# Efficiency improvements concerning orders with mixed goods at Trelleborg Wheel Systems

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# ABSTRACT

**Title:** Efficiency improvements concerning orders with mixed goods at Trelleborg Wheel Systems

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**Problem Statement:** Make the order handling process as well as the purchasing process more efficient by constructing a loading application for transport of mixed goods in containers and trailers and to put that application in a wider packaging logistic perspective by analysing the effects of an implementation of this application.

**Purpose:** To simplify the order handling process and the purchasing process at Trelleborg Wheel Systems and further to put load optimisation in a wider perspective. The purpose is also to show ability to apply scientific and engineering methodology and ability to apply gathered knowledge and skills from courses in the education.

**Method:** This thesis is done as a Case Study in order to study real circumstances. The approach is qualitative because our aim is to understand and analyse the entirety.

**Conclusions:** Load Optimisation has never reached as high status as route planning, lowered inventory levels and Just-In-Time deliveries in order to reduce costs. In the future congestions and regulations may force companies to include load optimisation in their strategies to manage the global competition. There are however some negative sides of load optimisation such as increased noise, increased accident severity, higher material handling costs and a need for trade-offs between load optimisation and Just-In-Time deliveries and low inventory levels.

The application created during this master thesis improves and makes the ordering and purchasing process easier at Trelleborg Wheel Systems in Trelleborg. The application is created specially for Trelleborg Wheel Systems' products and therefore adapts badly to other companies and products. If used in an appropriate way the application gives answers to if the specific products fits in the transport or not. If desired the application also draws the loading pattern to give a possibility to see any free loading space.

**Key Words:** Load optimising, mixed loads, VBA, packaging logistics, simulation.

# PREFACE

This master thesis is the final part of the Master of Science in Mechanical Engineering program. The thesis is done in collaboration with Trelleborg Wheel Systems and the division of Packaging Logistics at Lund Institute of Technology.

This thesis learned us a lot about working in a project for a predestined period of time, in this case 6 months, and there are many different persons we would like to thank for their help in our learning process. First of all our supervisor Fredrik Nilsson at Lund Institute of Technology and our supervisor at Trelleborg Wheel Systems Roger Carlsson. Secondly Hans Jakobsson and Kari Kronholm and other people at Trelleborg Wheel Systems for their help with gathering information, answering questions and showing us around.

We hope that this thesis has met the expectations from both Trelleborg Wheel Systems and Lund Institute of Technology and that the result from this thesis will be used at Trelleborg Wheel Systems in the future.

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# TABLE OF CONTENTS

# 1 INTRODUCTION

*This chapter will introduce the reader to the objectives with this thesis. To simplify the understanding some background information about the problem itself and Trelleborg AB as a company will be given as well.*

## 1.1 Background

This master thesis is a compulsory part of the Master of Science in Mechanical Engineering program at Lund University. The thesis is written at the division of Packaging Logistics and in collaboration with Trelleborg Wheel Systems.

The globalisation has escalated in the last 20 years. This has led to more and larger transports. Since the beginning of the 80s transport of goods on roads has, measured in ton kilometres, increased by 45 %. In combination with increased number of cars the result is that the system of roads in Europe soon is strained to a maximum. The largest problems at the moment are in the large heavily populated industrial areas like London, Frankfurt and the Ruhr area. The tendencies shows that even more areas will have large problems with heavy traffic in the future if nothing is done.[1]

The action program to solve these problems that is being discussed by decision-makers around Europe mainly consists of environmental fees and congestion charges. There have also been discussions about restricting trucks to drive at night in some areas.[2] These suggestions of change demand a more effective transport planning as well as a maximum utilisation of the transports.[3]

In a supply chain management point of view there is more to efficient logistics than efficient transports. Loading, unloading and order handling are important parts in a wider perspective of logistics.

One way to improve the efficiency in these steps can be to implement loading optimisation software such as CAPE, TOPS and LoadDesigner. These software helps to calculate the optimal placing of goods to get maximal volume utilisation during transport.

Load optimisation software has existed for about 40 years, but it is only in the last years that they have become sophisticated enough to be used in complex industrial applications. The software simply could not compare with the human brain until now.[4] The loading optimisation technique got its breakthrough at ICA's warehouse in

[1] Schary, P.B & Skjött-Larsen, T. (2003) p 221
[2] Wandel, S. *Lund University*. 2004-01-29. Lecture
[3] Jönson, G. (2001) p 47
[4] Murray, J. (1998) *Transport & Handel*. p29

Växjö where the software was included in an automotive system for pallet picking and pallet loading.[5]

At Trelleborg Wheel Systems the container and truck loading process is complex. Large agricultural tyres are mixed with small application tyres and boxes (see Figure 1.1). This results in that the small tyres can be loaded inside the large tyres (see Figure 1.2). The effect of this is that customer service cannot predict how many tyres that fit into the containers or trailers, resulting in problems with releasing orders large enough to fully utilise the containers or trailers. Trelleborg Wheel Systems considers this order handling process inadequate and that improvements have to be carried through.[6]


**Figure 1.1 A truck loaded with goods with different sizes and shapes.**


**Figure 1.2 Small tyres loaded inside larger tyres.**

[5] Murray, J. (1996) *Transport & Handel.* p15
[6] Carlsson, R. *Trelleborg Wheel Systems.* 2004-09-24 Meeting

## 1.2 Company Introduction

The foundation of Trelleborg AB is from 10th of October in 1896 when the company AB Velox, manufacturing bicycle tubes, was founded. Trelleborg AB was founded in 1905, through a fusion between AB Velox and another rubber company.[7] Trelleborg AB's main competence is within the field of polymer materials. The Trelleborg group has approximately 22.000 employees in about 40 countries and has annual sales of 22,5 Billion. About 90 percent of sales at Trelleborg AB derive from products within leading positions. Trelleborg consists of five business areas[8]:

- *Trelleborg Automotive*, is s developer and manufacturer of polymer-based components and systems for noise and vibration damping intended for light vehicles and industrial applications.
- *Trelleborg Wheel Systems* is a supplier of tyres and complete wheel systems for agriculture and forestry machines, lift trucks and other material handling vehicles.
- *Trelleborg Engineered Systems* is a supplier of industrial fluid systems, mainly tubes.
- *Trelleborg Building Systems* is a supplier of polymer- and bitumen-based building products for sealing and waterproofing applications for both industrial and consumer markets.
- *Trelleborg Sealing Solutions* is a global supplier of precision seals for the industrial, automotive and aerospace markets.

### 1.2.1 Trelleborg Wheel Systems

Trelleborg Wheel Systems has its main market in Europe and has approximately 2.100 employees. The head office is located in Rome, Italy and production units are for example located in Denmark, Italy, Sri Lanka, Belarus, Trelleborg (until 2005/2006) and the US. There are two business segments within Trelleborg Wheel Systems, *Agricultural and Forest Tyres* and *Industrial Tyres*.[9]

*Agricultural and Forest Tyres* develops and manufactures tyres and complete wheel systems for tractors and vehicles used in agriculture and forestry work. *Industrial Tyres* manufactures tyres and complete wheels for transport vehicles at airports and ports and material handling vehicles.[10]

Further on in this report TWS is a shortening of Trelleborg Wheel Systems.

[7] Naess, K. 2004-10-27 *Trelleborgs Allehanda* pA6
[8] Trelleborg AB, www.trelleborg.com 2004-10-26
[9] *Ibid*
[10] *Ibid*

### 1.2.2 Reorganisation of TWS

During this master thesis Trelleborg AB made an announcement that the production of tyres in Sweden (Trelleborg) shall be moved to other countries due to high production costs. The reorganisation shall be finished when 2005 turns into 2006. The warehouse in Trelleborg shall not be particularly affected by this reorganisation. The results of this reorganisation are not clearly stated while this thesis was written, all facts and information about the reorganisation are estimations. What officials at TWS are certain about is that the amount of goods moving into the warehouse in Trelleborg will increase, and due to that a discussion started about expanding the original purpose of this thesis to contain the purchasing process as well. Therefore consideration to the purchasing process as well as to the ordering process was taken when constructing the application.[11]

## 1.3 Problem Discussion

The central warehouse (Figure 1.3) for TWS is situated in Trelleborg. In the warehouse, tyres, rims and tubes are stored. The customer service (Figure 1.3) is also situated in Trelleborg though there are a few kilometres distance from the warehouse to the customer service.[12]

Some of TWS's customers demand as high filling rate as possible when ordering products. TWS load the tyres in containers for those customers and the customers have to pay full price for the container whether it is fully utilised or not. Therefore the customers want to be able to lay an order and know that the container is fully utilised. In order to achieve maximum filling rate the customer service at TWS must have continuous telephone contact with personnel at the warehouse.[13] To simplify the ordering process at the customer service it would be desirable if the customer service could determine whether there is room for more tyres or if the container is full when receiving an order. It is also of importance for the personnel at the warehouse to know that an order means a full container in order to have the opportunity to prepare the loading.

[11] Carlsson, R. *TWS*. 2005-01-25 Interview
[12] Carlsson, R. *TWS*. 2004-09-24 Meeting
[13] Svensson, C. *TWS*. 2004-10-19 Interview

**Figure 1.3 The Warehouse to the left, and the customer service to the right.**

Global transportations are increasing due to the globalisation. When discussing load optimisation at TWS there are other aspects to take into consideration. What impacts does load optimisation have on transports and what are the environmental issues? A whole perspective on load optimisation could give answers to why more companies should use load optimising software in order to gain more effective transports.

## 1.4 Problem Statement

Make the order handling process as well as the purchasing process more efficient by constructing a loading application for transport of mixed goods in containers and trailers and to put that application in a wider packaging logistic perspective by analysing the effects of an implementation of this application.

## 1.5 Purpose

The purpose of this thesis can be divided into two different focuses, a practical purpose and an academic.

The practical purpose could be seen as the part focusing on TWS and the academic purpose is the part focusing on Lund Institute of Technology. This does not mean that there is a clear distinction between these two purposes. There are connections between the two purposes; the reason to the split focus is to ease the writing and the understanding of the thesis.

*Academic purpose:* To put load optimisation in a wider perspective, in the aspects of implementation results, environmental issues, packaging requirements and thereby relating load optimisation to transports globally. The academic purpose for the thesis is also to show ability to apply scientific and engineering methodology, ability to apply gathered knowledge and skills from courses in the education plus to handle and work in a large project limited in time.

*Practical purpose:* To simplify the order handling process and the purchasing process at TWS and to make the process more independent on specific persons at specific positions, also known as tacit knowledge. One way to minimise the dependence on

tacit knowledge is to create an application that simplifies the ordering handling process.

## 1.6 Demarcations

A distinction between demarcations and limitations has to be made. The demarcations consider the thesis in general whilst limitations set the standards for the application. In this chapter the demarcations will be discussed. The limitations of the application are described and discussed in chapter 5.4.

The demarcations in the thesis are:

- With load optimisation we mean the loading patterns and volume utilisation in transport. When searching literature and information using "load optimisation" the results in most cases showed information about route planning. Route planning is one way to optimise loads in transport but this thesis concentrates on optimising the volume utilisation.
- Both the application and the report are based on the organisation at TWS in Trelleborg. If the organisation is different in other parts of the world the application and the discussions in this thesis may not be applicable.
- This project is limited in time. This means that after handing over the application to TWS at the end of this project time there will not be any possibilities to follow up the implementation and the application.
- Both the application and the report only consider tyres, rims and tubes. In reality TWS manufactures and sells more products but in lower volumes and frequency.
- A deeper economical analyse will not be done. The economical aspect of this project is not desired from TWS, meaning that the main purpose is not to save money but to simplify the internal order handling.

## 1.7 Target Group

The target group for this thesis is considered to consist of three major groups:

- Students studying for a Master of Science degree concentrated on logistics and material handling who are at the end of their studies.
- The supervisor for the thesis and other people at the division of Packaging Logistics at Lund Institute of Technology.
- The people involved in this project at TWS. This group mostly consists of officials.

The report is written in a way that makes it easy for most people who has knowledge in English to understand this thesis. No particular theoretical background about the subject, load optimisation, is required to understand the report. Though the ones which have most interest in this report, will be the groups who have been enumerated above.

To understand the coding and how the application is built some programming knowledge is needed, particularly in Visual Basic, and Excel to get as much out of the application as possible. To use the application no special demands besides some knowledge about TWS's products and the ordering process will be needed.

## 1.8 Structure of the Report

***Introduction***

The introduction chapter will make the reader familiar with the objectives with this thesis. To simplify the understanding some background information about the problem itself and Trelleborg AB as a company will be given as well.

***Methodology***

In this chapter the methods for the thesis is described. It gives the reader a possibility to have an opinion on the thesis' reliability and validity. The chosen method is motivated with methodological theories.

***Frame of References***

The Frame of References chapter gives an introduction to the theoretical models used further on in this thesis. The purpose is to make the understanding of facts and discussions as easy as possible. The models are chosen to fit in the context of the problem definition.

***Empirics***

The Empirical chapter show how different processes at TWS stand today. In addition to those general empirics concerning load optimisation is explained.

***The Software Tool***

This chapter explains the structure and the algorithm of the application in order to give the reader an insight to how the application works and how to operate it.

***Analysis***

The Analysis chapter discusses and motivates the choices made during the thesis. The results and impacts of these choices are also discussed. At the end an analyse about the reliability and validity of the thesis and of the results is carried through.

***Conclusions***

This chapter explains and clarifies the results of the thesis. A reflection on the results from the authors is also included.

***Reference List***

The references used in the thesis are showed to their full extent in this chapter.

# 2 METHODOLOGY

*In this chapter the methods for the thesis will be described. It gives the reader a possibility to have an opinion on the thesis' reliability and validity. The chosen method will be motivated with methodological theories.*

The Method chosen in a project strongly connects to what type of project it is, the existing knowledge in the area and how specific the problem itself is.[14]

The aim of any research is to increase the acceptance of certain statements. Some formalised rules have been put out to simplify this work. These rules can be seen as the methodology. If the presentation of the problem is weak or general the methodology helps to specify the problem. The method chosen to solve the problem leads the research on a specific path and in that way the problem itself becomes clearer.[15]

In the last few years the information flow has sat its mark on every one of us. The information given is of differing kind, for example one minute the TV shows pictures from suffering people in Africa and the other minute we get last minute updates from the different stock markets around the world. Some of all the information we trust, others not. The same selection applies to research and education. In this aspect methodology helps to decide whether the information given or the research results is trustworthy or under which circumstances the results are reliable.[16]

## 2.1 The Different Parts of Methodology

A Danish researcher called Jette Fog once said: "Before I know what to examine, I cannot know how to examine it". By this is meant that before choosing what method to use it is important that the research area has been clearly stated. There is no clear distinction between a quantitative and a qualitative method but a rough way to separate them is to say that in a quantitative research the information is turned into figures and quantities while in a qualitative research it is the researchers' interpretation of the information that is focused.[17]

### 2.1.1 Methodological Strategies

Being a part of a project the author/authors is facing many situations of choices or alternatives and strategic decisions have to be made. Choosing a strategy for the project is crucial. There is no strategy that is "the right one" though there are strategies more suitable than others. Decisions concerning strategy are usually made

[14] Wallén, G. (1996) pp45
[15] Holme, I. & Solvang, B. (1997) pp16
[16] Holme, I. & Solvang, B. (1997) pp29
[17] Holme, I. & Solvang, B. (1997) pp75

before the actual research begins.[18] The three most relevant strategies for this kind of project are Survey, Experiment and Case Study.

This project is about load optimisation and the loading process at TWS. It is a limited process and therefore Case Study will be the most appropriate strategy for this project. Surveys as course of action are a strategy of research rather than a way of research.[19] What distinguish Surveys is the combination of wide coverage, focusing on the moment at a given time and the dependence on empirical data.[20] The point of doing Experiment is to single out individual factors and study them in detail. The purpose is to discover new relationships or properties. Experiments are usually done in order to determine reasons for changes in the objects being studied.[21]

Performing a Case Study means that research is done on a smaller limited group or occasion. A "case" could be one individual, a group of individuals, an organisation or an occasion. When doing a Case Study the approach is a whole perspective and it is often used when studying processes and changes.[22] A benefit of a Case Study is that one can see what happens in real circumstances and that an occurrence really happens. On the other hand it does not automatically say if it is a regular phenomena or if there is a chance for it to occur in other circumstances.[23] The intention with this project is also to describe load optimisation in a whole perspective and this makes Case Study suitable for the project. In exploratory research, the issue could be how or why something is being done. A Case Study method would be desirable in those circumstances because it provides depth and insight into a little known phenomenon.[24] Some of the advantages in Case Study as a strategy are that it is possible to use more than one method and the possibility to use more than one data source. Disadvantages might be that it is focusing on processes instead of measurable data and the cases' limits could be hard to define unambiguously.[25]

In this project with the characteristics given in chapter 1 a *Survey* will not give the whole perspective but Surveys, like interviews, might be a part of the project.

### 2.1.2 Methodological Approach to the Thesis

This thesis will be written with a qualitative approach. Qualitative data is based on an interpretation process; the result of the research is based on the researcher's interpretation.[26] The purpose with qualitative research is to obtain deeper understanding compared to a quantitative method. The goal is to understand and to analyse the entirety. Qualitative researches are most often used when the researcher

[18] Denscombe, M. (2000) pp 9
[19] *Ibid*
[20] *Ibid*
[21] Denscombe, M. (2000) pp 55
[22] Patel, R. & Davidsson, B. (1994) p 44
[23] Wallén G. (1996) p 115
[24] Ellram, L. M. (1996) p 3
[25] Denscombe, M. (2000) pp 52
[26] Denscombe, M. (2000) p 244

wants to find out consequences of certain occurrences and what distinguish certain events or phenomenon.[27]

The other way to approach a thesis is quantitative. Quantitative research is based on numbers and it is presented as diagrams and tables.[28] This gives the research a sense of solidity and objectiveness.[29] Quantitative methods are most often used when finding relations between two or more occurrences.[30] This thesis considers one specific case and therefore a quantitative approach is impossible. The goal is to understand the tyre loading process and to go deep into problems concerning this specific process. Instead of collecting information from many people, as would have been done in a quantitative research, some strategically important persons with essential information were chosen as informants.

The qualitative approach also results in information collected at observations. The observations will mainly be done at customers' service and at the warehouse. A quantitative research would have made these kinds of observations difficult to accomplish.

