Decision Support for Work Flow Control in a Warehouse Management System

Gustav Rydeman
Abstract

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As volatility and customer demands increase, companies are simultaneously trying to reduce their logistic costs. Distribution centers are being forced to increase their agility and flexibility in order to rapidly execute on continuously evolving logistics plans. One proven way of gaining warehouse efficiency and create visibility into processes is through implementation of a Warehouse Management System (WMS) – a leverage technology that introduces automation in warehouse processes. With system directed task assignment work can be optimally balanced and distributed to available resources and auto-generate tasks with high quality. A critical aspect of this have shown to be prioritization of tasks in the dynamic terminal environment. To introduce a new work flow support into an existing organization requires changes in routines, roles and organization to harvest the real efficiency gains. In this report these problematics are applied to the distributing terminal of SCA Transforest, Tunadal, Sweden. A benchmarking study of a terminal in the same business, the Stora Enso terminal in Zeebrugge, Belgium, is the object of comparison. At the latter terminal system directed task assignment has been successfully implemented. Based on the findings from the benchmarking study and other research this report present important success factors as well as specific solutions to issues regarding automation, flexibility and process visibility - with the purpose to guide SCA Transforest in the future system development.
Populärvetenskaplig sammanfattning


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1 Introduction

As demand volatility and customer demands increase, companies are simultaneously trying to reduce their logistic costs. Distribution centers are being forced to increase their agility and flexibility in order to rapidly execute on continuously evolving logistics plans. Processes, technologies, physical environment and actors in the system must work efficiently together to create a high and cost efficient service level.

To effectively support fluctuating workload without increasing staff or decrease in service level warehouse managers seek to make the warehouse an agile and flexible part of the supply chain that can respond quickly to business changes. One proven way of gaining warehouse efficiency is implementation of a Warehouse Management System (WMS) – a leverage technology that introduces automation in warehouse processes.

In order to successfully introduce this kind of IT support and automation some necessary setup and configuration is obliged. Once the basic process capabilities have been automated, the company may get the rewards in terms of reduced labor costs and improved customer service, and the organization can begin to explore high performance capabilities that will enable this efficiency to continue (Aberdeen Group, 2008).

SCA Transforest, the logistic department of the business group SCA Forest Products, is situated in the bay of Tunadal close to Sundsvall, Sweden. SCA Transforest run a handful of goods terminals in Europe of which the Tunadal terminal is the largest and most complex. The terminal is cross-docking, housing and consolidating incoming goods that arrive to the node from all of the SCA mills in the region. The terminal is a so called hub that connects three modes of transport - railroad, road and sea freight - which makes the inbound-, warehouse- and outbound flows quite complex.

SCA Transforest have recently implemented a WMS to keep track of inventory and enhance visibility of the activities in their terminals. The focus so far has been on getting the system up and running at all the terminals before any major adjustments will be carried out. During the implementation period, some effort in adapting interfaces and educating operators have appeared but only to a level that have made the systems workable in the existing organization. Adoptions have been made so that the system could be fit in to the traditional, “manual” way of working. These adaptions resulted in a cut of the WMS functionality – the ability to direct and balance work based on optimized system decisions and task assignment.

Now, when the ambitious system roll-out have been successfully implemented at the major freight terminals, SCA Transforest wants to evaluate whether the work can be performed more effectively by using the standard system-directed functionality in the WMS. The efficiency gains they wish to achieve with a system-directed approach are, among others, a higher level of resource utilization such as the usage of trucks, warehouse space and operator skills. The warehouse layout and the terminal activities are very dynamic and differ a lot from a typical pick-warehouse. This is also why a system directed approach isn’t basically optimal, it may be too inflexible in the dynamic warehouse activities.

Implementation of a WMS involves numerous tasks that directly impact how people, product flow, procedures, equipment and information interact. While the details of these tasks vary between companies, there are elements common to all implementations, and the success of any implementation hinges on how well an organization manages these elements (Singer, 2007).
2 Context and background

First of all, a short introduction of the business group SCA Forest products, the logistics department SCA Transforest AB and their network of terminals. Some prospects of how the investment is supposed to create value in the SCA terminal handling will also be presented.

2.1 SCA Forest Products in brief
Svenska Cellulosa AB, SCA, is a Swedish manufacturer of paper, pulp and sawn timber. The group also develops, manufactures and markets packaging and hygiene products. With approximately 50 000 employees in 50 countries, SCA reached 110 billion USD in sales 2008 (SCA 2008:1). SCA is the largest private holder of forest in Europe. They manage 2.6 million hectares of forest of which 2 million hectares are used for timber production. The product sectors are strongly linked to each other in a value chain to make optimum use of the forest raw material. The main market is Europe but their products are exported globally. Paper products make up for 50% of the yearly sale, which makes SCA the sixth largest manufacturer of printing paper in Europe.

