,*Third-Party Logistics: Is there a future?*,The International Journal of Logistics Management Vol.10 Nr.1 1999

Blom G, *Sannolikhetsteori och statistisk teori med tillämpningar*, Studentlitteratur, 1989

Bowersox, D.J., Closs, D.J., Stank, T.P., *21st Century Logistics: Making Supply Chain Integration a Reality*, Council of Logistics Management, 1999

Closs, D.J.(editor) *Journal of Business Logistics Vol. 19 No. 2*, Council of Logistics Management, 1998

Enoksson L., *ABC om streckkoder*, Mentor Communications, 1996

Holme, I.M., Solvang, B.K., *Forskningsmetodik*, Studentlitteratur, 1997

Kelton, D.W., Sadowski, R.P., Sadowski, D.A. *Simulation with Arena*, McGraw-Hill, 1998

Larsson E., Ljungberg A., *Processbaserad verksamhetsutveckling*, Studentlitteratur, 2001

Larsson, H. *Effektivare logistik med hjälp av IT*, Edifact Transport AB, 1999

Lumsden, K. *Logistikens grunder*, Studentlitteratur, 1998

Lundahl, U., Skärvad, P-H., *Utredningsmetodik för samhällsvetare och ekonomer*, Studentlitteratur, 1999

Persson, G., Virum, H., *Logistik för konkurrenskraft*, Liber Ekonomi, 1998

Rosén Peter,*Tredjepartslogistik i svensk industri-En kartläggning*,Department of Business Administration School of Economics and Commercial Law Gothenburg University, published at http://swoba.hhs.se/gunwba/abs/gunwba1999_372.htm, 2002-02-04

Rushton, R., Oxley, J., Croucher, P. *The Handbook of Logistics and Distribution Management*, The institute of Logistics and Transport, 2000

Röll, M.(editor) *Logistics – The Stinnes Magazine* Vol. 11 No. 3, 2001

Simchi-Levi, D., Kaminsky, P., Simchi-Levi, E. *Designing and Managing the Supply Chain*, McGraw-Hill Higher Education, 2000

Literature, continued

Wallén, G. *Vetenskapsteori och forskningsmetodik*, Studentlitteratur, 1996

Zhang C., *Advantage with RFID Application in B2B Logistics*, Chalmer MoP 2001:16

Interviews

Carlsen, M., Dell Department Manager, Schenker, Copenhagen Denmark, 2002-04-25

Bergling, P., PhD Student of Production Management at Lund Institute of Technology, 2002-05-21

Buus, A., Logistics Administration Front Office Dell, Schenker, Copenhagen Denmark, 2002-01-23

Grumbt, A., Consultant, Copenhagen Denmark, 2002-01-22

Jensen M., Key Account Manager, Schenker, Copenhagen Denmark, 2002-03-30

Klargaard, G., IT Development Manager, Schenker, Copenhagen Denmark, 2002-03-08

Lindgren, G., University Professor of Mathematical Statistics at Lund Institute of Technology, 2000-09-28

Lumsden, K., University Professor of Logistics at Chalmers Institute of Technology, 2002-04-30

Madsen, E., National Department Manager, Schenker, Copenhagen Denmark, 2002-01-23

Malm, A.T., University Professor of Corporate Strategy, Department of Business Administration at Lund University, 2002-01-31

Skermer, P., Hub Manager, Schenker, Copenhagen Denmark, 2002-01-28, 2002-02-04

Strandby, M., Nordic Traffic/Department Manager, Schenker, Copenhagen Denmark, 2002-01-23

Wandel, S., University Professor of Logistics at Lund Institute of Technology, 2002-05-21

Sources from the Net

http://transpondernews.com/, 2002-05-07

Nova, Schenkers Intranet, 2002-02-01

www.autosim.com, Discrete Event, vol 12, nr 1, 2000

www.dell.com, 2002-02-04

www.ise.se, 2002-05-23

www.schenker.com, 2002-02-04

www.stadskartan.se, 2002-04-01

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Appendix A1. Simulation results for the *Original Model* with different number of arriving trucks.