The application that is the main purpose with the thesis is meant to be used at one specific department at TWS. The consequence of this is that there is no possibility to have a quantitative approach concerning questionnaires and Surveys.

Researches done in qualitative methods are often characterised by the persons doing the research.[31] Therefore objectivity has to be something to consider all through the project.

### 2.1.3 Inductive-/Deductive Methods

One goal in every research is to gradually improve the understanding of the subject that is being studied. There are two main ways to go deeper into the subject, either the deductive or inductive way, also known as the proving or the discovering way. In a deductive research there is a logic deduction that is taken from general principles and in an inductive research specific observations leads to general principles.[32] An easier way to explain deduction and induction is to say that when the theories comes first and then the research tests these theories it is deduction and when the research results in theories it is called induction.[33] If the two ways are combined it is called an adductive approach. This is when theory and empirics are alternating through the project.[34]

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[27] Starrin, B. & Svensson, P-G. (1994) p 23
[28] Patel, R. & Davidsson, B. (1994) p90
[29] Denscombe, M. (2000) p 208
[30] Starrin, B. & Svensson, P-G. (1994) p 23
[31] Patel, R. & Davidsson, B.(1994) pp 99
[32] Holme, I. & Solvang, B. (1997) pp50
[33] May, T. (2001) p47
[34] Kirkeby, O F, (1994) pp145

The thesis is done in a strong inductive way, meaning that hypothesis and theories came during the project process. Observations and interviews as well as literature were used to form these hypotheses and theories. No theories were first formed and then tested in a strictly deductive way.[35]

## 2.2 Input Sources

In this project there are different input sources such as interviews, written material and observations. These will be discussed and analysed in this chapter.

### 2.2.1 Interviews

To use interviews as input sources to a research could seem tempting due to the similarities between a simple conversation and an interview. The problem is that an interview is not as simple as it seems. It could be a complete failure if not careful preparations have been done.[36]

Interviews are often used when a decision has been made that the information needed in the research has to be profound. There are two important questions that have to be answered before deciding to do an interview. First, does the research really need the kind of detailed information that an interview gives? And secondly, is it reasonable to rely on information collected from a small number of informants?

When interviewing to gather information no strict questionnaire is being used in this project, instead some important questions or subjects were written down just as a reminder of what to discuss. This is called a *semi-structured interview*. In a semi-structured interview the areas to be discussed are predetermined and even questions are prepared. In this case the interviewer are more flexible in letting the informant express his or her own ideas and to speak more freely about the specific area. The emphasis lies on the informant that describes his or her point of view. [37] The reasons to choose the semi-structured interviewing type is that it is easier to get the informants own opinions clearly stated as well as the fact that it is easier to go deeper into the problem with this type of interview. Our own situation also affected the choice of interview type. We will be situated at the same department as many of the people that are going to be interviewed and this makes it easier to get to a personal level when discussing a topic. A structured interview would ruin this and make it harder to get the information needed.

Another way to do an interview is to introduce the subject and then let the interviewed person/persons speak freely about this subject. This is called *unstructured interviews.* This interview method is not going to be used in this project though the semi-structured interviews could be partly unstructured. This is desirable because the interviewer wants the informant to answer in his or her own words. This often results

[35] May, T. (2001) p181
[36] Denscombe, M. (2000) pp130
[37] *Ibid*

in better answers in a complex approach to the problem.[38] In the unstructured interview the researchers role is to interrupt as seldom as possible.[39]

When doing interviews it is often important to have the informants own words. A *structured interview* means that the interviewer has a large control over the questions and answers. The interview is more like a questionnaire answered face to face. The researcher has a list of questions and the informant can only choose answers from a list.[40] The informant's opinion may not be fully described in the answers to choose from and in this project this is important. The large advantage with structured interviews is that the researcher gets standardised answers that are easy to assemble.[41] This is not significant in this case.

In this master thesis interviews will be made with Roger Carlsson (APPENDIX A), Christina Svensson (APPENDIX B) and Ingemar Thörn (APPENDIX C) at TWS.

#### *2.2.1.1 The Interviewer Effect*

One thing that has to be taken under consideration when thinking about the interview reliability is how the interviewer affects the informant. Surveys has been done that show clear connections between the interviewer's gender, age and ethnic origin and how much and honest information the informant wants to give. The effect of the interviewers identity naturally depends on what subject discussed. When discussing a personal and intimate subject the interviewer effect becomes greater. This can result in that the informant gives answers that he/she or she thinks the interviewer wants or expects. There is not so much an interviewer can do to minimise this problem but to be polite, punctual, have a keen ear and being neutral. It is all about getting the informants' respect and trust.[42]

#### *2.2.1.2 Interview Reliability*

The advantage by having an interview as an information source is that it gives primary information. The information is given to you without having to pass a middleman. This makes the information more reliable than getting it from books, magazines etc. However, it is important to remember the interviewer effect, meaning that the interviewer can affect the answers that the informer gives. It is also important to remember that the person interviewed on a specific subject are very involved and therefore can exaggerate the answers just to make his or her point clearer. Our situation at TWS helps to avoid these problems. Since we will be there often and they can see us almost every day the interviewer effect decreases.
One further way to make the information from interviews more reliable is to interview different persons in different positions and with different educational level.

[38] Denscombe, M. (2000) pp134
[39] *Ibid*
[40] *Ibid*
[41] *Ibid*
[42] *Ibid*

By interviewing both the customers' service officials and the warehouse workers information from both sides are collected. Information from persons with different approaches to the subject can in some ways conduct a reliability control on each other.

One important part of an interview is how to deal with the information given under the interview. There are different ways to make the information from interviews reliable. The best way is of course to record the interview on tape, but we have chosen to write down answers and important parts of discussions. The fact that there always are two persons doing the interview and taking notes reduces the risk of lost information. The reason why we have done this choice is that the informant does not get as nervous as when using a tape recorder.

When using information from an interview the writers must make a selection of what information to use. There is a risk that the information gets taken out of its perspective and that the writers misunderstand the informants' line of argument.[43] This has to be taken under consideration when deciding the reliability of the information.

### 2.2.2 Written Sources[44]

In the beginning of a research project it is important to study the present knowledge in the research area. This could be done by studying the available literature. The purpose of the literature study should also be to find new ways to approach the research.

In a qualitative approach to the literature it is up to the researcher to understand the context in which the text is written. This method can be seen more as a literature process. It is the researcher that selects relevant information to analyse. The researcher also put together different parts of literature to show tendencies and patterns. The advantage with this is the flexibility in the selection process.[45]

#### *2.2.2.1 Books, Magazines and Academic journals*

When collecting literature our goals have been to get information from a wide spectrum of sources. In the selection of the literature used for the project the author and publisher will have great influence. The publishing year is also something that will be taken into consideration. The purpose is to get a high grade of reliability. Literature from for example universities will have high priority due to its high reliability.

Books and magazines should be judged as all other sources meaning that not all facts written in these sources can be trusted. The researcher has to estimate the sources'

[43] Starrin, B. & Svensson, P-G. (1994) pp128
[44] Denscombe, M. (2000) pp187
[45] May, T. (2001) p232

credibility depending on the author, how old the information is and in which context the books and magazines are written.

Experts always inspect academic journals before the material is being sent to printing. This gives the reader some assurance about the quality of the material.

There is no absolutely safe way to know if a book or magazine could be trusted but there are some guidelines to find reliable books or magazines.

Concerning magazines:

- A magazine that has been put out for a long time is often more reliable than a fairly new magazine.
- If the magazine has any national connection (for example "British Medical journal) it could be a sign of "good" material.
- Who is the author?

It is even harder to decide whether the information is reliable when it comes to books, but some guidelines can be used:

- Have you heard of the publisher before?
- If the publisher is a university it could be a sign of reliable facts.
- Is the book a second or later edition? If so, it could mean that there has been a demand for new editions.
- If the book is available at libraries, how often has it been lent? This could implicate if the book has been demanded.

As said before these advices have to be seen as guidelines. There is no right or wrong when deciding how reliable information is, it is up to the reader to make up his or her own mind.

#### *2.2.2.2 Webb Sources and the Internet*

When using information sources from the Internet it is even more important to be meticulous with whom the author is, due to the fact that there is no control of what is being published on the Internet. The same guidelines as above can be used but with even greater degree of suspicion. The Internet sources in this thesis are chosen upon trustworthiness, authors such as universities could be considered trustworthy.

The subject of this thesis has made the literature search process difficult. The main problem has been to find adequate literature concerning the core problem of the thesis, load optimisation. However, some articles from different magazines have been found and will be used.

### 2.2.3 Observations

With observations the aim is to study behaviours and events in their natural environment. Observations are often used to compliment information collected with other methods and in a theoretical way decide characteristics for a specific phenomenon.[46] The observations done to collect information to this thesis can be seen as open and structured. Observations could be either open or hidden. *Open observations* are built on acceptance from object/objects on which the observations is made. Here the object/objects know that they are observed. *Hidden observations* mean that the object/objects of the study do not know that they are observed. This is a good thing when the object/objects have to act as natural as possible.[47] In this case the "objects" know that they are being observed. It is practically impossible to do relevant observations without the "objects" knowing about it. Apart from that it does not matter if the observations are open, the container loading process does not change when being observed. It is, however, important that the observations are done in a way that they do not cause interruption in the loading process. Interruptions may lead to irritation and unwillingness to cooperate in the future among the workers. The specific loading pattern does not change due to an interruption, but it is important from a personnel political point of view to avoid interruption.

There are different types of observations, *structural observations* and *unstructured observations*. Structural observations deal with observations when the behaviours and events that are going to be observed are determined in advance. Unstructured observations are used when the aim is to collect as much information as possible, "everything" has to be registered. In this thesis the observations are structured due to the fact that we knew what to observe, the loading and the loading pattern. Both types of observations needs preparations, how much varies but the amount of preparations has effect on the result.[48]

One advantage in choosing to observe instead of interview is that any possible misunderstandings due to cultural or linguistic differences gets eliminated. Instead of having someone to tell what happens you see it with your own eyes.[49]

## 2.3 Criticism of Source

When doing research it is important to keep a critical and questionable approach. Using written sources one must consider if it is a reliable source or not[50]. Here, articles, Internet sources and books coming from the university world could be considered trustworthy. Having oral sources one must consider if the person interviewed is affected by his/her role, both professional and private. Verifying the

[46] Wallén, G. (1996) p73
[47] Holme, I. & Solvang, B. (1997) pp111
[48] Patel, R. & Davidsson, B.(1994) pp 74
[49] May, T. (2001) p185
[50] Eliasson, R (1995) p135

information is a good way to get high reliability particularly when having secondary information.

### 2.3.1 Objectivity

In most projects objectivity is essential though sometimes difficult, or rather impossible, to have total objectivity in a project. Most often projects are not expressions of the whole truth; it is reality from a certain point of view. Independent of which kind of research the project is based on; sooner or later there is a point where statements are based on a normative characteristic.[51]

Though we might have some preconceived opinions about loading tyres we have no connection to TWS besides this project. That creates good possibilities for objectivity in the project. During the project our aim is to keep the high grade of objectivity.

The persons interviewed for this project, deliberately or not, are influenced by their professional role and their opinion on the activity. This is something that has to be taken into consideration when interviewing persons at TWS. Interviewed people outside TWS will probably have a high grade of objectivity.

### 2.3.2 Primary-/Secondary Information

Researchers has the opportunity to either gather new information from different sources on their own, also called primary information, or to let other people gather information for them, called secondary information. [52]

Primary information could be gathered through interviews, Surveys or observations and in this thesis mainly interviews and observations will be used to assemble primary data or information. The advantage with primary information is that it is relevant for this specific thesis and that it is up to date. The disadvantage is that it is time-consuming to gather.

Secondary information could be used to get a theoretical base as a starting point. In this project the secondary sources are just like that, to gather basic background information. The advantages with secondary information are that it is efficient in time and there is a lot of secondary information to be found. The main disadvantage with secondary information is that it could be outdated. The product data used in the software could be seen both as primary and secondary. Secondary due to the fact that it was an employee at TWS that gathered it without us being present and primary because the data was just downloaded from an ERP[53] system (Movex) without him interfering in any way.

[51] Holme, I. & Solvang, B. (1997) p 30
[52] Patel, R. & Davidsson, B. (1994) pp 56
[53] Enterprice Resource Planning

## 2.4 Validity and Reliability

Validity means that the researcher has done only the things that are predetermined and nothing else.[54] Reliability means that the research is done correctly[55], it is a measurement in preciseness of the research. This means that an experiment, test, or any measuring procedure yields the same result on repeated trials.[56]

The validity and reliability can differ between the application and the report. This because the aim with the application is to make it specifically for TWS's products and the report should put load optimising into a wider perspective.

### 2.4.1 Validity of the application

The application is the part of this master thesis that TWS has the most interest in. There are clear directions from TWS on how they want to use the application. This is of course open for discussions but clear directions on how the application will be used helps because then it is the constructors and their knowledge about programming that sets the limits for the validity. Though continuous discussions during the coding process is important in order to be sure the validity is kept, both between the constructors and TWS. Good validity affects the time spent on constructing the application. Poor validity means too much time spent on programming things that has no purpose when using the application later on.

To ensure high *internal validity*, which deals with how the study was conducted[57], focus has to be on the limitations. To few limitations in the application will affect the internal validity in a negative way. Internal validity also concerns if the authors of the study has taken alternative explanations into account when facing relationships in the study[58].

*External validity* is a way to measure whether there is possibilities to generalize the test or if it is transferable[59]. An optimising application with very high external validity would resemble the existing optimising software on the market. The problem with existing software is that they are not applicable in the case with TWS's loading process. Therefore the external validity will probably be quite low in the application, considering the mix of products at TWS. Though modifications of the application might make it possible to be useful for other applications. At least a modified application could be useful for other users having similar products.

If the application is useful when selling TWS's products it ought to be useful when purchasing the same products.

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[54] Thurén, T. (1991) p22
[55] *Ibid*
[56] Writing at CSU, http://writing.colostate.edu 2004-10-17
[57] *Ibid*
[58] *Ibid*
[59] *Ibid*

### 2.4.2 Validity of the report

To achieve a high level of validity in the report it is essential to discuss the content of the report before the actual writing process begins. Here the extra time put on preparations will pay off later in the process when this minimises the time put on removal of non-motivated content.

In order to make the *internal validity* high the preparations and the review of the finished project must be done carefully. Reviewing is something that has to be done continuously through the project.

The aim of the report is to put load optimisation at a large perspective, this means if our goal is achieved the report will have a high grade of *external validity*. Reviewing is a key factor when considering external validity.

### 2.4.3 Reliability of the application

The aim with the application is to calculate how much of each type of goods ordered there is room for in a container or a trailer. The intention is to make it easy to achieve as high filling rate as possible without too much contact between the people at the warehouse and the customer support. The reliability for the application will be shown as if the application stands the test of time. If the application works as it is supposed to do then the reliability is high.

Collecting empirical data is crucial for the reliability and a key component to achieve high reliability is the observations of the loading process. If the observations are done correctly it will be easier to recreate the loading in the application. Also the interviews play an important part in achieving high reliability. A well-structured interview helps collecting empirical data. This makes the conditions to create an accurate application higher and at the same time the reliability increases. The aspect of the user-friendliness is an important part. If the application is good at calculating the amount of goods the reliability is partly good, but if the application is complicated to use then the total reliability for the application is poor. If the coding is done correctly the result will be the same if you run the application over and over with the same mix of products, thus high reliability.

The way the orders are handled at TWS varies little over time. This is a reason to believe that the *stability reliability*, which determines whether the same test varies over time[60], ought to be high.

The ultimate test for reliability for the application is if it will stand the test of time. This of course if no outer circumstances is changed. If the application still is at use a year after implementation then one can suppose that the reliability is good and if the application still is at use five years after implementation then the reliability is

[60] Writing at CSU, http://writing.colostate.edu 2004-10-14

excellent! Here it is important to perform as many test runs as possible before handing over the application to the user.

### 2.4.4 Reliability of the report

In the whole project it is a little harder to achieve a high reliability. Our aim is to put load optimisation in a larger perspective at the same time as the focus stays on load optimisation. Much work has to be done discussing the relevancy of the sources used in the empirical part. Whether books and articles used in the project have high reliability is something that must be taken into consideration. Here the extra time put on the choice of written material will pay off in the end, hopefully in a report with high reliability.

*Interrater reliability* is the extent to which two or more individuals agree. In some cases there can be different interpretations between the authors in the writing process.[61] The interrater reliability in this report is something one can affect through discussions between the participants of the project during the whole process. Here it is important to have a continuous dialog to ensure no difference in interpretations come up in the observations and in the written material used.

[61] Writing at CSU, http://writing.colostate.edu 2004-10-14

# 3 FRAME OF REFERENCES

*The Frame of References chapter gives an introduction to the theoretical models used further on in this thesis. The purpose is to make the understanding of facts and discussions as easy as possible. The models are chosen to fit in the context of the problem definition.*

## 3.1 Excel and Visual Basic for Applications

Excel is a calculation-software from Microsoft. It is a part of the Office software package. The application is developed to calculate, write, analyse and present information and Excel uses cells to process numbers and text. Files created in Excel are called workbooks and a workbook contains worksheets. The worksheets have matrixes with cells that make it easy to arrange and sort data and text.[62]

Visual Basic for Applications (VBA) is a tool for adaptation and personal adjustments in Microsoft's software.[63] Visual Basic is a family of programming languages defined by Microsoft and VBA is one of them. With VBA it is easy to create buttons for the worksheets in Excel, which simplifies working in Excel, for example with one button one calculation could be done which otherwise would need many steps to be terminated. With VBA it is also possible to create new user forms in Excel, that might use Excel worksheets as a base. User forms could have a completely different layout, created by the VBA-developer, compared to the Excel worksheet and several user forms could be used in an application. The layout in a VBA user form could contain buttons, text-boxes etc. This makes the layout customised for the task which the application is created for.

Microsoft Office is the most commonly used office software[64] and this results in that applications made in Excel and VBA could be used in most computers without installation of any additional software.

### 3.1.1 Alternative Software

There are lots of alternatives program languages to choose from when creating software with a specific algorithm and using graphics. All of them are able to compute an algorithm such as ours and display it in some kind of graphics.