The business group SCA Forest Products produces paper - newsprint, coated- and packaging paper - pulp, sawn timber and forest-based biofuels. The paper mill SCA Ortviken, pulp producer SCA Östrand as well as the head office of SCA Forest Products and the headquarters of the logistic department, SCA Transforest AB, are located in Sundsvall, Sweden.

2.1.1 SCA Transforest and The Tunadal Terminal – a node in the SCA logistical system
The Interforest terminal in Tunadal, Sundsvall (ITS) is located between the pulp mill SCA Östrand and paper mill SCA Ortviken. In direct connection with the terminal is also the SCA Tunadal sawmill. The terminal in Tunadal store and handle most of the region’s goods pending further distribution. Each year, about 1,9 M tons of goods pass thru the terminal in Tunadal. Trailers and goods-wagons feed the terminal with paper reels from the nearby paper mill SCA Ortviken, pulp from Östrand and sawn wood from the adjacent sawmill in Tunadal.

SCA Transforest have associated terminals strategically placed in Tilbury, Lübeck and Rotterdam, close to the European markets (Figure 1). The terminals are so-called hubs that connects all modes of transport; rail-, sea- and road freight. The terminals are quite different in organization, size, goods flow, logistic complexity, work culture etc. But the products handled are the same, newspaper reels, liner reels and pulp bales.

Figure 1. The SCA Terminal network and sea bound distribution
About 74% of SCA’s timber, pulp and paper products is sea freight, handled by SCA Transforest via their own network of terminals in Sundsvall, Umeå, Rotterdam, London and Lübeck. Approximately 11% is transported by truck and 15% by railroad (Eriksson, Interview).

The following picture illustrates the work conditions and contexts of the stages in the distribution chain from mill to customer in the paper industry. The pictures are taken from both the SCA and Stora ENSO distribution chain.

Figure 2. Contextual example and overview of the distribution as organized by SCA and Stora Enso illustrated with photos from the operations. In the upper scheme the Tunadal Terminal can be positioned as Production Warehouse Terminal A2 and the Zeebrugge terminal as European Terminal warehouse A5 in their respective logistic system.

2.2 The prospects of using WMS at SCA Transforest

When SCA Transforest implemented the current WMS system they chose not to use the standard WMS functionality, i.e., where the system directs trucks in the warehouse. Instead they developed a custom-made functionality together with RedPrairie where the truck operators choose from the order queue what to work with, which reels to pick and in which order. The reason for doing this, was that for the loading of some vessels, it is decided very late in which sequence different articles should be loaded in the vessel. Having the system deciding the sequence to pick different reels should then not work out in a good way. A great negative consequence of this solution is that the systems ability to balance and direct work disappear. The solution is very much focused on the truck operator to manage and prioritize work and procedures.

No assignments are distributed, instead all available tasks are shown in the RF and the truck operator choose what task to work with. The chosen task may then not be the most appropriate with respect to location, priority etc. The solution requires a lot of paperwork and communication over com-radio between truck operators and planners, something that many find disturbing and a source of misunderstanding etc.
2.2.1 Expectations on what to achieve

One expectation that the company has on the WMS and its system directed functionality is a more optimal balancing of work so that available workforce could be utilized more efficiently. For example may drivers in various parts of the warehouse be directed to help each other in a more optimal / efficient way than today. If there is little work in one area of the terminal the truck drivers in this section will automatically be instructed to do work in another area (or where this resource is currently needed). With a system directed approach and reliable system-environment interaction and organization the possibility to optimize parts of the warehouse operations will increase – a future goal of the terminal.
2.3 Problem definition

To manage a terminal or a dynamic warehouse is a very complex and difficult task with regard to the different processes and numerous factors and resources these involves. To minimize the labor costs and increase resource utilization a number of actions can be taken. The question is where the productivity potential exists and how it may be exploited. SCA Transforest want to investigate in what ways they can increase the benefits of their Warehouse Management System (WMS) with focus on higher resource utilization by balancing of workload and exploiting of potential productivity.

In a socio-technical system were operators and planners use a supportive system to manage and execute work effectively the demands on system setup and design are extensive. When automation is also a part of the system in total some important factors must be taken into account to ensure a reliable system output.

Altogether have this led to the following questions which this thesis intend to answer:

- What are the requirements for a successful implementation of a system directed work approach?
- What is the actual productivity potential for the concept of a system directed work approach in relation to the manual work procedure?
- What level of truck operator autonomy is the most appropriate?
- What can / should be automated to achieve a higher productivity rate?
- For what activities is a system directed approach possible?