A1.1 Two Arriving Trucks:

Cross-Docking Time (min)	Nbr of Boxes
166.797318	1294
153.399749	1227
148.358875	1232
148.209173	1225
167.976018	1342
138.511442	1214
147.906972	1229
154.068939	1256
165.47323	1343
142.683841	1235
147.386417	1219
149.972578	1249
168.590933	1388
153.723637	1278
171.097204	1348
160.042798	1274
149.761055	1279
136.992177	1193
165.294041	1279
153.863274	1249

A1.2 Four Arriving Trucks:

Cross-Docking Time (min)	Nbr of Boxes
254.337567	2557
251.150032	2470
239.534107	2492
237.58691	2412
242.795564	2501
256.165665	2526
230.076427	2474
227.249207	2440
265.773343	2674
250.586302	2443
246.387975	2487
238.227839	2446
247.025862	2607
248.507135	2561
252.631456	2590
254.899956	2462
236.148552	2536
248.741276	2429
235.900487	2506
233.193777	2428

A1.3 Six Arriving Trucks:

Cross-Docking Time (min)	Nbr of Boxes
337.668625	3752
349.854098	3778
333.693312	3730
316.36585	3599
329.300294	3734
348.777053	3774
322.310029	3646
328.854838	3649
360.829238	3946
328.29843	3747
346.439664	3687
350.067553	3792
345.25898	3817
334.7798	3778
353.23067	3890
346.441937	3745
352.805872	3852
366.163832	3871
357.112474	3874
350.810935	3733

Appendix A2. Simulation results for the *Värnamo Model* with different number of arriving trucks.

A2.1 Two Arriving trucks:

Cross-Docking Time (min)	Nbr of Boxes
157.463779	1294
151.48369	1227
148.003866	1232
146.706405	1225
170.654991	1342
139.934135	1214
143.798351	1229
162.464019	1256
156.810288	1343
148.746372	1235
148.89886	1219
152.453934	1249
183.324962	1388
166.299483	1278
170.823655	1348
160.83433	1274
146.284457	1279
132.673096	1193
155.817578	1279
156.518773	1249

A2.2 Four Arriving Trucks:

Cross-Docking Time (min)	Nbr of Boxes
254.300995	2557
241.543833	2470
231.952816	2492
231.822967	2412
238.508129	2501
254.632745	2526
235.122136	2474
242.348214	2440
257.882946	2674
250.011621	2443
247.989469	2487
243.031412	2486
264.031248	2607
256.730611	2561
260.139355	2590
246.981337	2462
249.63162	2536
242.919339	2429
241.776444	2506
225.748422	2428

A2.3 Six Arriving Trucks:

Cross-Docking Time (min)	Nbr of Boxes
342.114222	3752
339.792694	3778
331.35655	3730
316.931055	3599
343.132196	3734
346.215125	3774
353.50494	3763
319.962418	3638
367.339977	3945
335.650491	3747
336.520324	3687
365.384731	3792
343.499029	3817
336.625053	3778
358.278109	3890
344.696951	3745
344.459265	3770
343.639798	3680
328.112431	3677
343.852799	3733

Appendix A3. Simulation results for the *Single Process Model* with different number of arriving trucks.

A3.1 Two Arriving Trucks:

Cross-Docking Time (min)	Nbr of Boxes
154.297991	1294
154.93947	1227
148.197247	1232
149.344838	1225
161.256525	1342
142.281241	1214
142.489447	1229
154.630941	1256
163.72842	1343
151.925587	1235
156.587636	1219
156.859757	1249
166.999999	1388
156.333625	1278
168.987645	1348
152.398237	1274
159.729202	1279
146.836998	1193
161.234871	1279
154.465269	1249

A3.2 Four Arriving Trucks:

Cross-Docking Time (min)	Nbr of Boxes
272.162094	2579
272.567692	2533
277.718235	2519
270.978873	2513
270.706145	2596
254.771018	2418
262.421675	2458
277.974605	2519
277.069206	2583
264.736681	2511
266.484581	2456
283.843777	2552
286.71782	2620
266.067496	2515
269.645386	2578
268.733408	2520
271.433424	2562
259.524671	2375
273.696051	2540
273.224491	2495

A3.3 Six Arriving Trucks:

Cross-Docking Time (min)	Nbr of Boxes
386.931551	3769
385.569794	3795
401.101729	3785
370.657593	3594
400.444228	3849
376.783687	3689
371.615625	3686
387.127628	3825
389.670793	3783
393.285358	3827
389.813987	3719
405.285189	3857
401.173695	3914
397.104816	3766
397.198838	3849
379.334974	3728
392.143364	3870
381.756853	3647
399.215219	3789
384.432579	3677

Appendix A4. Simulation results for the *RFID Model* with different number of arriving trucks.