A programming language is an artificial language made for computers. There are several programming languages that are useful in expressing calculation in a computer for example Java, C++ and C#. All programming languages must be compiled or interpreted into another code, machine language, so that the computer

[62] Reading. E. (2000) p5
[63] Ek, J. Eriksson, U. Isanovic, S. (2000) p7
[64] *Ibid*

could understand the coding. Machine language consists of zeros and ones.[65] Using programming languages there has to be a compiler installed to the computer. Without a compiler you cannot produce executable software.[66]

## 3.2 Computerised Load Optimisation

When loading there are different reasons to load in a special way. The goods could be unloaded in a special order or the goods must be mixed in a special way due to safety reasons. Often there is an ambition to fill the containers as much as possible. Through times the computerised loading software has had it hard to compete with the human brain.[67]

Computerised loading help has been tested since the mid sixties. It started with a software that told what to put into a box to achieve maximal utilisation. Though the software did not tell in which order the goods were going to be put into the box or how it was going to be placed.[68] In the beginning of 70s there were computer software that displayed sketches in black and white of the loading pattern. Those software were not any success due to the difficulties to read and understand the sketches.[69] In the 90s the load optimising software has gotten easier to use and adapted to the user by using different colours and 3D views of the loading pattern.[70] But 72 percent of trucking companies in the US still (Sept. 2001) prefer using manual methods for load building.[71]

Searching on Internet one can find several load optimising software such as CAPE PACK, MaxLoad, LOADcaptin, LoadDesigner, and OptiPack etc. A quick look states that they are quite similar. The worlds two leading load optimising software are LoadDesigner and OptiPack.[72] All software displays the loading pattern in colourful 3D though they cannot manage all loading algorithms. MaxLoad do not support loading smaller goods into larger goods that have free space, for example smaller tyres or boxes into the space in the middle of larger tyres[73] neither could LoadDesigner or OptiPack.[74]

## 3.3 Optimisation and Simulation

It could in some aspects be hard to clearly distinguish the difference between a simulation and an optimisation. These concepts are described below. In many cases a simulation includes an optimisation, but not necessarily.

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[65] Wikipedia www.wikipedia.org 2005-01-20
[66] Programming FAQ http://gerek.coolfreepage.com 2005-01-20
[67] Murray. J. (1998) *Transport & Hantering.* p29
[68] *Ibid*
[69] Murray. J. (1996) *Transport & Hantering.* p15
[70] Murray. J. (1998) *Transport & Hantering.* p29
[71] Inbound Logistics www.inboundlogistics.com 2005-02-03
[72] Integrator www.integrator.se 2005-02-03
[73] Lee, E. *TOPS Engineering Corporation* 2004-10-05
[74] Sjögren, P. *Integrator Per Sjögren AB* 2004-11-03

*Optimisation* could be described as decision problems formulated in mathematical terms. The aim is to minimise or maximise a function based on certain conditions on the solutions.[75]

*Simulation* is a way to present a system with another in order to study its dynamic behaviour. Discrete simulation is a new technical and scientific method. A course by imaginable events is modelled in a computer software where a complete investigation is done by a number of simulations where the parameters are varied systematically.[76]

## 3.4 Basic Logistics

The definition of logistics, according to Council of Logistics Management, is: "Logistics is that part of the supply chain process that plans, implements, and controls the efficient, effective flow and storage of goods, services, and related information from the point of origin to the point of consumption in order to meet customer's requirements".[77] Supply Chain is the flow that is the entire set of activities involving the organisation and flow of material and other resources to produce and deliver the final product.[78] The flow of a short supply chain is displayed in Figure 3.1.

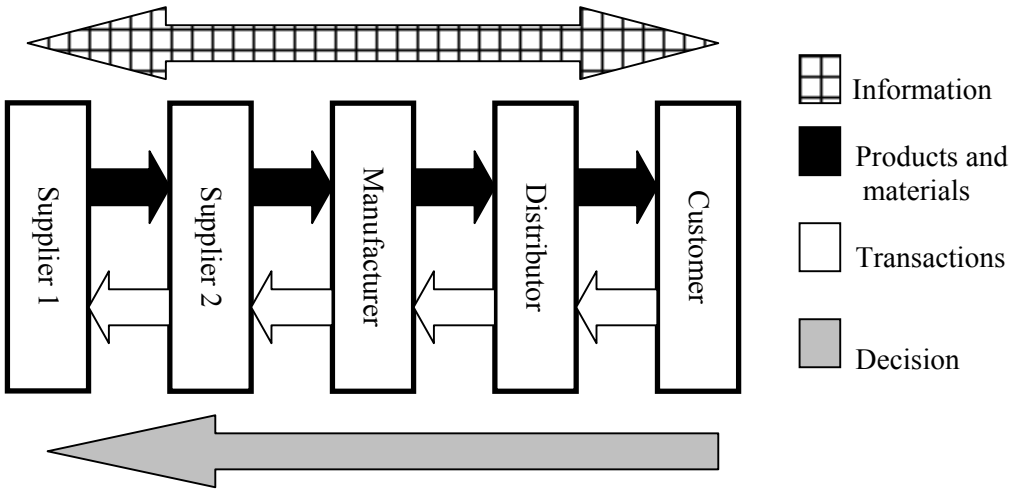


**Figure 3.1 The flow of a short supply chain with the information-, material-, transaction- and decision-flow.**

### 3.4.1 Third-Party Logistics

Third-Party Logistics means that a company leaves parts of or the whole logistic chain to another part that is specialised in logistics. This means the third-party logistic

[75] Optimization Partner www.optimizationpartner.se 2005-01-20
[76] Nationalencyklopedins internettjänst www.ne.se 2005-01-20
[77] Teknisk logistik. LTH www.tlog.lth.se 2005-01-21
[78] Schary, P.B & Skjött-Larsen, T. (2003) pp23

company can use their core competence and economics of scale to achieve efficiency. The shipper may be able to simplify and streamline routine logistic operations such as documentation, distribution planning, inventory control and personnel administration. Dealing with one or a few third-party operators on a long-term basis is more efficient than working with a number of independent companies through individual connections.[79]

## 3.5 Packaging Logistics

Packaging Logistics is defined by Dominic *et al.* as: "An approach which aims at developing packages and packaging systems in order to support the logistical process and to meet customer/user demands."[80] There are three main demands for the package to fulfil; flow, marketing and environmental demands. Marketing demands involves ways to add value to the product and make it more attractive. The environmental demands are. easy to recycle, and a package that does not use too many resources.[81]

The flow function of a packaging system includes functions that contribute to make the handling more efficient in the distribution or at the consumer. This includes: supply of packaging material, packaging activities, internal material flow, distribution, transporting, handling, storing, disposal and return handling. When packaging logistics is concerned. these following seven functions are the most important: volume efficiency, consumption adaptation, weight efficiency, process integration, usability, protection and identification. The functions support different parts of the distribution chain because of the different actors' differences in demands and requirements regarding the packaging system.[82]

### 3.5.1 Packaging system

Packaging can be classified as primary, secondary and tertiary packaging with regard to the levels of packaging, see Figure 3.2.

- ***The primary package*** is the one the consumer usually takes home, in english the package that is in contact with the product[83]. Its main purpose is to make the product accessible and at the same time protect and keep the properties of the product[84].
- ***The secondary package*** contains several primary packages. Secondary packages should make the handling of the products more effective. It can sometimes be designed for placement directly on the shelves in the retail stores.[85]

[79] Schary, P.B & Skjött-Larsen, T. (2003) pp 226
[80] Dominic. C *et al* (2000) pp32
[81] *Ibid*
[82] Dominic. C *et al* (2000) pp50
[83] Saghir. M (2004) p7
[84] Dominic. C. *et al* (2000) p24
[85] *Ibid*

- ***The tertiary package*****,** also called transport packages, is used when a number of secondary packages are assembled on a pallet or a roll container[86].

There could obviously be more levels than shown in the figure.[87]

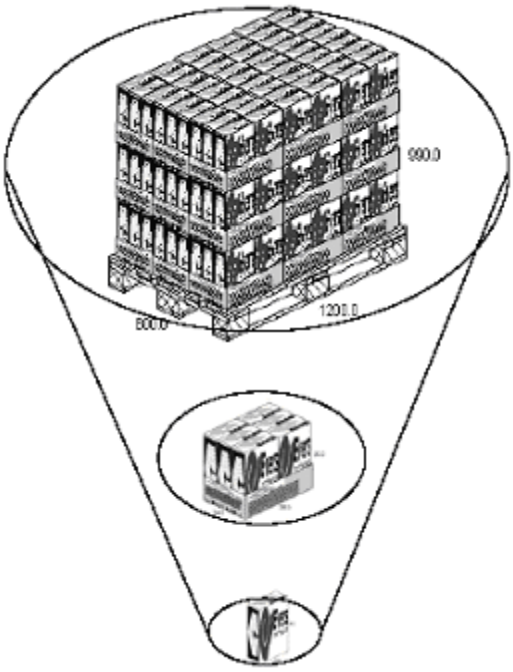


**Figure 3.2 The different levels of packages. The primary package on the bottom and the tertiary on top.[88]**

A packaging system has five different categories of purposes; to hold the product directly (the primary package), to display information about the product and the handling, to protect from leakage of the content and give protection from the surrounding environment, make handling and transports easy and finally to display the product and its brand as a marketing tool.[89]

Different actors in the supply chain have different demands and needs on the packaging system. Most often there has to be trade-offs between the different needs.[90] For example people at the warehouse might want lots of protection for the pallets to ease the handling when the products are sensitive to impacts and on the other hand the retailer do not want to much protection cause this makes the unpacking difficult.

[86] Saghir. M (2004) p210
[87] Dominic. C *et al* (2000) p27
[88] Saghir. M (2004) p210
[89] Jönsson & Johnsson (2001) pp24
[90] Saghir. M (2004) p93

### 3.5.2 Volume Efficiency

Volume efficiency is defined as a total measure for the utilisation of total available volume from packing to consumption. Volume efficiency is measured in filling-rate. There is inner- and outer filling-rate where outer filling-rate is the relation between the actual packaging unit and the available volume in for example a pallet. Inner filling-rate is the relation between the outer volume of the package and the volume of the product. Having a high degree of filling rate saves resources, both economical and environmental.[91]

To achieve better filling rate there is a possibility to use a load optimising software (see chapter 3.2). An example is disposable paper cups from Duni. After using CAPE PACK to optimise their packages they changed the loading patterns, both for the mugs in the cartons and the cartons on the pallets. The result was an increase of 50% with mugs per pallet and they went from 11 000 pallet per year to 7 000. This corresponds to 1,6 million SKR per year saved from a single product, Figure 3.3.[92]

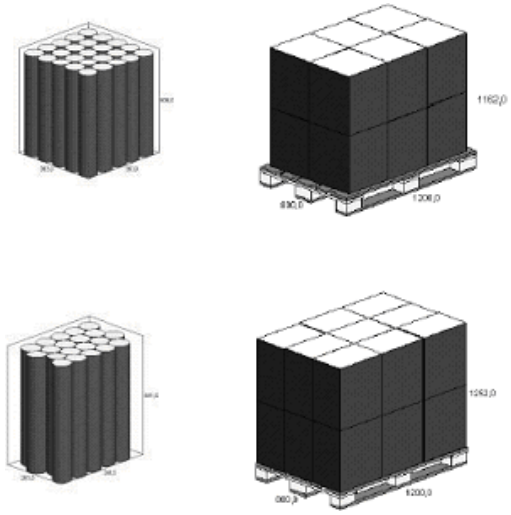

**Figure 3.3 Efficiency improvements at Duni AB. The improved loading pattern is below the old loading pattern.[93]**

## 3.6 Strategy of Change

Through the years companies in general have been focusing on *what* to change in their organisation to become more effective, profitable and competitive. Not much effort has been put down to look into *how* to implement these changes to get the

[91] Dominic. C *et al* (2000) pp61
[92] Dominic. C *et al* (2000) p70
[93] Packforsk www.packforsk.se 2005-02-10

desired results. The last few years however, the implementation problem has gained more interest.[94]

### 3.6.1 Organisational Changes

To make the process of change effective there are three important things to consider:[95]

- The people involved must understand what is causing the change.
- The people involved must accept the change.
- The solutions must be of good quality.

A combination of these three statements is a principle for how effective changes occur. A general understanding of the problem among workers is necessary to get acceptance. It is also important to be able to deliver a quality solution.. Acceptance could also be the outcome of threats but in the long run threats tend to lower the morale and increase unwillingness to future changes.

Before implementing a change process it is important to carefully consider the effects the process have on different parts of the organisation. The cost for the process in strictly financial terms might have been considered but it is important to also take in consideration the cost in terms of management time. One other thing that must be considered is that implementation of the change process and the day-to-day ordinary work in some cases ends up in conflict with each other. To manage to fulfil the day-to-day operations workers might need to put the changing process aside.[96]

### 3.6.2 Two Different Strategies of Change[97]

An American study was conducted to see why the number of companies that failed with their processes of change was high. The outcome of that study among other things was a separation of two different types of strategy. The study made a distinction between a programmatic change process and a learning change process.

The programmatic process is control and order. The aim is to go from a starting point to an end point in planned and controlled steps with as little interruption as possible. The strategy is based on the starting and the end point of the changes, the distance between going from one point to another should be as controlled as possible through planning and regulations. With this strategy it is not unusual to copy other companies changing processes.

The learning strategy of change is not only based on getting the goals of the change fulfilled. In this strategy it is important that the whole organisation, from workers to officials, learn from the changing process. The whole organisation should be involved

[94] Rendahl, J-E. (1997) pp11
[95] *Ibid*
[96] Johnson, G & Scholes, K. (2002) pp537
[97] Rendahl, J-E. (1997) pp15

in the process of creating goals for the changes. This strategy at its best encourage the organisation to be more active in the learning process as well as in the goal oriented change process.

### 3.6.3 Implementation[98]

The theories concerning IT implementation in organisations are weak and would need more research to be clarified. The information available mainly concerns large and advanced IT systems being implemented in large organisations. The problems occurring in those cases also exists in smaller organisations with less complex IT system. The difference is the magnitude of the problems.

One perspective to see the IT implementation from is diffusion. Diffusion means communication about new ideas, technologies or processes. An article by Russel and Hoag states; the diffusion and the rate of adoption to a new system depend on different factors such as organisational factors, communication channels, leadership factors and perceived attributes of the innovation. Each factor contains a number of variables that have either positive or negative influence on the adoption rate. The relevant variables for this thesis are among the leadership factors (management level support and opinion leaders) and the perceived attributes of the innovation (relative advantage, compatibility and complexity). By relative advantage means the degree to which the perception of an innovation is better than the idea it replaces. Compatibility is the perceived degree to which the innovation is consistent with the existing values and needs. Complexity means to which extent the innovation is considered difficult to understand and use. Compatibility and relative advantage has a positive influence on the adoption rate while complexity has negative influence. The perceived attributes of the innovation can however change over time even if the innovation itself does not. Over a period of time, retailer perceptions of EDI[99] changed until it was perceived having relative advantage and compatibility instead of being complex. The leadership factors, management level support and opinion leaders, has gained interest in the most recent studies. The influence the management support has on adoption rate has been well understood. But it is also the opinion leaders at a lower rung that has great influence on the adoption rate. Positive discussions about the innovation among lower rung personnel could influence the adoption in a positive way.

[98] Russel, D & Hoag, A. *International Journal of Physical Distribution & Logistics Management* (2004) pp 102
[99] Electronic Data Interchange

# 4 EMPIRICS

*The empirical chapter will show how different processes at TWS stands today. In addition to that general empirics concerning load optimisation will be explained.*

## 4.1 The Logistic Flow of TWS

TWS is a global company, and this means that TWS manufactures their products and have customers all over the world. Most of the logistics is outsourced; an outsider company often runs both transports and warehousing. In numbers 100% of the transports and 50% of the warehouses are outsourced.[100]

### 4.1.1 Geographic Locations

TWS's products are manufactured on four continents. Large quantities are made in Belarus and Sri Lanka and the Belarus factory is increasing its amount of tyres manufactured for TWS. There are also factories in India, USA, Korea, China, Taiwan, Sweden and Italy manufacturing TWS's products. The Italian factory is the largest one considering the value of the total goods.[101]

There are two large warehouses for TWS's products, the one in Trelleborg and one outside Rome in Italy. The amount of goods going out from the warehouse in Trelleborg is approximately 12 000 tons per year and 15-20 trucks leaves the warehouse in Trelleborg each week with tyres, rims and tubes (2004). The warehouse in Italy sends about 30 000 tons per year. There are also some warehouses in for example Germany. [102]

TWS have sales companies on all continents. In Europe there are sales companies in Germany, France, England, Spain, Sweden etc. There are also sales companies for example in USA, Brazil, South Africa, Australia, Russia and Singapore.[103]

A map that displays the locations of TWS's production plants and sales offices could be seen in Figure 4.1.