2.4 Purpose

The primary purpose of this case study is to explore the possibilities and potential of exploiting the terminal resources in a higher level than today. The aim of the thesis is also to provide SCA Transforest with a roadmap on how to reach a successful implementation of a system-directed work approach taking organization, operators (usability) and monitoring factors into account - all with focus on increased efficiency. This doesn’t have to result in costly changes because the aim is to organize the work and use of existing resources in a smarter way resulting in less waste and higher productivity.

2.5 Limitation

After the preparatory discussions of the scope of the thesis the environmental limitation was set to the Tunadal terminal based on the following factors. The terminal in Tunadal is the most complex of the SCA Interforest terminals. This is probably also where the greatest savings potential are to be made. The IT and logistics resources at SCA Transforest are also located in Tunadal. The study is therefore based on the operations at the Tunadal Terminal.

The complexity of flows and the terminal’s size contributes to a large problem space that isn’t fully representative for the other Interforest terminals. There are significant differences between the terminals regarding size, flow, transports, organization, work culture, etc. The analysis that I will present in this study deals, however, with problems of a more general type and is certainly of interest when dealing with WMS-oriented problems at all Interforest terminals. The generalizability of the results will be discussed in the ending section.
3 Method

The following chapter will present the method used and the basic approach of my study. I will also give a more detailed explanation of the Benchmarking method used, and to end up, a description of the content of each chapter.

3.1 Basic Approach

A Socio-technical system approach is the basic view in this case study. The terminal is seen as an open system, where technology, people, organization and its surroundings are taken into account. The terminal can be looked at as a system containing numerous sub-systems. The terminal is also a part of a bigger context where restraints and external disturbances such as economical and regional conditions, union rules etc contributes to the formation of the terminal operational system. This dictates a broader, holistic system perspective. It is a system where humans with different expert capabilities are organized and it is characterized by multiple groups of actors/users with different perspectives/interests/goals that may create a lack of rational purpose efficiency. Together with the physical environment, trucks, human resources, IT have to interact with each other in an efficient way. The greatest benefit of people in complex socio-technical systems is as the role of an adaptive operator. The terminal must adapt to the fluctuating flow of goods thru the system. Flexibility and the ability to adapt in an efficient way, without loosing focus on productivity and long-term effectiveness is crucial.

The aim of the thesis advocates a holistic approach. A deeper understanding of the organization and the processes impose a qualitative approach, but some quantitative data will be analyzed to point at certain patterns in the warehouse operations.

3.2 Case study

My study has the character of a case study. The focus of a case study is to investigate a less distinct group, i.e. an individual, a group of individuals, a organization or a situation. The study doesn’t need to be restricted to one case but may include more cases. The cases are studied from a holistic perspective and the aim is to get as comprehensive information as possible about the chosen field (Patel, 2003). By using case study methodology the investigator is able to focus on specific events or phenomena and try to get the factors that are important for the these specific areas. A case study is the research strategy best suited when questions like “how” and “why” are going to be answered (Bell, 2000).

My aim is to explore a chosen phenomenon, the approach is defined as explorative. An exploratory study is characterized by the existence of gaps in the knowledge of the phenomenon. By retrieving as much information as possible about the area of survey, a more detailed explanation of the selected topic can be presented (Patel, 2003). My study has the character of being explorative, given that I intend to bring in new knowledge based on empirical evidence and existing theories of the field.

3.3 Data Retrieval

As background information observations made of the different terminal activities, studies of interface manuals and interviews with planners, truck operators and managers was conducted.
3.3.1 Interviews
There are two basic types of implementation for interviews; controlled or open interviews. Short interviews are usually more structured and controlled. Less controlled or open interviews means that the interviewer has a number of question areas to be treated, but not a specific list of questions.

In an open interview, the interview is more of a conversation in nature. The interviewer is not obliged to follow the form of a questionnaire or interview guide. A guided interview is based on a list of questions. The interview is more of a question-answer nature. In summary, the open questions focus more on what the interviewees think is important to address, while the answers may become more accurate at guided interviews (Bell, 2000).

One must also take into account the so-called interview effect - the interviewer may consciously or unconsciously influence the respondent to answer a certain way. Although, age, sex and education may also effect the respondents answers.

3.3.2 Contextual interviews and observation interviews
Observation interviews are a further development of observation as a method, combined with an interview. Contextual interviews means that you follow the operator you want to observe and actively takes part of the work and the environment in order to get a more concrete picture of the context and problems. Observed interviews are designed to deepen the understanding of operator's thinking, deeds and how he relates to his environment. The interviews are often unstructured; questions arise during the study or observation time. It is the observer’s task with the respondent’s help to identify what is important and get the conclusions confirmed by the respondent (Andersen, 1996).