A4.1 Two Arriving Trucks:

Cross-Docking Time (min)	Nbr of Boxes
131.041169	1294
124.558148	1227
119.628208	1232
121.071722	1225
134.146859	1342
120.856549	1214
117.534768	1229
123.847369	1256
133.534773	1343
119.990079	1235
125.044687	1219
125.996085	1249
139.050361	1388
125.050201	1278
135.722141	1348
127.948079	1274
126.146773	1279
116.336253	1193
129.857054	1279
120.97588	1249

A4.2 Four Arriving Trucks:

Cross-Docking Time (min)	Nbr of Boxes
220.887473	2581
218.425776	2488
219.123646	2504
220.585779	2543
220.491099	2530
215.406057	2422
219.330217	2513
214.801343	2488
231.637837	2678
211.978676	2441
216.18279	2473
216.416425	2505
231.844712	2583
208.539537	2431
229.821077	2622
223.817296	2519
212.621233	2484
213.747925	2466
222.286404	2546
218.971275	2529

A4.3 Six Arriving Trucks:

Cross-Docking Time (min)	Nbr of Boxes
317.55525	3850
305.652884	3683
320.759143	3831
315.35788	3836
311.482071	3804
304.720826	3709
304.620559	3751
316.430724	3833
318.868221	3880
301.595001	3667
311.648779	3752
327.127521	3891
320.733599	3816
309.939284	3746
326.51906	3892
308.449768	3720
303.073854	3742
313.504735	3756
322.293403	3792
314.727727	3753

Appendix A5. Simulation results for the *Single Process-Värnamo Model* with different number of arriving trucks.

A5.1 Two Arriving Trucks:

Cross-Docking Time (min)	Nbr of Boxes
158.877822	1294
153.383889	1227
157.30291	1232
153.499183	1225
160.795821	1342
151.418984	1214
145.037196	1229
153.884723	1256
163.74138	1343
150.488186	1235
151.339535	1219
152.094379	1249
166.87037	1388
147.781427	1278
163.999436	1348
150.446817	1274
152.815117	1279
146.235658	1193
157.329603	1279
150.779662	1249

A5.2 Four Arriving Trucks:

Cross-Docking Time (min)	Nbr of Boxes
274.271426	2555
278.259288	2533
273.313536	2519
273.392567	2465
271.756674	2596
262.73286	2418
268.659808	2560
267.030577	2480
282.938125	2583
267.995161	2511
266.198875	2451
288.563934	2573
290.571602	2620
267.601118	2515
273.038753	2534
272.50181	2567
268.211547	2535
251.077112	2332
278.882302	2560
266.997068	2418

A5.3 Six Arriving Trucks:

Cross-Docking Time (min)	Nbr of Boxes
392.861395	3812
394.913191	3756
401.831789	3824
379.569156	3634
398.210005	3876
382.877232	3674
394.352013	3820
377.315006	3684
399.616902	3851
390.51153	3774
385.209964	3730
408.340954	3832
404.73909	3873
385.289707	3740
400.172412	3781
401.332027	3808
394.272822	3839
362.716805	3501
402.986523	3830
378.913036	3667

Appendix A6. Simulation results for the *Single Process-RFID Model* with different number of arriving trucks.