[100] Carlsson, R. *TWS*. 2005-01-25 Interview
[101] *Ibid*
[102] *Ibid*
[103] *Ibid*

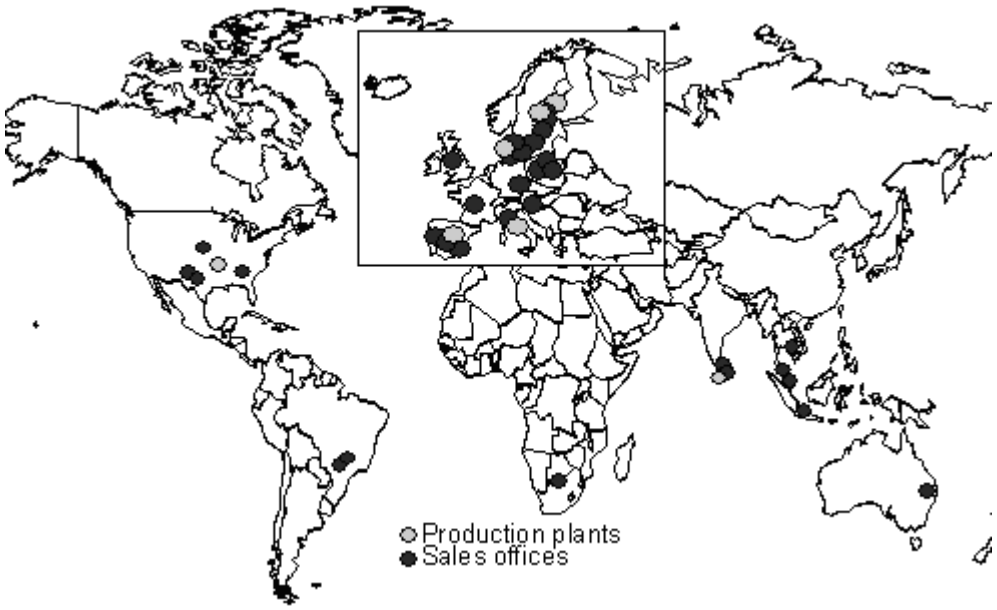


**Figure 4.1 Production plants and sales offices globally.**

TWS has customers and retailers all over the world. About three quarters of the sales is in Europe and North America, but Asia is also large markets for TWS's products.[104]

### 4.1.2 Flow of the Products

The material flow into the factories mainly consists of bulk products such as rubber material. Most of the goods go from the factories to the warehouses in Trelleborg and Italy though if a customer or a sales company orders large quantities they get their goods directly from the factory. Depending on the contract, the sender sometimes pays the freight and sometimes TWS has to pay the freight. Forecasts are made once a year based on sales previous years and expected sales. TWS lets the manufacturer know how much they are expected to buy that year to make it easier for the manufacturer to plan the production. TWS then places their orders, as the need come appear.[105]

The warehouses send most of their goods to the sales companies all over the world. If a customer is ordering large quantities the warehouse delivers directly to the customer, for example orders larger than 200 kg from a customer in Germany is delivered directly. In Scandinavia the warehouse in Trelleborg sometimes deliver directly to retailers, if they have large orders. The customer can choose if he/she want the products palletised and wrapped in plastic. The recipient pays the freight of the

[104] Trelleborg AB, www.trelleborg.com 2005-01-26
[105] Carlsson, R. *TWS*. 2005-01-25 Interview

goods from the warehouses and this means that they desire as high filling rate as possible.[106]

The products all gets a label containing information about the product, for example article number and buyer before being sent from the warehouse. The containers and trailers also gets a label that shows destination, buyer, seller and what products to be freighted.

Sales companies deliver to the customers and retailers and a visualisation of the whole product flow could be seen in Figure 4.2.

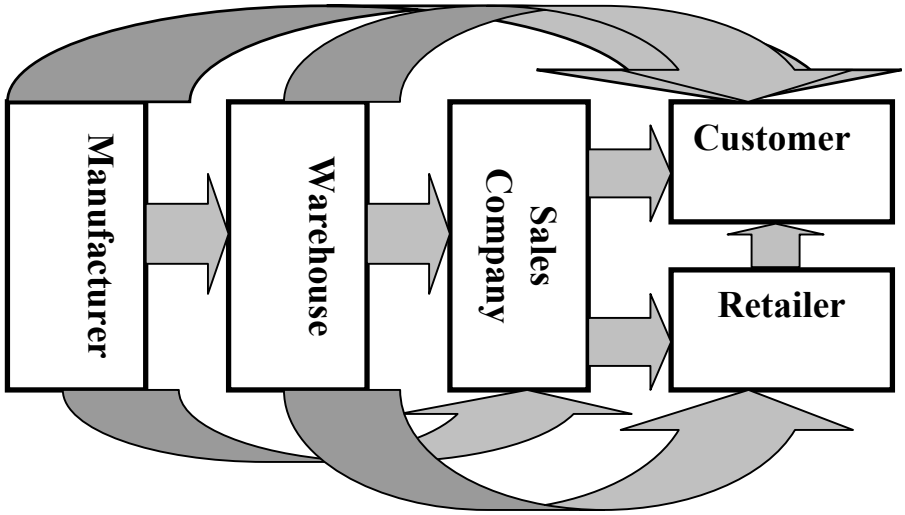


**Figure 4.2 Flow of products at TWS.**

### 4.1.3 Reorganisation of TWS

At present date there is production of tyres in Trelleborg but during 2005 the production will be relocated to other factories. This involves 156 employees being forced to quit their jobs.[107] From the tyres manufactured in Trelleborg about 80% will be manufactured in Belarus, and 20 % manufactured in a new factory in India. This means that the inflow to the warehouse in Trelleborg will increase and as a result of that the purchasing process will increase their work.[108]

### 4.1.4 Third-Party Logistics

At TWS third-party companies run most of the warehouses and handling the transports around Europe. The advantages in using a third-party company is that TWS only have to pay for the quantity stored or transported, eliminating fixed costs. The

[106] Carlsson, R. *TWS*. 2005-01-25 Interview
[107] Trelleborgs Allehanda www.trelleborgsallehanda.se 2005-01-27
[108] Carlsson, R. *TWS*. 2005-01-25 Interview

disadvantages might be that there is more personnel turnover in a third-party warehouse and hired personnel have no particular relationship to the products. Trelleborg AB owns the warehouse in Trelleborg.[109]

## 4.2 Ordering Process

One person at the customer services mainly handles the ordering process at TWS. The person is located at the office building a few kilometres from the warehouse in Trelleborg. The orders most often come via e-mail or phone[110].

One container load often consists of many orders going to the same destination. This because one order seldom fills a whole container. At the destination the different orders in the container are split for further transport to their final destination. The customer service collects orders and when the collected orders to one destination are enough to fill or almost fill one container the orders are sent to the warehouse. The collected orders come with instructions to the warehouse on what kind of container and when to load it. When the collected orders to one destination are only almost filling a whole container, according the customer service, there is a dialogue between the customer service and people at the warehouse and decisions are made jointly on what size to use and what products to use as so called fill-up products to achieve as high filling rate as possible in the container. The fill-up products are products that is in the order that the customer have large turnover for and a few more does not matter. Then an order confirmation is sent to the customer and a copy is sent to the warehouse as well. The order confirmation contains for example information about price, destination and the quantity ordered, including additional items, and here one could see if anything is assembled. An order confirmation could be seen in APPENDIX D.[111]

## 4.3 Purchasing Process

As could be seen in chapter 4.1 the logistic structure of TWS is complicated with suppliers all around the world. This put special demands on the purchasing officials, for example one supplier responded to a question about when the goods could be in Trelleborg with a date (28), but without specifying in which month.

### 4.3.1 Today

The purchasing orders are primary based on historical data but also on prognosis of future sales. An official assemble all these data and comes up with a purchasing proposal to the purchasing staff based on a month sales. The purchaser then tries to put out orders to resemble the proposal. But depending on which supplier the order goes to, different safety margins when to release the order is used. Through

[109] Carlsson, R. *TWS*. 2005-01-25 Interview
[110] Svensson, C. *TWS*. 2004-10-19 Interview
[111] Carlsson, R. *TWS*. 2004-09-24 Meeting

experience TWS has learned which suppliers have high delivery precision and thereby sufficient safety margins could be used.[112]

TWS does not have standard rules for how to do with the freight cost. In about 50 % of the deliveries TWS pay the freight cost and in 50 % of the deliveries the supplier pay the freight cost. I a way TWS always pay for the freight, either by direct freight costs or. Indirect. by higher product costs. Therefore the container utilisation during transport is important in an economical aspect. The transports of tyres are expensive in relation to the value of the transported goods. When transporting goods from the factory in Sri Lanka to Trelleborg the transport cost is 10 % of the total order cost. To assure that the containers are fully utilised during transport TWS uses something called "fill-up size", see chapter 4.2.

### 4.3.2 After Reorganisation

The reorganisation itself will, according to Roger Carlsson and Ingemar Thörn, not lead to any significant difference in the purchasing process. The flow of products internally will, however, to a large extent increase. The production in Trelleborg will mainly be moved to Belarus and the products will then be transported to the warehouse in Trelleborg. The amount transported to Trelleborg each year will be approximately 350 trailers. All these products must be purchased from Belarus, so the purchasing officials will have to carry a greater load.[113]

## 4.4 Transports

Today we are allowed to travel freely almost everywhere in the world. Within the EU the movement of both people and goods are extremely free. The total freedom within the EU has its price; the possibility to move freely is threatened by the freedom to move itself. Every day there are traffic congestions on approximately 7500 kilometres of the main roads in the EU. This causes costs in many aspects, for example time, fuel and environment.[114]

It is not only the roads that have problems with congestions; even freights over the sea experience the congestions. For example at the west coast of the US where the ports are busy and has problems to expand further. Therefore companies, for example Toyota, have started to transport their goods to Mexican harbours instead, and then transport it further on to the US by train. By doing that the companies save money and have the opportunity to expand their activity near the harbours.[115]

[112] Thörn, I. *TWS.* 2005-01-26 *Interview*
[113] *Ibid*
[114] Europa vid ett vägskäl, www.europa.eu.int 2005-01-27
[115] Logistics Today – A cure for west coast congestion, www.logisticstoday.com 2005-01-28

### 4.4.1 Transport utilisation

The most obvious form of transport under-utilisation is empty running. About 30 % of the truck-kilometres are empty running, but this differs a lot from country to country. The percentage of empty running is however slowly declining. For example if the percentage of empty running in Great Britain had stayed on the same level as in 1980 (32,6%) the carbon dioxide emissions 1991 would have been 1,6 million tons greater.[116]

Most of the available statistics concerning loading factors are based on weight usage and not volume utilisation and thereby little research has been done on space utilisation of vehicles. But in a study conducted in Sweden and the Netherlands a couple of experts were asked about the volume utilisation on transports not filled. The volume utilisation then was very low, about 28 %. The study also showed that in these cases about 80 % of the deck area was used. This means that it was the height of the transport that was badly utilised; only about 47 % of the height was used. In a study on grocery distribution the calculations showed that there were (1997) 15% extra grocery trucks on the European roads as a result of poor height optimisation.[117]

One thing that should be clearly stated is that there is a weight limit for transports. If the weight is the maximum allowed there is nothing to do about the volume utilisation.

In reality it is not always that simple to optimise the transports. Tradeoffs between transport efficiency, “Just-In-Time” deliveries and inventory costs have to be done. The last few years the trend among companies has been to reduce inventory levels, which has a negative effect on transport utilisation.[118]

### 4.4.2 Environmental effects

The environmental effects caused by transports are strongly connected to the congestions (Figure 4.3) on the transport net. The congestions in EU causes the fuel costs in Europe to increase by 6%, and thereby the pollution increase by the same figures due to the congestions.

[116] Hensher, D & Button, K. (2003) pp674
[117] *Ibid*
[118] *Ibid*

**Figure 4.3 Congestions cause increased fuel costs by 6% in EU.[119]**

The transport sector alone stands for about 28 % of the carbon dioxide discharges (see Figure 4.4) in the EU and road transports stands for approximately 84 % of these carbon dioxide discharges. If the trend of today continues the pollution with carbon dioxide related to transports will be 40 % higher 2010 than 1990.[120]

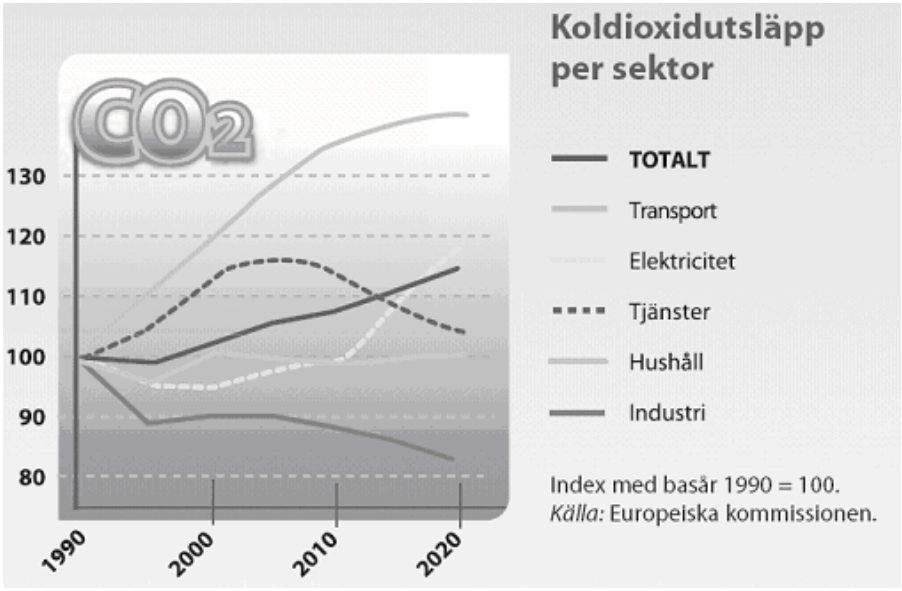


**Figure 4.4 Carbon dioxide discharges divided into sectors. The sectors described to the right are Total, Transport, Electricity, Services, Households, and Industry. [121]**

[119] Europa vid ett vägskäl, www.europa.eu.int 2005-01-27
[120] *Ibid*
[121] *Ibid*

The environmental problems caused by freight transports are most obvious in the urban areas, with high traffic density and large populations. The logistical trends has both decreased and exacerbated the problems. One thing that has made the traffic situation worse in the urban areas is the trend to have smaller back storeroom and thereby a lower level of inventory in the shops. That demands more frequent deliveries with smaller quantities. On the other hand many grocery companies in Europe and the US have increased their control over the shop deliveries using large distribution centres. The result of that are reduced emissions of carbon dioxide and other noxious gases. But there is, however, not only a positive side of these changes. By coordinating the grocery deliveries the trucks used in the cities are a lot larger than they used to be. The two alternatives to choose among are to have fewer but larger trucks or a larger number of smaller trucks. The "many small, few large" dilemma is complicated by the fact that some environmental effects (air pollution, accidents levels and traffic congestion) correlate mainly with vehicle numbers, while others (noise, vibration and accident severity) are a function of vehicle size and weight. As the technology in making engines less noisy and vibrating moves forward the trucks can get larger and larger without increasing the level of noise and vibration.[122]

## 4.5 Load Optimisation at TWS

When loading goods at the warehouse in Trelleborg the loading staffs are using different ways to fit in as much goods into the containers. For example are there lots of different sizes on the tyres and to achieve as high filling rate often it is possible to put things into the hole of the large tyres. Also most tyres, which are not assembled with the rims, could be compressed both in width and in the diametric dimension. Most often are there two persons loading a container/or trailer, one manoeuvring the forklift and one assisting. The person in charge of the loading uses his long working experience when loading tyres as optimal as possible. At the loading there are other aspects to take into consideration, a too complex loading pattern would increase the time of loading and it might make the unloading too hard.[123]

[122] Hensher, D & Button, K. (2003) pp680
[123] Carlsson, R. *TWS.* 2004-09-24 Meeting

# 5 THE SOFTWARE TOOL

*This chapter explains the structure and the algorithm of the application in order to give the reader an insight to how the application works and how to operate it. The text could in some parts be hard to understand but the pictures are there to help. A manual for the application could be seen in APPENDIX E.*

## 5.1 Ordering process with the application

When the customer service gets an order they create a new destination in the application or use a destination saved in the application, Figure 5.1.

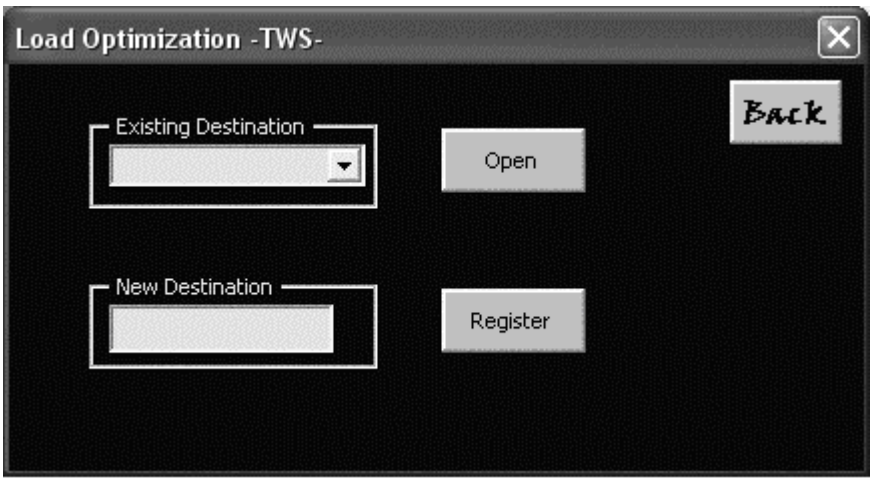


**Figure 5.1 In this form the user choose if it is a new or existing order.**

From this form the user will reach the optimisation form, Figure 5.2. In this form the user can add the products from the order. Here displays whether the goods added will fit into the chosen type of transport or not. On the form the length utilisation could be seen in percent of the trailer/container's length that is utilised by the goods. If there is space left in the container the user could either await next order to the destination or add more items to the orders until the container is full. If the container is full the orders could be sent to the warehouse and a container could be ordered. If the container is overloaded the goods that did not fit will be displayed to the right on the user-form and the user could remove items until it is not overloaded. When the destination is fully booked it is possible to display the container loading graphically. Then it is possible to print the pattern to be sent to the warehouse. After the orders for a specific destination is sent to the warehouse, thus the container is full and the destination is "finished", the user can delete the whole destination.

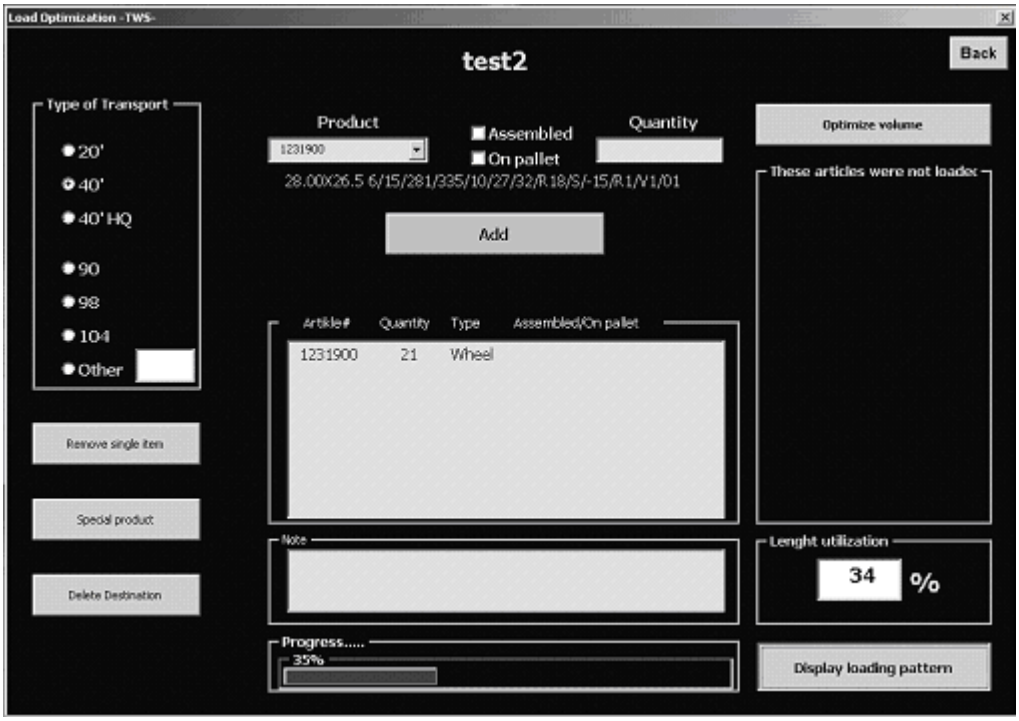


**Figure 5.2 The optimising form.**

In the optimising form it is possible to remove a single item or several items. It is also possible to remove the whole destination. There are different choices to be made before an accurate optimising could take place; what kind of transport, if the item is assembled or not or if the items should be on a pallet. There is also a possibility to add a special product, a product that is not in the product catalogue by pressing the "Special product" button, then the user have to apply the properties for the product in the form popping up, Figure 5.3.


**Figure 5.3 The Special Product form where it is possible to add a product that is not in the catalogue.**

When the application starts the user has to choose if he/she is going to add an order/optimise or do an update of the product catalogue. If add an order/optimising is desired the procedure is as described above. Otherwise the user will get a form where he/she has to choose whether to remove a single product, add a single product or update the whole product catalogue.

A scheme of the structure of the complete application can be seen in APPENDIX F.

## 5.2 Application Algorithm

The application's algorithm is based on how the warehouse workers load the containers and trailers. The algorithm has been created through observations at the warehouse as well as through discussions and interviews with both officials and warehouse workers.

The application algorithm is divided into two large steps:

- Assembling tyres to optimised piles.
- Container loading.

These steps mean that the application first optimises the tyres in height to utilise as much of the container height as possible before starting to load the tyres in the container.

The different steps are described more detailed below.

### 5.2.1 Assembling tyres to optimised piles

The application assumes that every tyre should lie down and be assembled to piles. Piles are created of tyres starting with the largest tyre. Largest means largest in the aspect of diameter. A pile is created if the total number of the specific tyre creates a pile higher than 1 meter (see Figure 5.4). If not, the application moves on trying to create a pile of the second largest tyre. If it is possible to create a pile, then as many piles as possible due to the height of the container is created.

When a pile is created the application checks if there are any tyres in the order that fits inside the pile. If so they are added to the pile. A pile can only have tyres inside if the large tyre outside is not assembled as a complete wheel with rim and tube.

The next thing checked is if any smaller tyre fits on top between the top of the pile and the roof of the container. In that case they are added to the pile and if possible filled with smaller tyres.

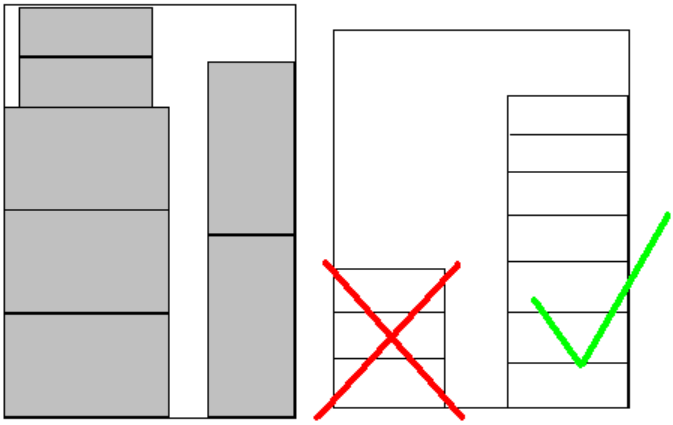

**Figure 5.4 To the left, smaller tyres are loaded on larger tyres and tyres are standing beside them. To the right, the piles must be higher than 1 meter.**

In this way the application goes through all different tyres in an order and creates piles. In the end the tyres that cannot create piles will be left standing upright. These tyres are created as areas with the height of the container as a limit to how many tyres that can be standing on top of each other.

However some customers want to receive their tyres on pallets. In that case the application calculates how many tyres that fits on a pallet and how many pallets the order quantity creates. The application creates these pallets as areas. The next step in this algorithm put tyres that fit on top of the pallets. The tyres put on top of the pallets is then filled with smaller tyres if possible.

Customers can also order tubes in different quantities. The application then calculates the number of cartons of tubes and then how many pallets needed to put the cartons

on. If the number of cartons is less than 15 they are not taken under consideration during the loading operation. This decision was made together with both officials and warehouse workers in a workshop (APPENDIX G). The warehouse workers pointed out that if it is less than 15 cartons there are always places to put them. The pallets with tubes are then created as areas just like the tyres on pallets. Similar to the tyres on pallets, tyres that fit on top of the tube pallets are put there and are then being filled with smaller tyres.

The piling algorithm could seem complicated, but all these steps are necessary due to the complexity in the product flora.

### 5.2.2 Loading Algorithm

The algorithm for loading the container has been carefully thought through and discussed with both officials and warehouse workers several times before it was implemented in the application. A comprehensive discussion about the loading algorithm was held at the workshop. The aim was to come up with loading patterns that resemble the loading operation today.

The application seeks to place first a pile and then an area all the time. It starts with the largest pile with consideration taken to its diameter and places it in a corner at the bottom of the container. Then the largest area is placed in the opposite corner at the bottom of the container. The area between these two are then filled with the largest pile or area that fits. This can be seen as one cycle of the algorithm.

Then it starts all over again. The largest remaining pile is put as far into the container as possible but at the opposite side from the other large tyre. After that the largest remaining area is put at the opposite side from the other area, then the space between is filled with as large piles or areas as possible. Two cycles has now been completed, see Figure 5.5. This is the main loading cycle and it continues until the container is nearly full.

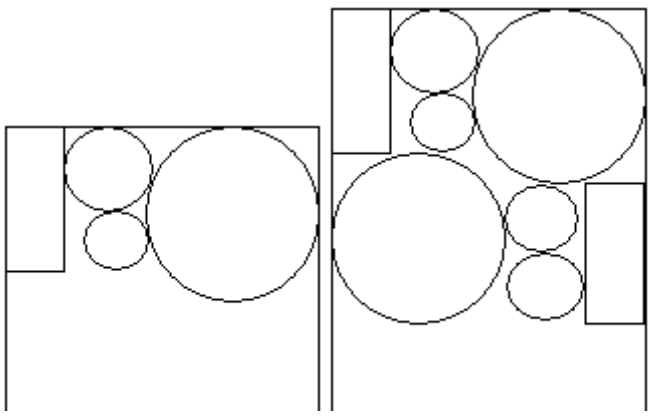

**Figure 5.5 Loading after one respective two loading cycles.**

When the container is almost filled and there is no room for more areas or piles the areas is turned 90 degrees and then tested again to see if there is enough space for them, see Figure 5.6.

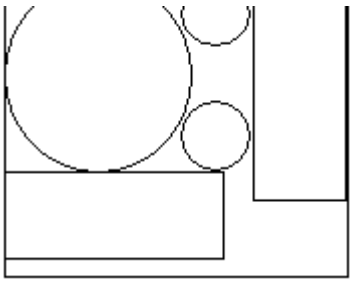

**Figure 5.6 90 degrees turned area at the end of loading.**

If there are piles that have not been placed in the container when it is full they are split and turned into standing tyres (areas). The loading algorithm then starts all over again. The application tries to load the container five times or until all products in the order is placed in the container.

The algorithm described is the basic part of the loading. However, to find the best way of loading, the application does two different loading algorithms and then decides which one is the best. The two algorithms differ only in the sequence when the space between a pile and an area shall be filled. The first algorithm is searching for the largest remaining pile that fits in that space and then if there is no pile that fits the areas are searched through. The second algorithm fills the space the opposite way around, thus starts with the areas and if no one fits continues with the piles.

## 5.3 Problems Encountered

During the process of creating the application some problems were encountered. These had to be solved either by making a limitation in the application or a generalisation through discussions with our supervisors. This chapter will show and discuss these problems in order to show the complexity in the application and in the container loading process.

Our largest problem with constructing the application was the difference in softness between the tyres. Some tyres are very rigid and impossible to compress, and other tyres can hardly stand its own weight. This fact has great impact on the container loading. When loading the container the workers use the forklifts and press the tyres together to make room for more tyres. A soft tyre could be pressed to about 80-85 % of its original width. On a tyre with a width of 70 centimetres that is 10-14 centimetres. With three of these tyres piled on top of each other that make 30-42 centimetres of extra piling space. Through discussions with both officials and warehouse workers during the whole process of constructing the application a generalisation was made. An official went through all the tyres in the product

catalogue and decided whether the tyre was compressible or not. If the tyre is compressible it had to be decided which rate of compressibility it has. An agreement was made to only use three steps of compressibility: 5 %, 10 % or 17%. Test runs in the application showed that with the softest tyre the compression had to be 17 % to fit the right amount of tyres in the container. The most appropriate way would be to go through all the tyres and test them in the application to know the exact compression, but that is time-consuming.

One other thing that made the process difficult was the complexity of the container loading. The products have a wide range of dimensions, from large agricultural tyres with a diameter of approximately 2 meters to small tyres with diameters of 20 centimetres. This made it difficult to make generalisations. TWS also delivers tubes and rims either sold separately or assembled to complete wheels. In most cases the tyres and wheels are delivered without lying on a pallet but some customers specifically asks for the tyres or wheels to be delivered on a pallet. The tubes are sold in cartons, and if the number of cartons is small the workers at the container loading said that no consideration had to be taken to the cartons, there are always spaces to put them. That meant that somewhere a line had to be drawn when to take the cartons into consideration when loading the container. Through discussions with both officials and warehouse workers we came to the conclusion that if there are more than 15 cartons they were put on a pallet, but the maximum number of cartons on a pallet is 25. So if there are 30 cartons 25 of them are put on a pallet and 5 are not taken under consideration.

Another problem that came across was the fact that the interaction between Excel and VBA is time consuming. This shows when for example changing in the product catalogue, reading data from the product catalogue and when VBA shall draw the graphics of the loading pattern. Especially the drawing part is extremely time consuming. One suggestion to avoid this problem was to draw the graphics in another application. The suggestion was to use Java and Wings 3D for the graphical part. Wings 3D is a freeware that easily can draw 3D pictures. The reason for us not to choose this solution was that TWS does not have Wings 3D, and thereby it would have to be installed on the computers in Trelleborg. This was something we wanted to avoid because it makes the implementation harder. Simplicity in both the application and the implementation was prioritised.

The application uses a lot of Excel macros, and to be able to use them a certain adjustment has to be made in Excel allowing Excel to run macros. The problem with macros is that they are sensitive to viruses. This adjustment is something that cannot be taken away and therefore we have to instruct the people using this application in how to make the proper adjustments. On some computers another adjustment has to be made, the definition of the decimal comma. The application does not recognise the comma if it is a “,”, instead it should be a “.”. This adjustment has to be made in the “Regional options” in the “Control Panel”.

In the beginning of this master thesis the instructions was to create an application that made the ordering process easier when delivering tyres to TWS’s customers. During

this process Trelleborg announced a major reorganisation (see chapter 1.2.2) of the production of tyres. This reorganisation started a discussion about using the application in the purchasing process as well. To adapt the application to the purchasing process the dimensions of the trailers used had to be added. This is a very difficult step due to the fact that there is a wide spectrum of different trailer dimensions. The dimensions are similar to each other but to have the desired accuracy in the application the dimensions have to be very exact. Together with officials we decided to do a generalisation about the trailer sizes. The application has three standard trailers to choose from: 90 $m^3$, 98 $m^3$ and 104 $m^3$. If none of these suits the transport the choice to customise a specific trailer is available. By typing the cubic meter of the transport the application calculates the size of the transport. The width (2.48 m) and length (13.62 m) is fixed and thereby it is the height that varies.

## 5.4 Software Limitations

To get the complexity of the application on a desirable level some limitations has to be done. Many of these limitations are consequences of the problems encountered discussed in chapter 5.3.

The limitations are:

- The whole volume inside the tyres will not be used for loading of other products. The tyres are seen as solid rings (see Figure 5.7).
- No consideration is taken to patterns on the tyre (see Figure 5.7).
- Only three standard sizes of trailers are used. When using the trailer with optional volume the application uses the most common length and width to calculate the height. No other dimensions are available to use.
- A generalisation is made when loading cartons with tubes on pallets. The cartons are only loaded on pallets if they are more than 15 and fewer than 25.
- There can be only two different articles in a pile. Inside these two however, an infinite number of different articles can be loaded.
- Different tyres have different properties when it comes to compressibility. The application has standard numbers of compressibility in a default setting. Officials at TWS can at any time change these numbers to make them more accurate.
- The application just shows that the container/trailer is full and which articles that did not fit into the container/trailer. It does not show different combinations that would fit.


**Figure 5.7 Tyres are seen as solid rings when other tyres are loaded inside. In reality the whole inside volume is used when tyres are loaded into other tyres.**

# 6 ANALYSIS

*The Analyse chapter discusses and motivates the choices made during the thesis. The results and impacts of these choices will also be discussed. At the end an analyse about the reliability and validity of the thesis and of the results are discussed.*

## 6.1 Optimisation Versus Simulation

The application could be described both as an optimisation and a simulation application, it could be hard to distinguish a clear border between simulation and optimisation, though in the report we have chosen to call it an "optimising application". In our application there are properties that suites both definitions.

The application tries different ways to load the goods when they do not fit into the container/trailer. If there are some piles that do not fit they will be split up to be areas. This could be done several times since the conditions are changed every time the amount of piles and areas are changed. This is done to ensure as optimised loading as possible. This is typical optimising when one is trying several possibilities to achieve the best result.

Besides finding the optimal loading pattern it is important that one finds a pattern that is possible for the personnel at the warehouse, responsible for loading the containers/trailers, to load and of course unload the container/trailer. If the application suggest a too complex loading pattern that is hard to resemble the application would be impossible to use in real life. A too complex loading pattern might also result in problems with unloading a container/trailer. This means that the optimising has to be controlled thoroughly. There are some conditions that have to be followed. The optimising must be done in the same way as they load the goods today. This is more a description of simulation where the aim is to imitate the reality or a virtual reality.

The two different areas of use, purchase and customer services have different needs. The customer services main needs is a tool that imitates the loading that takes place at the warehouse and purchasing process is in need for a tool that helps to optimise their orders for goods going into the warehouses. Here one could say that customer services need a simulation tool and purchasing needs an optimising tool.

## 6.2 The Software Tool

Excel is used for the application and there are some disadvantages with using Excel instead of using Java or another programming language. The interaction between Excel and Visual Basic is not very effective. With a programming language that has a graphic function this procedure might be more effective. This non-effective interaction between Visual Basic and Excel is minimised by not having to communicate too much between the two parts. This means that the user of the application could optimise without displaying the loading pattern. Having the result, the length utilisation of the container that is displayed in the optimising form, the user

only has to show the loading graphically when he/she thinks the container is full. This means that the time consuming interaction is reduced a great deal.

There has to be some adjustments in the settings for Excel and Windows, for example macros has to be enabled in some computers to make the application work properly. Perhaps some might get anxious, having to change the settings, though this does not affect other software or applications noticeable, as far as we know. The adjustments, that is necessary when using Excel, has to be compared to the fact that there has to be other software installed (a compiler) if for example Java or C++ is going to be used. Everyone that is supposed to work with the application might not have the knowledge about installation of software or even the permission to install software on his or her working computer.

### 6.2.1 The Algorithm

To start with, it should be clearly stated that the application algorithm does not in any way allude to being a strict optimising algorithm according to the definition of optimisation (see chapter 6.1). It could however be used to optimise transports, but the algorithm itself is not only an optimising algorithm. Its only purpose is to resemble the current loading pattern as good as possible. We think, through the observations at the warehouse, that time have learned the container loading staff to load the containers as optimal as possible. The purpose with this thesis, that could be read in chapter 1.5, is not to optimise the container loading but to simplify the order handling process and in some way to avoid being dependent on tacit knowledge.

The problems when designing the application discussed in chapter 5.3 helped us to make the appropriate demarcations in the algorithm. The goal with the algorithm was to make the application resemble the loading pattern in real life. We believe that we have come as far as possible in doing that. One could of course put down an unlimited amount of time in improving the algorithm bit by bit, but somewhere a line has to be drawn where the time spent improving the algorithm is not worth the small improvements it gives. Especially in a project with limited time available, such as this thesis, one have to draw that line somewhere.

The algorithm resembles the real loading pattern in many ways, it starts with the largest tyres, it alter between placing lying tyres, standing tyres and pallets, it tries to turn the tyres 90 degrees to make them fit and so on. These things are the really important parts of the loading. However, in some cases the algorithm does not resemble the real loading pattern. For example if there just is one standing tyre the worker in real life loads this tyre as the last one if it does not fit perfectly somewhere else in the container. Dynamic choices like that are hard to translate into static programming code, and therefore our algorithm places this standing tyre as early in the container as possible. In most cases that will not have an impact in the loading, but in some cases it does (see Figure 6.1). In those cases the application demands a little creativity from the user to see that one or two extra tyre would fit in the container.