A6.1 Two Arriving Trucks:

Cross-Docking Time (min)	Nbr of Boxes
139.581421	1294
137.181585	1227
135.975412	1232
131.888359	1225
138.955864	1342
134.115584	1214
126.442702	1229
138.953694	1256
143.866068	1343
132.61942	1235
132.829315	1219
136.243877	1249
150.645426	1388
140.487751	1278
144.838508	1348
138.049727	1274
136.505674	1279
132.559687	1193
136.334807	1279
138.299799	1249

A6.2 Four Arriving Trucks:

Cross-Docking Time (min)	Nbr of Boxes
260.531258	2579
253.56776	2487
249.897628	2475
248.179802	2465
250.317543	2553
244.02302	2416
243.925808	2454
249.641687	2497
257.899163	2551
251.926372	2511
246.55785	2461
253.282159	2469
267.953091	2620
250.655233	2476
260.995688	2565
251.09725	2516
248.219608	2520
240.093091	2382
263.665304	2575
251.517515	2449

A6.3 Six Arriving Trucks:

Cross-Docking Time (min)	Nbr of Boxes
371.609643	3819
365.388693	3713
361.629349	3698
370.234941	3754
372.527044	3825
358.901454	3691
357.168944	3677
362.241202	3716
372.99771	3744
371.346087	3777
374.572439	3764
366.654559	3701
376.77309	3868
372.409415	3755
380.255203	3842
364.534008	3706
369.77473	3819
359.701951	3606
376.047298	3727
370.834321	3747

Appendix A7. Simulation results for the *RFID-Värnamo Model* with different number of arriving trucks.

A7.1 Two Arriving Trucks:

Cross-Docking Time (min)	Nbr of Boxes
143.379145	1294
138.392531	1227
128.616725	1232
131.063174	1225
142.816826	1342
127.571573	1214
130.743309	1229
140.547441	1256
144.073229	1343
131.61188	1235
138.729644	1219
141.080936	1249
149.113836	1388
140.177459	1278
156.292422	1348
137.594431	1274
138.494276	1279
123.370773	1193
137.673657	1279
142.464358	1249

A7.2 Four Arriving Trucks:

Cross-Docking Time (min)	Nbr of Boxes
241.990887	2581
235.344159	2488
221.509252	2504
231.143608	2543
227.781828	2530
231.48916	2422
225.439155	2513
222.6667	2488
233.791181	2678
217.991785	2441
223.056077	2473
228.747231	2505
235.271281	2583
219.811408	2431
243.067112	2622
228.570371	2519
220.642463	2485
226.22001	2466
229.263676	2546
228.466116	2529

A7.3 Six Arriving Trucks:

Cross-Docking Time (min)	Nbr of Boxes
335.280847	3863
316.797318	3683
330.117033	3831
323.568907	3836
326.178843	3804
315.648723	3709
321.651733	3751
339.451754	3833
344.68314	3918
317.092944	3667
319.608444	3752
338.953642	3891
335.439672	3816
326.478515	3746
341.124132	3892
310.966528	3720
319.214407	3742
322.886513	3756
332.157259	3827
320.925756	3753

Appendix A8. Simulation results for the *RFID-Värnamo-Single Process Model* with different number of arriving trucks.

A8.1 Two Arriving Trucks:

Cross-Docking Time (min)	Nbr of Boxes
136.745927	1294
133.033305	1227
133.591334	1232
128.958167	1225
143.483349	1342
131.323331	1214
126.409225	1229
130.677084	1256
139.865967	1343
129.199009	1235
128.280046	1219
135.450751	1249
141.700032	1388
136.531579	1278
147.685193	1348
135.459069	1274
134.669961	1279
127.442023	1193
136.271396	1279
131.849382	1249

A8.2 Four Arriving Trucks:

Cross-Docking Time (min)	Nbr of Boxes
253.053265	2541
247.69351	2469
249.100632	2475
252.028362	2513
253.331684	2553
241.341134	2416
239.090415	2507
249.562109	2519
252.524801	2551
245.720947	2487
247.842908	2456
253.361908	2482
263.681244	2620
245.969996	2459
262.606689	2602
252.839676	2516
252.018307	2578
235.886298	2382
266.251202	2650
244.666129	2418

A8.3 Six Arriving Trucks:

Cross-Docking Time (min)	Nbr of Boxes
372.922898	3785
369.457554	3762
366.598208	3752
355.488887	3729
368.666267	3779
356.738375	3698
356.418983	3702
364.773803	3764
371.124595	3808
366.424907	3745
355.841118	3576
370.227307	3743
383.796267	3937
369.730639	3742
380.909433	3904
364.912943	3752
373.371543	3889
367.359179	3712
391.278086	3952
362.984849	3672