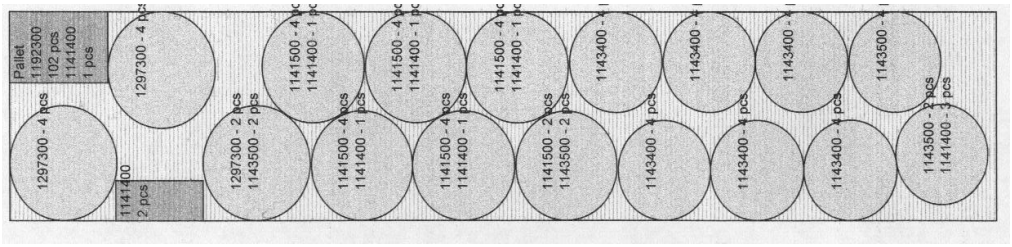


**Figure 6.1 Loading of a container from left to right. Here it would be better if the standing tire is loaded last.**

Another problem discussed in chapter 5.3 was the tyre compression. This is the Achilles' heel in the application. We have had many and long discussions with our supervisors and officials at TWS on how to resemble the compression in the application. As could be seen in APPENDIX H the compression has large effect on the container loading. The best way would of course be to examine the real compression for every tyre, but that is impossible. One suggestion could be to generalise and say that every tyre could be compressed 5 % in both width and diameter. This would however be even worse, because not every tyre is compressible; it is not even a majority that is compressible. The soft tyres are on the other hand sold in large quantities. The compressibility for the tyres varies between zero to approximately 20 percent and this large spectrum made it necessary to make some kind of scale between the different tyres. An official at TWS went through the product catalogue and put a mark on and scaled the tyres that he/she thinks is compressible. The scale was 5, 10 and 17 % compression in aspect of the width. A decision was also made to set the compression of the diameter to 5 % on the tyres that are compressible in the width dimension. Dimensioning the compression like this is a compromise between time available and the application trustworthiness. In the long run it would of course be good for the application if the official at TWS continued the study in how compressible the tyres are and then put that numbers in the product catalogue.

A computer software is stupid in the sense of being static, it cannot make own decisions depending on different circumstances. This means for instance that the application, when the container is full, does not show what tyres would fit if a specific tyre were removed and how many tyres of a specific type that has to be removed to make room for the others. The complexity and the number of available options are too large to make these kinds of decisions.

### 6.2.2 Implementation and Follow-up

As could be read in chapter 3.6 it is important to not only focus on *what* to change in a changing process but on *how* to change it too. What to change with this thesis is clearly stated at this point, but how to implement this application in the day-to-day operations has to be discussed.

To make a successful implementation acceptance for the application among the users is important. When talking to the workers about their tasks and their working situation we felt that they understood why the application is being created and that they wanted it to be implemented. However, to keep this good spirit about the change the quality of the application must be good, concerning both the application results and user friendliness.

The implementation shall be carried through in steps. The first period a couple of users test the application to find out if any changes have to be made in the application and if it can be used at their position. The tests are carried through when time is available between the usual tasks. Then after discussing eventual changes and their possibilities another test period comes, this time more in the day-to-day operations. The evaluation after this test period is the last time to influence the application before it is handed over persistently. In the beginning the application are going to be used by few people at one specific department. If it works well the application then can be spread to different departments or suppliers. The responsibility for the implementation and the maintenance of the application lies on Roger Carlsson and his co-worker Hans Jakobsson. They have a deeper understanding and knowledge about the application depending on that they have been involved in the process of creating the application.

We like the idea to start the implementation in a small scale and then if the usage of the application turns out well increase and spread the application to more people. It gives the opportunity to modify and improve the application at an early stage of the implementation. It is also easier to abort the whole implementation process if the application does not meet the standards that TWS demands.

The strategy of this process of change can be seen as a learning strategy according to the definitions in chapter 3.6.2. It has not been a controlled path from start to finish, instead the construction and implementation process has been a learning process both for us and the people involved at TWS. We have learned a lot about how the different functions operate, the different products and how to translate the dynamic real world into the static computer world. We think that the people involved at TWS have realised the complexity of their products and the logistical structure.

As could be read in chapter 3.6.3 there are a number of factors that are important for a successful IT implementation. When implementing the application it is important that it has a relative advantage to the system in use. In this case there is a large advantage to use the application instead of having to phone the warehouse when creating an order. This advantage however means that both the people at the customer service and the warehouse to some extent will lose the contact with one another. This contact could be desired from the people involved in order to not being isolated. Thereby the compatibility is hard for us to have influence on. The one variable in the perceived attributes of the innovation factor that we have influence on is the complexity. The complexity of the application has negative effect on the adoption rate and therefore we have strived for simplicity in the interaction between the user and the application. Our thought is that there should be a minimum number of options to choose from in

order to make the application easy to use. The leadership factors are out of our control; we can only make recommendations to use the application. It is then up to the management to implement the application in the way they think is the right. To get the so-called opinion leaders positive to the application is not easy, but we think that being around and interviewing people at the office and so on creates a positive curiosity towards the application.

### 6.2.3 Effects on the Ordering/Purchasing processes

One of the two purposes with this thesis is to simplify the ordering and purchasing processes. So, does the application really fulfil that purpose?

Our opinion is that the application simplifies the ordering process more than it does to the purchasing process. On the other hand the application could be a way to simplify the unloading of the containers at the warehouse in Trelleborg. A discussion about that will be done a little bit later.

The ordering process today is unwieldy in the aspect of the often-needed communication between the customer service personnel and the warehouse personnel. Using the application decreases the need of this kind of communication. The application and its results should not in any way be seen as a "law" that has to be followed. It is the creativity of the user that makes the real difference. To be able to create an order that fills the container to a maximum demands some experience both with the dimensions of the products and with the application. The application can, when used in the ordering process, be seen as a simulation tool instead of an optimisation tool. The application simulates the loading operation in order to tell the customer service how much the warehouse workers can fit into the container. The downside with the application is a bit contradictory; the contact between the warehouse workers and the officials at customer service decreases. This may lead to an enlarged "we against them"-thinking and that the warehouse workers feel left outside without any chance to influence the loadings and freights at all.

When using the application in the purchasing process it becomes more of an optimising tool than a simulation tool. An explanation to that statement is that if used in the purchasing process the transports coming in to the warehouse in Trelleborg are loaded in a way that the warehouse workers are familiar with and thereby one can say that the transports are loaded in an optimised way. As it is today many containers arriving are loaded in a bad way, with no loading structure and just filled to a maximum, causing extra efforts and extra time in the unloading operation. The application could help to get the transports loaded to a maximum with an acceptable loading pattern. After the reorganisation at TWS the purchasers will have an increasing amount of work to do. Our application could then be a useful tool to make the purchasing orders more adapted to the transport type and thereby reduce the need of communication between the purchaser and the supplier. This could be done either by using the application in Trelleborg by the purchasers or by letting the suppliers use the application in order to get properly loaded transports to Trelleborg.

### 6.2.4 Future Possibilities/Other Possible Markets

The problem that TWS has in the ordering system itself is not unique; it is the properties of their products that make this problem and thesis unique. It was hard to find other companies except tyre companies that the application could work for. One type of companies that might have use for the application are companies producing rubber hoses. These are rolled in circles and are compressible just like tyres. These rubber hose companies can always dimension the rolls in a way that fits the transports while tyre companies cannot do that.

The conclusion is that the problem itself with loading containers and trailers in an optimised way is not unique, but every company has its own uniqueness. A model used at one company cannot be copied to another without modification. The agriculture and forest tyre companies have a very specific problem to face.

On the other hand the application is suitable for different tasks within TWS. To start with the application will be used at the customer service in Trelleborg, but different TWS warehouses, for example in Italy (see chapter 4.1.1 for logistic structure), could at a later stage use it. TWS can take the application one step further by letting their suppliers in different parts of the world use it to get optimised transports to Trelleborg and Italy as described in chapter 6.2.3.

As we have stated a couple of times in this thesis the future possibilities for the application depends on how much work the responsible officials put down to keep the application updated to the products in use. To make the application work even more properly the continuous work with the compressibility of the tyres are important.

## 6.3 Load Optimisation

The effects of load optimisation can be hard to predict. One could think that optimising the transports always will be of benefit to the environment, but that is not the case. The discharges decrease if the transports are optimised, but on the other hand the noise and severity of accidents increases. Also the economical effects are hard to predict, if optimising the transport utilisation it is not rare to see that the level of inventory increases and so on. This chapter discusses the effects of using and not using load optimisation in transports.

### 6.3.1 Economical Effects

There are a lot of logistic activities involved with TWS's products and it is TWS's customers that have to pay for the costs. Either they have to pay the freight cost directly when having an order delivered or indirectly by paying a higher price for the products. Having an effective logistic throughout the whole chain (Figure 4.2) affects the prices for the products sold by TWS. If the supplier of raw materials to the manufacturer that manufactures tyres for TWS has ineffective logistics then the raw material supplier has to have higher prices and this affects the whole chain. If the manufacturer has to pay a high price then TWS has to pay a high price when

purchasing tyres from the manufacturer and all of this affects the price that the end-consumer has to pay. It is the same with all of the steps in the supply chain, if the logistics in one part of the supply is ineffective then it results in a higher price for the end-consumer. Therefore it is in TWS's interest that the whole supply chain is effective, from raw material to end consumer. A way to make the logistics effective is to optimise the transport with respect to volume efficiency. To the factories most deliveries are bulk products and from the sales companies smaller loads are delivered. Thus in TWS's case it is deliveries from the factories and the warehouses that is the most suitable for load optimising since here is full container/trailer loads more common. Here computerised load optimising, see 3.2, could be an advance against the competitors if the optimising results in more effective logistics. TWS does not handle all goods directly. Since some deliveries, if they are large enough, goes from factory to consumer, see 4.1.2, TWS does not deal with that goods. Here it is important that TWS shares its knowledge and resources to the factories to achieve efficient logistics here as well since this affects TWS's products. Of course it is hard to know if streamlining TWS's suppliers results in lower prices for TWS or if it is a chance for the supplier to raise their margins. Though it ought to be an argument for TWS when discussing pricing with their suppliers.

### 6.3.2 Environmental Effects

There is not only a direct potential for economical and competition savings involved when discussing load optimisation. By optimising the transports the environment is saved from unnecessary pollution. A relevant question to ask is how much environmental responsibility a single company should or could take? If the environmental responsibility results in higher costs and thereby smaller profits per sold item companies are not likely to take this responsibility. The only way to make companies in general increase their cost is through laws and fees. The environmental fees that are under discussion at the moment aims to put companies under pressure to make their transports more environmental friendly. One way to be more effective in transport is to use some kind of load optimisation. It could be either route planning or volume optimisation.

As could be read in chapter 4.4 Just-In-Time production and the urge to decrease stock levels has a negative impact on transport efficiency. This is something that in our opinion TWS is not that dependent on. Since they sell the products to own market companies and not so much direct to customers the lead-time becomes of less importance. In that aspect it would be an advantage to optimise the volume utilisation in transport. The negative side of that is that TWS has outsourced a lot of the warehouse activities. That means that the cost for keeping stock would increase if larger quantities were transported. One area that TWS really could improve in order to save the environment is the service to transport orders larger than 200 kg direct from warehouse to customer if the customer is based in Germany (see chapter 4.1.2). 200 kg could be just one large tyre, and to save the environment we think it would be better to first deliver to the appropriate market company and then coordinate transports in the specific area.

The “many small, few large” dilemma described in chapter 4.4.2 is interesting. Our conclusion is that this dilemma does not affect TWS. First of all, TWS’s customers are not situated in large city centres. Their products are sold to companies active mostly in the countryside or in the industrial areas. The customers in the industrial areas are mostly large customers ordering large quantities making discussions about small quantities transported in urban areas of less importance. From an environmental point of view we think that the logistic structure that TWS has is well adapted to both environmental and economic aspects. One possible change could be to decrease the number of warehouses to increase the opportunity for coordinated transports. On the other hand that results in longer transports to market companies and customers, which has a negative effect on the environment.

### 6.3.3 Future Possibilities

Transports are constantly increasing all over the world and with that follow congestions and pollution. Due to that decision makers have come up with some measures such as exhaust emission control and forcing the truck and fleet companies to have more effective transports. A way to make more efficient transport is to maximise the volume efficiency, load optimising. This means that one could believe that load optimising will have a higher priority in the future and with this follows increasing markets for load optimising software. Here decisions from governments or the EU might have a great impact. If they introduce regulations in the traffic, transport companies might be forced to streamline their transports, maybe with load optimising.

The people behind the load optimising software are probably continuously improving their products. This results in refined technology that makes the software better and better. Meaning they will be easier to work with, for example more user-friendly and easier to adapt to the different products there might be in a company. This makes us believe that the interest will increase for load optimising software in the future. If the markets for such software increase, then the prices probably will go down.

To save resources production companies uses “lean production” and “Just-In-Time” to achieve smaller inventory levels. This makes the need for more frequent deliveries larger and load optimising more difficult. Smaller back storerooms in urban areas have the same effect. This will have a negative effect on the need of load optimising in the future though smaller vehicles and coordinated transports will have the opposite effect.

## 6.4 Packaging Logistics at TWS

Some of the TWS’s customers want their goods on pallets to facilitate unloading and to protect the goods. If it makes the unloading easier then it almost certainly makes the loading easier. The negative side of palletising is that it makes load optimising more difficult. It is harder to load a container volume efficient when there are restrictions on the loading pattern. This means that the freight’s share of the price increases for the customer since there are fewer goods in the container. On the other

hand if the palletising makes handling easier then the customer saves resources in the unloading and this might even out the increased freight cost. It is all up to the customer and if palletising saves resources at the loading as well it might reduce the prices for the customer. This might be considered a trade-off; easier handling against poor volume utilisation. The costs saved by easier handling have to be put up against increased freight costs, see Figure 6.2. This might be a question of labour. In some places labour is cheap and in some places labour is expensive. Customers in North America might be more interested in easy handling and customers in Brazil might give priority to cheap freight.

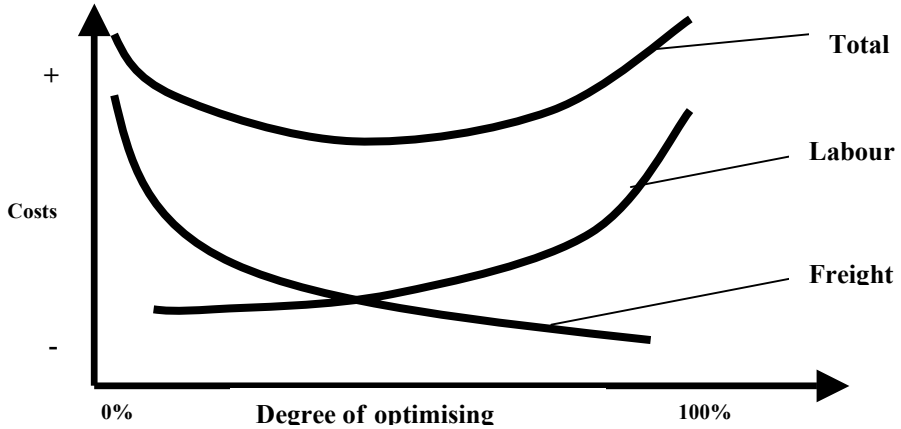


**Figure 6.2 Costs as a function of the degree of optimisation.**

One important purpose for a packaging system is to protect the products. In the case with TWS's products, their need for protection is considered low. At least not when they are stored in a warehouse or loaded in a container or a trailer. Tyres are insensitive to impacts, in fact at the loading occasionally the tyres are compressed quite much and this has to be done by violence sometimes. Moist is no problem if the tyres are not exposed for a very long time and there is no need to protect the environment against the tyres during transport and warehousing. Thus the need for packaging the tyres is low considering protection. Rubber is a good material in that way. The tubes are packed in cardboard boxes and this is mainly to keep them together, the need for protection is not very high since tubes are also made of rubber. The rims are made of steel, which is also insensitive to impacts, though the paint might come off if scratched. Here one might consider some protection, some kind of packaging, to ensure no damage during transport and handling.

Another important purpose for the packaging system is to make the handling easy. Here palletising, as discussed above, might be both positive and negative though it is positive for handling. There might be other ways to pack tyres to make handling more effective but this will most certainly also make load optimising less efficient especially if one consider the mix of sizes and geometries of TWS's products. Rims are heavier than tyres and more sensitive to impacts which results in that they are often placed on pallets to make the handling easier and the rims less scratched. If

there are many boxes of tubes in an order they are placed on pallets. The boxes are square, which makes it easy to stack on a pallet. If there are few tubes in an order the boxes are not placed on pallets but on the other hand the sizes of the boxes makes them quite easy to deal with by hand and easy to fit in the spaces between or inside the tyres.

The third purpose for a package is to display information about the product, the transport and storing instructions. On the tyres there are always some information about the product and on each tyre there is also a slip of paper with the article number. On the rims there might not be so much information, besides a slip of paper, and perhaps this might cause some problems when there are many different sizes in the container. On the tube-cartons there are information about the content. Here the need for information is larger since it is impossible to see the size of the tubes and the amount of tubes in each carton. Information about how to store tyres, rims and tubes should not be something essential since all parts of the supply chain deals with few product types and they ought to know how to store those products.

If TWS would package all of their goods, individually or more, in some kind of package the volume would increase for the same amount of products meaning there will be fewer goods in a container. Putting all tyres or rims in boxes would protect the products and it might also facilitate the handling and increase the information but also reduce the volume efficiency.

Transporting tyres, rims and cartons of tubes there are of course needs for protection against the climate, pollution and dusts. Then a container is an ideal load carrier since it protects the goods from those things as well as keeping the goods at place. The sizes of a container are standardised and it is easy to handle them with lift trucks and on (or in) the container there are information, for example about the goods and the destination. This means that a container fulfils all the need there is on a package, at least for goods like tyres, rims and tubes. A container could be considered as a tertiary package. The volume efficiency on a tertiary package is, in this case, very much up to the person/persons loading the container. When it comes to a trailer the conditions are almost the same, which means that a trailer could also be considered as a tertiary package.

## 6.5 Thesis Validity

This chapter discusses how the theoretical methods stated in chapter 2 worked in the thesis. The validity of the whole master thesis is also discussed.

### 6.5.1 The Application

Throughout the whole process in creating the application our assigners at TWS has been clear about how they want to use the application. This means that there have been few discussions between the constructors about what we want to achieve with the application and thereby keeping the validity (chapter 2.4) high. Though there have not been many discussions about *what* to accomplish with the application, there have

been many discussions on *how* to achieve it. There could be numerous ways to do an application that fulfils the primary goal. Different layouts of the application and different algorithms might do the things desired for the application. The layout of the application is something TWS have not had many opinions about in advance but during the construction of the application the assigners have been giving the chance to make comments on how the application is designed, see 6.2.2. This makes the validity high for the application considering the layout. Doing continuous feedback has also minimised large strategic changes late in the construction progress. Also the algorithm has been checked during the creating process; first by observations and asking how the container/trailer would be loaded with a special mix of the goods and later on by letting the loading staff look at some loadings made by the application. This makes us believe that the algorithm makes the application resemble the real loading quite good. based on the feedback given from the loading staff at the warehouse. This is of course depending on what kind of mix of tyres, rims and tubes there are in the orders handled by the application, and some is better then others. Also we have not been able to check our loadings by the staff at other places where loading occurs, for example at the manufacturers. Thus in most situations the validity of the algorithm is good though there are situations where it is not so good and in these situations the user has to use his/her knowledge about the products and collected experience.

As discussed in chapter 6.2.4 the application is customised for TWS's products and their way of loading. Without modifications there is no other use for the application except for other tyre companies. Though with some modifications maybe there are some places where the application might come in handy, for example rubber hoses. This would make the external validity (chapter 2.4) quite low though there are possibilities to use the application in most of the stages through the supply chain, see chapter 6.3.1, and this increases the external validity.

### 6.5.2 The Report

Throughout the whole process of writing this report there has been discussions on what to write about and how to write about it. Continuous dialogues and reviewing has been central to ensure high validity. Most of the content is written with the both of us at the same place, the master thesis room at IKDC[124]. This has made it easy to get a second opinion when writing a section and you always know what the other one is writing about. Due to these things we consider internal validity (chapter 2.4) to be fairly high.

In the report we discuss load optimising and our application in a larger perspective from TWS's perspective, see chapter 6.2.3 and chapter 6.2.4. Here we find more ways to use the application besides the just the ordering handling, see chapter 1.4. This together with the discussions about the environmental effect in chapter 6.3.2 makes the external validity high.

[124] Ingvar Kamprad Design Centre at Lund Institute of Technology

## 6.6 Thesis Reliability

This chapter discusses the reliability of this master thesis. It is important to clarify the strengths and weaknesses to give the reader a possibility to determine the reliability of the thesis.

### 6.6.1 The Application

In the actual application the reliability (chapter 2.4) is high. If one uses the same mix of products and marks the same properties, assembled or on pallet, the application will give the same result over and over again. Though if the user-friendliness is poor then the same mix and the same properties do not give the same result due to the user does not know how to fill in the optimising form. To avoid mistakes by the user we have had a continuous dialogue with the people at TWS to ensure that it is easy to understand how to use the application. Other things done to increase the user-friendliness are that not all settings, that might only be useful rarely, are possible. This means that the result of the application gets a lower reliability due to the intention to keep it user-friendly. This makes the total reliability higher.

The application is made exclusive for TWS and it is customised for TWS's purchasing (chapter 4.3) and customer service (chapter 4.2). The loading process, see chapter 4.5, is standardised and this makes it easy to see patterns in the loading when making the observations. This makes the stability reliability (chapter 2.4) high.

So far, after some tests by the people at TWS and us, one can consider the reliability of the application as good.

### 6.6.2 The Report

Here we have had many discussions concerning the content of the report, if it is relevant information, and the information gathered. The wide perspective on load optimising might do the reliability poor if the information is not relevant for the project. Environmental issues (chapters 4.4.2 and 6.3.2) together with the economical effects (chapter 6.3.2), we consider the driving force to implement load optimising. Therefore much concentration has been on those two subjects. We have not been able to find that much information about load optimisation and then there is a risk that one uses all information gathered resulting in poor reliability. Here the discussions have been essential to ensure a fairly high reliability.

# 7 CONCLUSIONS

*In this chapter the results of the thesis will be explained and clarified. A reflection on the result from the authors will also be included.*

In chapter 1.5 we stated two different purposes for this thesis. The conclusions will therefore also be divided into different parts depending on the purposes. The different parts begin with stating the respective purposes.

## 7.1 Practical Purpose

*"To simplify the order handling process and the purchasing process at TWS and to make the process more independent on specific persons at specific positions, also known as tacit knowledge. One way to minimise the dependence on tacit knowledge is to create an application that simplifies the ordering handling process."*

To fulfil this purpose we decided to create an application that makes the order handling process as well as the purchasing process more effective. The application also results in less dependence on specific persons, so called tacit knowledge.

The application is made exclusively for TWS and their products. Since the products have relatively unique characteristics the application is hard to adapt to other companies and products. We have strived for making the application as simple as possible to use. When we looked at the existing loading optimisation software we found them complicated to use and that was something that we wanted to avoid in order to get a successful implementation. By preciseness we mean that the application is well adapted to TWS and their product flora and that the application generates results that resembles the real loading operation in a precise way. Our main concern is the compressibility of the tyres and how that affects the reliability of the application.

The purpose is primarily to make the ordering process more effective. Though there might be some economical advantages for TWS if they were to use load optimisation. If the whole supply chain, or at least the parts that are most suitable, used load optimisation there might be money saved because of less and more efficient transports and this could result in lower prices for TWS's customers and perhaps, in extend, increase TWS's market share.

## 7.2 Academic Purpose

*"To put load optimisation in a wider perspective, in the aspects of implementation results, environmental issues, packaging requirements and thereby relating load optimisation to transports globally. The academic purpose for the thesis is also to show ability to apply scientific and engineering methodology, ability to apply gathered knowledge and skills from courses in the education plus to handle and work in a larger project limited in time."*

The need for packages to TWS's products is low. Stored in a warehouse or transported in a container or a trailer they do not need much protection except maybe for the rims, they are a bit sensitive against scratches. The warehouse, container or trailer gives enough protection against climate, pollution and dust. The need for more information on the products is also quite low though some kind of packaging, or palletising, to make handling easier might be needed sometimes. The trailer or container might be considered a tertiary package since they fulfil most of the definitions of a package; protection, information carrier and easy to handle. If TWS would pack their products in some other package it would probably have a negative effect on the volume efficiency. The tyres themselves might therefore be considered as packages.

The globalisation results in an increased need for transport planning and optimisation. The volume utilisation in transports is relatively neglected compared to other possibilities for companies to reduce costs. Load optimisation does however not always go hand in hand with existing company strategies such as Just-In-Time and decreasing inventory levels and this may be one reason for load optimisation not being implemented to a higher extent. Another reason is that it is only in the last few years that the existing load optimisation software have become sophisticated enough to compete with the human brain. Load optimisation is not only positive from an environmental point of view. When optimising the transports they tend to get larger which increases the noise and the accident severity. The air pollution does however decrease when optimising the transports.

## 7.3 Concluding Words

Our conviction is that if TWS have patience and lets the implementation process take some time and if the mangers encourage the workers to use the application in their daily work the result can be a very useful tool. The application needs an active user that takes own decisions and do not take the results from the application as some kind of law. The application gives advices to how many products that fit in the container, it is up to the user to take the decision whether the application is right or not.

Our suggestion to TWS is to use the application created in this master thesis for a while. If the application is useful, Trelleborg might introduce it to other parts in the supply chain. The organisation around the warehouse in Rome may be the one most suitable due to its similarity with TWS in Trelleborg. If the users of our application state that a more sophisticated software is necessary and desired then TWS should start thinking about implementing a commercial load optimisation software that can be connected to the ERP-system.

Our conviction is that in the near future load optimisation software will have its large breakthrough. The software is becoming cheaper and the need for companies to cut costs is increasing all the time. The congestions and the environmental fees intensify this need for load optimisation.

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*The references used in the thesis are showed to their full extent in this chapter.*

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Logistics Today – A cure for west coast congestion
http://www.logisticstoday.com/displayStory.asp?S=1&sNO=6854&MLC=SC_Global Logistics&OASKEY=CurrentIssue 2005-01-28

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http://gerek.coolfreepage.com/programming/programmingfaq.htm 2005-01-20

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Trelleborg AB,
www.trelleborg.com 2004-10-26

Writing at CSU,
http://writing.colostate.edu/references/research/relval/index.cfm 2004-10-17

## 8.5 Other

Lee, Eva. Business Manager *TOPS Engineering Corporation* 2004-10-05 E-mail

Sjögren, P. Integrator Per Sjögren AB 2004-11-03 E-mail

# APPENDIX A - R. CARLSSON, INTERVIEW

Roger Carlsson intervju 2005-01-25

- Logistiska strukturen (produktion till slutkund) TWS?

- Efter omorganisationen?

- Tredjepartslogistiken? Hur mycket gods? Samlastning? När används det?

- Hur görs prognoser?

# APPENDIX B - C. SVENSSON, INTERVIEW

Christina Svensson  Intervju 2004-10-19

- Vilken sorts transporter ska applikationen användas till?
- Hur sker kundkontakt? Telefon? E-mail?
- Hur ofta efterfrågas fulla containers/trailers?
- Vilken/vilka sorts kunder efterfrågar fulla containers?
- Finns det något mönster i ordrarna?
- Hur vill ni att programmet ska se ut och fungera?

# APPENDIX C- I. THÖRN, INTERVIEW

Intervju med Ingemar Thörn 2005-01-25

- Beskrivning av hela inköpsprocessen.

- Finns det några problem i inköpsprocessen?

- Finns det några förslag på lösningar på problem? Saker som kan förbättras/förenklas?

- Vad görs för att man ska få fulla lastbilar?

- Vad innebär den nya organisationen för inköpsavdelningen? Mer inköp av däck? Finns det siffror?

- Hur hänger storleken på däcken ihop med vilken fabrik de tillverkas? Tillverkar varje fabrik bara däck med ungefär samma dimension

# APPENDIX D – ORDER CONFIRMATION

## ORDER CONFIRMATION

TRELLEBORG



| Date | Cust no | Your dt |
|---|---|---|
| 050209 | 8801560 | 040929 |

| Your reference | Order dt | Your order | Order no |
|---|---|---|---|
| MAURILIO NETO | 040929 | SW010/04-723-OKT | TDB0410 |

Our reference
CHRISTINA SVENSSON

Payer
TRELLEBORG DO BRASIL LTDA
DIVISAO FOREST & FARM
R.CEL. JOAQUIM A. MARTINS, 2794
LENCOIS PAULISTA-SP, CEP 18682-050
BRAZIL

Customer
TRELLEBORG DO BRASIL LTDA
DIVISAO FOREST & FARM
R. CEL. JOAQUIM A. MARTINS, 2794
LENCOIS PAULISTA-SP, CEP 18682-050
BRAZIL

Delivery method
VESSEL

Goods mark
TRELLEBORG DO BRASIL
LENCOIS PAULISTA / SP

Currency
USD

Delivery terms
FOB-FREE ON BOARD

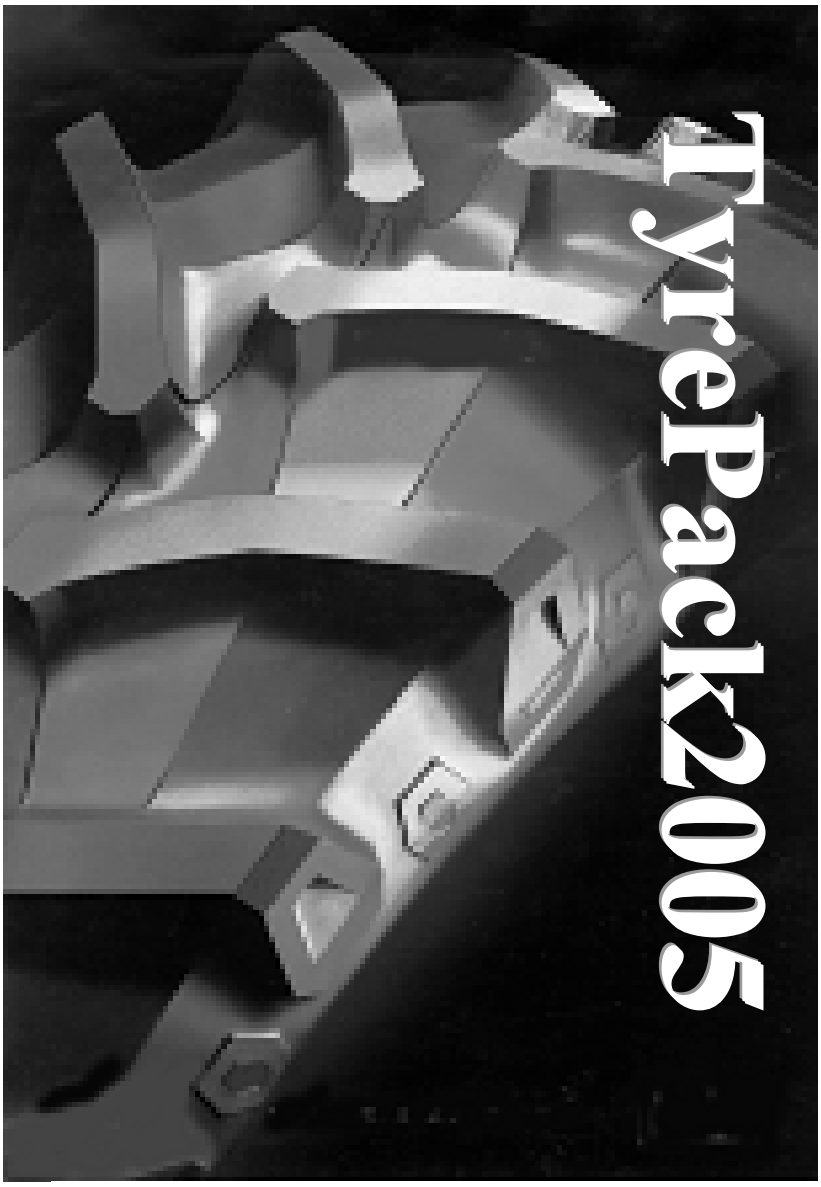
Payment terms
30 DAYS FROM DATE OF INVOICE

| Ln | Item no / Description | | Quantity | U/M | Dely dt | Sales price | Discount | Amount |
|---|---|---|---|---|---|---|---|---|
| 20 | 1469900<br>600/55-26.5TT 160A8 T428 SBFS | 0 | 12 | PCS | 041015 | 733,27 | | 8.799,24 |
| 50 | 1469700<br>600/65-34TT 157A8 T422 SBFS | 0 | 4 | PCS | 041015 | 888,39 | | 3.553,56 |
| 60 | 1133300<br>700/40-22.5TL 12 T404 | 0 | 50 | PCS | 041015 | 503,02 | | 25.151,00 |
| 70 | 1136102<br>620/50-22.5TL 160D T404 AMPT DA | 0 | 13 | PCS | 041015 | 423,03 | | 5.499,41 |
| 80 | 1255800<br>VENTIL 35GWS (TR-618) | 0 | 500 | PCS | 041015 | 0,53 | | 265,00 |
| 90 | 1134500<br>600/50-22.5TL 12 T404 | 0 | 4 | PCS | 041015 | 221,19 | | 884,76 |
| | PESO NETO 94,50 KGS/PCE | | | | | | | |
| | | | | | Order total | | | 37.670,76 |

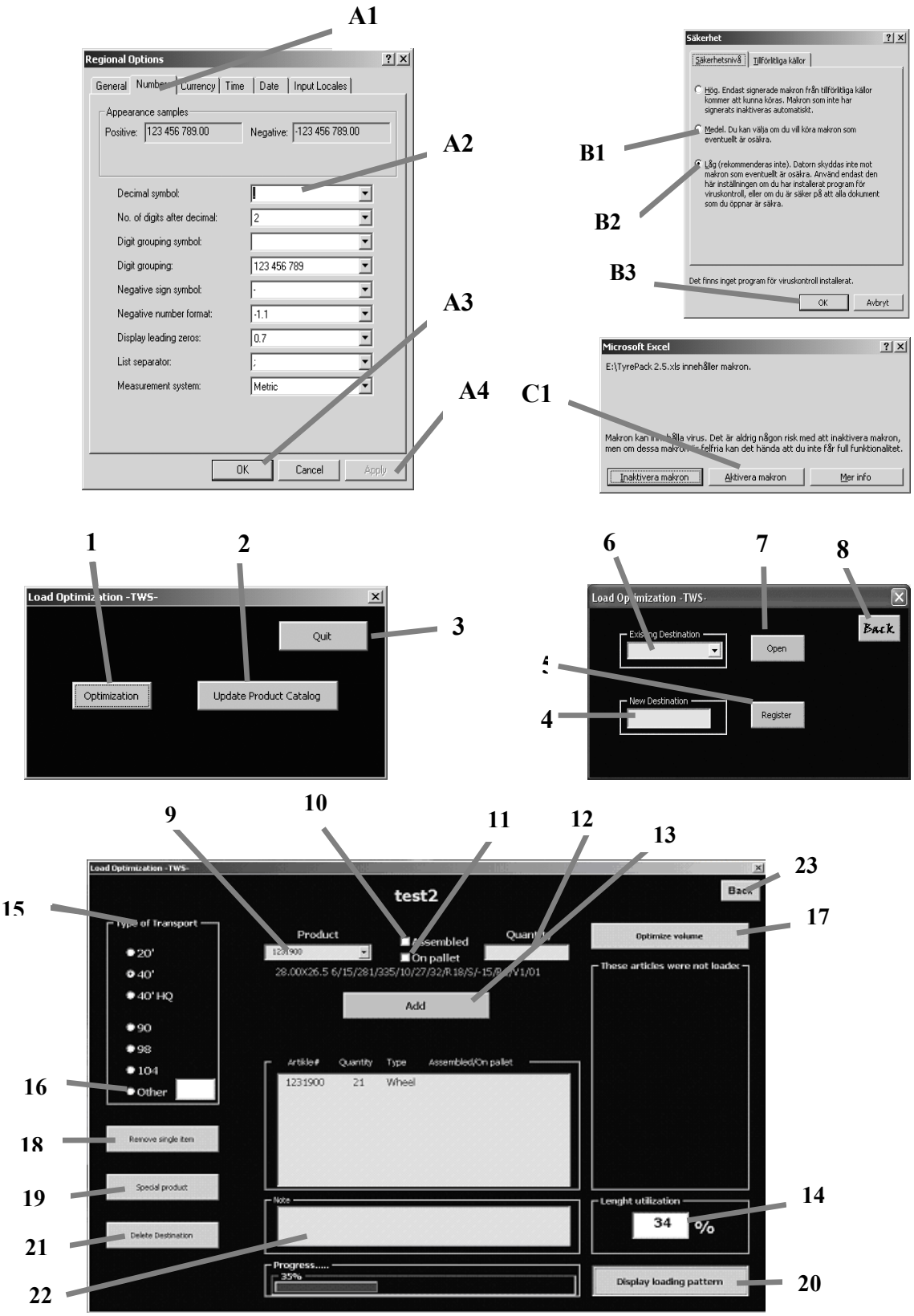
TRELLEBORG INDUSTRI AB
BU AGRI & FOREST TIRES
SE-231 81 TRELLEBORG

Phone +46 (0)410 51000
FAX +46 (0)410 13996
Internet: www.trelleborg.com

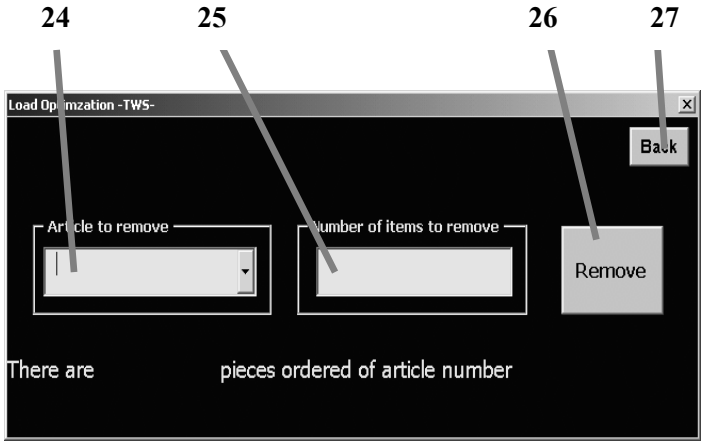
## APPENDIX E – USERS MANUAL

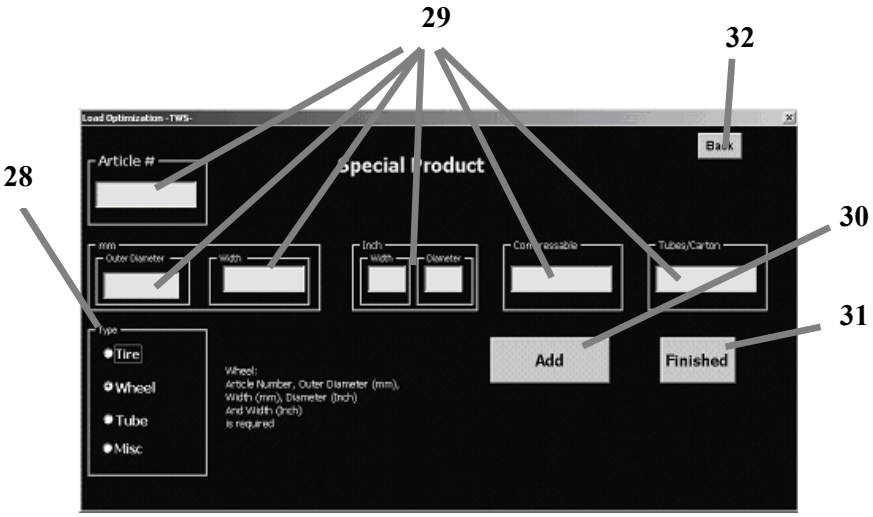


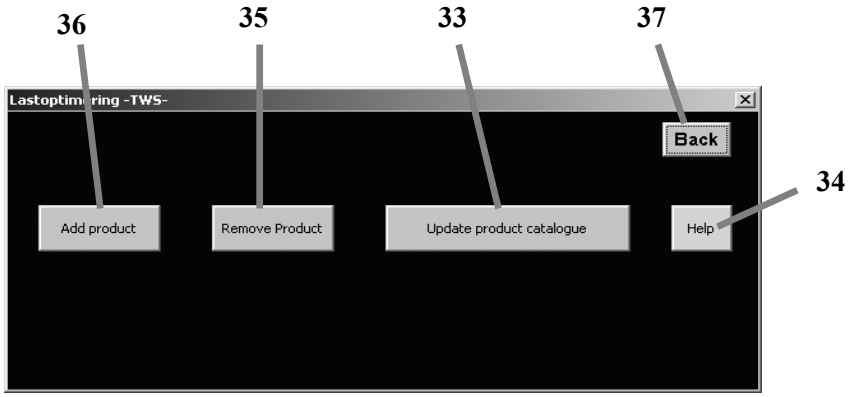

# Users Manual


A1
A2
A3
A4
B1
B2
B3
C1
Regional Options
General
Number
Currency
Time
Date
Input Locales
Appearance samples
Positive: 123 456 789.00
Negative: -123 456 789.00
Decimal symbol:
No. of digits after decimal: 2
Digit grouping symbol:
Digit grouping: 123 456 789
Negative sign symbol: -
Negative number format: -1.1
Display leading zeros: 0.7
List separator: ;
Measurement system: Metric
OK
Cancel
Apply
Säkerhet
Säkerhetsnivå
Tillförlitliga källor
Hög. Endast signerade makron från tillförlitliga källor kommer att kunna köras. Makron som inte har signerats inaktiveras automatiskt.
Medel. Du kan välja om du vill köra makron som eventuellt är osäkra.
Låg (rekommenderas inte). Datorn skyddas inte mot makron som eventuellt är osäkra. Använd endast den här inställningen om du har installerat program för viruskontroll, eller om du är säker på att alla dokument som du öppnar är säkra.
Det finns inget program för viruskontroll installerat.
OK
Avbryt
Microsoft Excel
E:\TyrePack 2.5.xls innehåller makron.
Makron kan innehålla virus. Det är aldrig någon risk med att inaktivera makron, men om dessa makron
felfria kan det hända att du inte får full funktionalitet.
Inaktivera makron
Aktivera makron
Mer info
1
2
3
Load Optimization -TWS-
Quit
Optimization
Update Product Catalog
6
7
8
Load Optimization -TWS-
Back
Existing Destination
Open
New Destination
Register
4
5
9
10
11
12
13
15
16
18
19
21
22
23
17
14
20
Load Optimization -TWS-
test2
Back
Type of Transport
20'
40'
40' HQ
90
98
104
Other
Product
Assembled
On pallet
Add
Optimize volume
These articles were not loaded
Artikle#
Quantity
Type
Assembled/On pallet
1231900
21
Wheel
Remove single item
Special product
Delete Destination
Note
Lenght utilization
34
%
Progress.....
35%
Display loading pattern

II


24
25
26
27
Load Optimization -TWS-
Back
Article to remove
Number of items to remove
Remove
There are
pieces ordered of article number


29
32
28
30
31
Load Optimization -TWS-
Back
Article #
Special Product
mm
Outer Diameter
Width
Inch
Width
Diameter
Compressable
Tubes/Carton
Type
Tire
Wheel
Tube
Misc
Add
Finished
Wheel:
Article Number, Outer Diameter (mm),
Width (mm), Diameter (Inch)
And Width (Inch)
is required


36
35
33
37
34
Lastoptimering -TWS-
Back
Add product
Remove Product
Update product catalogue
Help

**Before running TyrePack:** **1.** Change the setting for dots and commas by clicking as follows: *"START"*=> "*Settings"* => "*Control Panel"* => "*Regional Options"* (the globe) => "*Numbers"* [**A1**]. Set "*Decimal comma*" [**A2**] to a ".". Click "*Apply*" [**A3**] and then "*OK*"[**A4**].

**2.** Open Excel
Click "*Tools"* => "*Macro"* => "*Safety"* => "*Medium"* [**B1**] (or "*Low"*[**B2**]) => => *OK* [**B3**].
Close Excel

**Start TyrePack:** Start TyrePack by double clicking on the "TyrePack" icon. If safety is set to Medium then the "*Enable Macros"* [**C1]** has to be clicked.

**Before closing TyrePack:** Consider whether any destination is needed in the future. If not, delete the destination (see *Delete destination* on the next page).

**Exit TyrePack:** Click "*Back*" [**8, 23, 27, 32, 37**] until the first choice form is active and the "*Quit*" [**3**] button is available. The "*Quit*" button [**3**] also saves.

**Create new destination:** **"**Click *Optimisation"* [**1**] => Type the new destination name in the "*New Destination*" [**4**] field => Click *Register* [**5**]. To continue read A*dd article to destination* below.

**Open existing destination:** Click *Optimisation* [**1**] => Choose destination from the "*Existing Destination*" list [**6**] => Click "*Open*" [**7**].

**Add article to destination:** Choose article to add in the "*Product*" list [**9**]. Mark "*Assembled*" [**10**] if the product is assembled to complete wheels (all parts in a complete wheel must be marked *"Assembled"*. Mark "*On Pallet*" [**11**] if the product should be placed on a pallet. Write the quantity to be added in the "*Quantity*" field [**12**]. Click "*Add*" [**13**]. The products are now added to the chosen *Type of Transport* [**15**] (read *Changing transport type* below). At the bottom of the right hand side of the form in the "*Length utilization* field [**14**]", the used length as percentage of the whole transport type length is showed. If you want to add more products to the destination, just start over by choosing article from the "*Product*" [**9**] list.

**Changing transport type:** Mark the desired transport type. When marking a transport type the added products are loaded and the

length utilization can be seen again. If the trailer desired are not in the "*Type of Transport" field* [**15**], mark the "*Other*" field [**16**] and write the volume in cubic meters for the trailer in the square field. The application then calculates the height of the trailer assuming the length to be 13,62 meters and the width to be 2,48 meters. (If "*Other*" is used the "*Optimize volume*" [**17**] button must be clicked to be able to se utilized length)

**Remove article from destination:** While in the main form press "*Remove single item*" [**18**]. Choose which "A*rticle to remove"* [**24**] from the list and type the *Number of items to remove* [**25**]. Then press the "*Remove*" [**26**] button.

**Add special product:** In the main form, press "*Special Product*" [**19**]. Choose which "*Type"* [**28**] of product you want to add. The text beside the product type shows what fields that has to be filled out. Fill the required fields [**29**] and then press "*Add*" [**30**]. When you are ready adding products click "*Finished*" [**31**] or "*Back* [**32**].

**Display loading pattern:** If you at any time want to see how the application has loaded the articles in the transport type, press "*Display loading pattern*" [**20**]. You must be aware that this action is time consuming and might take a few minutes.

**Delete destination:** When the destination is ready and it will not be needed any more, delete it. Some destinations could however be saved as references. To delete a destination, choose the *Existing destination* [**6**] [**7**] and move on into the main form. Press the "*Delete destination*" [**21**] button down to the left. Note that it is the active destination that will be deleted.

**Update product catalogue:** Go back to the first form and choose "*Update product catalogue*" [**2**]. In the next form choose "*Update product catalogue*" [**33**] again. Then a dialog box will open where you should choose which file to set as new product catalogue. **NOTE!** It is **very** important that the new catalogue have the exact same structure as the present. Otherwise the application will not work properly. See *Catalogue structure* below for the appropriate content. You can also or press "*Help"* button [**34**] on the *Update product catalogue*" form.

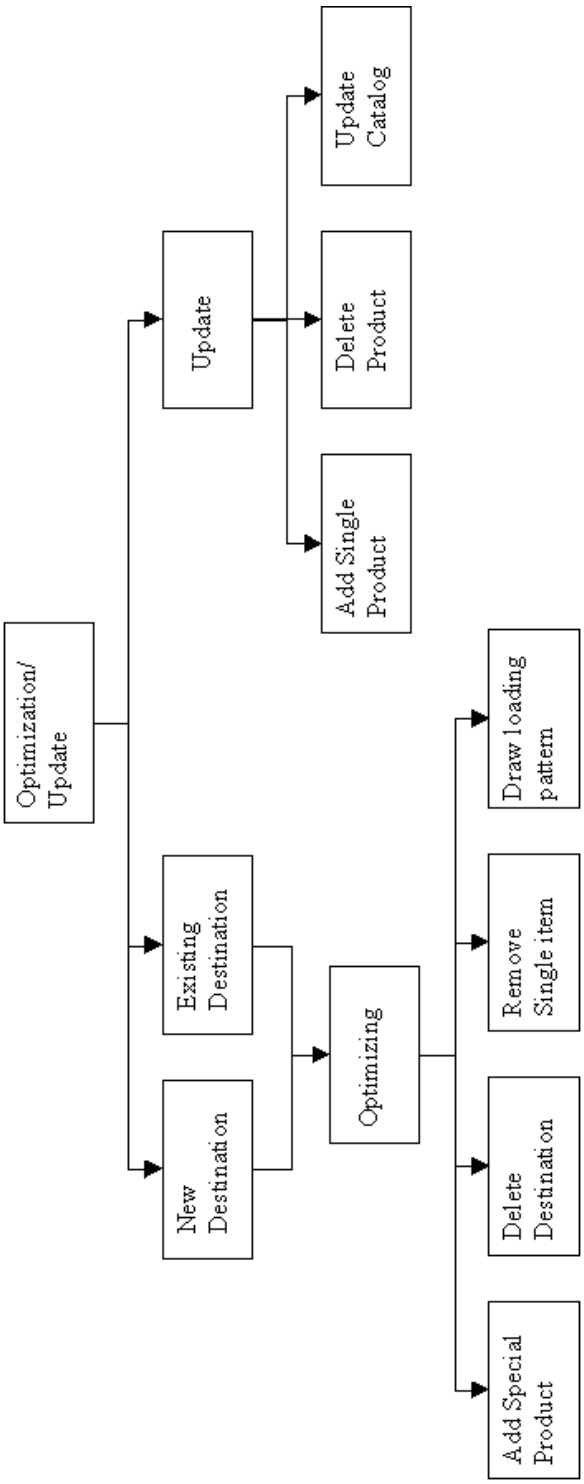
**Remove Product:** By removing a product the product will be deleted in the product catalogue. Start by pressing "*Update product catalogue*" [**2**] in the beginning, then press "*Remove product*" [**35**] and select the desired product. Then press "*OK*".

**Add Product:** By adding a product it will be added in the product catalogue together with all the other products. Start by pressing "*Update product catalogue*" [**2**] in the beginning, then press "*Add product*" [**36**]. The procedure is the same as *Add special product* above. (Choose "*Type"* [**28**], fill the fields [**29**], press "*Add*" [**30**], if you ready; "*Finished*" [**31**])

**To optimise a transport:** When adding products to the destination the present length utilisation is displayed but when the transport is overloaded; the length utilisation just states "*>100%*". To get the transport as full as possible some "trial and error" is needed, i.e. try to remove one piece at a time to see when the optimum transport configuration occurs. Note that removing the products stated as "remaining" may not lead to a fully utilised transport. The user has to try back and forth a while to get the desired transport loading. There is also the possibility to add a note to the destination in the "Note"-field [**22**] in the optimizing form.

**Catalogue Structure:**
Column 1 (A) - **Article number** (Artikelnr)
Column 3 (C) - **Name** (Namn)
Column 5 (E) – **Diameter Inch** (Diameter Tum)
Column 6 (F) – **Width Inch** (Bredd Tum)
Column 7 (G) - **Diameter mm** (Diameter mm)
Column 8 (H) – **Width mm** (Bredd mm)
Column 9 (I) – **Amount/carton** (Kartong Antal)
Column 11 (K) – **Type Article** (Typ Artikel)
Column 31 (AE) – **Inch** (Tum)
Column 32 (AF) – **Collapse Width** (Sammanpressning Bredd)
Column 33 (AG) – **Collapse Diameter** (Sammanpressning Diameter)

# APPENDIX F - SCHEME OF THE APPLICATION



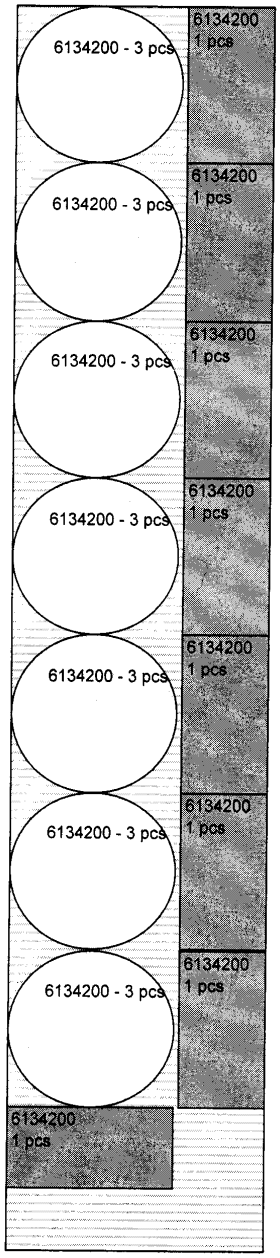
# APPENDIX G - WORKSHOP

Workshop 2004-12-07

Medverkande Roger Carlsson. TWS
Hans Jacobsson. TWS
Kari Kronholm. TWS
Lasse Larsson. TWS
Patrik Gustafsson
Michael Byman

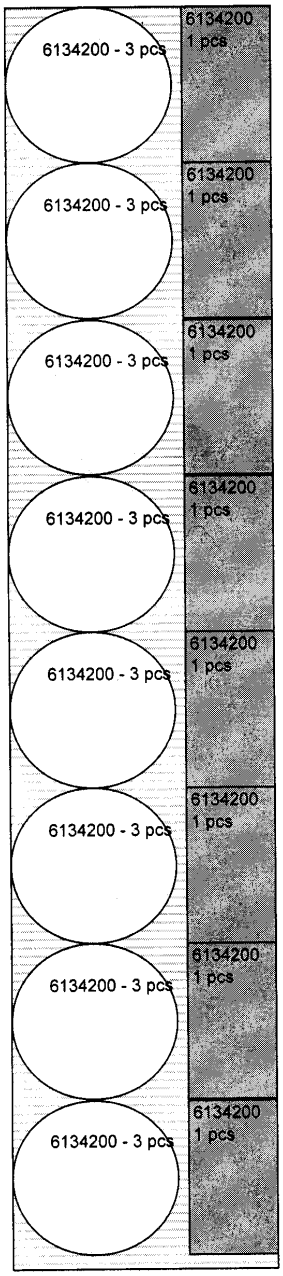
- Fälgar. Hur lastas de generellt? Antal fälgar på pall? Pallar på höjden?
- Vilka däck går att pressa in? Skogsdäck? Hur kan man urskilja dem i katalogen? Hur mycket går de att pressa ihop? Generalisering?
- Nyckeltal? Vilket mått vill ni ha som visar hur full containern är? Längdutnyttjande? Volymsutnyttjande? Densitet?
- Räkna inte slangar färre än 100st? Hur många är rimligt att få plats med utan att ha dem med i beräkningarna?
- Slangar på pall? Hur många ska lastas innan de läggs på pall?
- Hur stor kan innerdiametern bli? Är det rimligt att de kan bli större än 1500 mm?

# APPENDIX H - COMPRESSIBILITY




**5%** compressibility on the diameter.

**29** tyres loaded




**7%** compressibility on the diameter.

**32** tyres loaded