3.3.3 Primary data
Some data-mining from the WMS log was conducted and Martin Barkman, WMS consultant at SCA Transforest, provided the output, a complete list of the actions in the WMS made over a period of one week. The data-sheet has been an object of analysis on what, how and by who tasks have been executed during the period.

The interviews that I have conducted at the Tunadal terminal have been of an open contextual nature. The interviews in the benchmarking study were guided but no questionnaire was used. The documentation of the interviews was always made simultaneously or directly after the interview. A complementing mail interview with persons at the Zeebrügge terminal did also take place.

3.3.4 Secondary data
Background information regarding Stora Enso and their terminal in Zeebrügge was collected from their homepage and other official sources.

I have also studied reports, white papers and documents from other surveys and benchmarking studies describing different problematics of the implementation of a WMS. I have primarily studied reports from The Aberdeen Group, an organization that provide the branch with extensive up to date data based on benchmarking studies. Aberdeen conducts probing research studies across all aspects of business and technology with 100s of companies participating in each research study to assure research depth and quality. The Aberdeen Group is the leading provider of fact-based research focused on the global technology-driven value chain and has, as stated at their website, “established the market leading position when it comes to understanding the measurable results being delivered by technology in business”. The reports were primarily a source of understanding how other companies gained efficiency with the implementation of a WMS and restructured their distribution centers to become best in class companies.
3.4 Comparative case study

As an extra input a case study on how system directed work has been implemented at a similar distribution terminal was conducted. I will critically discuss the findings from this study as an input for possible method improvements.

3.4.1 Benchmarking

Benchmarking is about to systematically compare yourself with the "best in class" to improve your own operations. It is important to emphasize that Benchmarking is not a one-off – it is something going on continuously over a long period (Kotler, Armstrong, 2001, p. 423).

By comparing the work processes, input and output, with other companies or parts of their operations, extraction of valuable information can be a good help to improve methods and processes. This is known as Benchmarking and the process of how this can be implemented summarized in three steps (Trimble, 2006):

1. Evaluate and measure the own activities or specific processes to identify weaknesses and strengths.
2. Conduct a benchmarking study and document the processes that are more productive and well designed than their own processes.
3. Evaluate how the processes and procedures could be adapted along with what they have learned by those who carry them out in a better way.

There are several types of strategies in the implementation of a benchmarking project. Examples of these are (Andersen, 1996, p. 19 ff):

**Internal Benchmarking**: different parts of the organization are compared with each other, e.g. in this case, other terminals and services. If the comparison shows that a terminal, for example Rotterdam, have succeeded in achieving a better (desired) result than another terminal, Rotterdam is used as reference and studies are conducted on how the activity is organized in Rotterdam. The advantage of internal benchmarking is that the information is readily available and differences in corporate culture are usually small. Also the cost of internal benchmarking is lower when it requires less preparation and no "start-up fee".

**External Benchmarking**: when own activities are compared with similar organizations, such as competitors in the same industry. A prerequisite for external benchmarking is to work in such a way that both parties can add value from the project, otherwise the project will fail because of discord. Despite the problems that can occur when external benchmarking is carried out it is still considered the best and the most effective form of benchmarking when it offers good opportunities for new insights and useful information.

Benchmarking need not only relate to the individual metrics, but also to qualitative data. Then so-called non-parametric comparisons can be made. These two are:

**Functional Benchmarking**: Compare its features with "Excellent" organizations, regardless of industry, such as comparisons of the distribution and administrative functions. It can be about a wholesale supplier of groceries to cooperate with a wholesaler for spare parts relating to logistics and inventory problems.

**Generic Benchmarking**: Compare with companies in other sectors than what the organization normally appears in.
Since I was not able to get precise metrics or statistics from the object of comparison the study can be identified as a non-parametric functional benchmarking study. This is of course not optimal, but it can anyhow bring many valuable insights.

3.4.2 External functional benchmarking at Sea-Ro terminal, Zeebrugge

I got the opportunity to conduct a case study in an external terminal where a similar version of the Red Prairie WMS system had been implemented. The terminal of reference was the Stora ENSO terminal in Zeebrugge, Belgium. The terminal is run by Sea-Ro and handles the same type of forest products as the SCA terminals. The advantage of this study was that they have almost exactly the same warehouse processes in comparison with SCA Transforest, and handles the same type of products by their specific requirements.

The focus of the study was on subjects regarding primarily the set up of the system and the terminal in order to adapt to the known uncertainty, i.e why and what technical and organizational solutions have been implemented and how they are working with productivity improvements. The outcome will be input for improvements of the methods at Tunadal where productivity potential have been identified. I will not explicitly compare performance indicators but discuss the type of indicators used in Zeebrugge.

Contextual background information, such as economic, logistic, cultural and organizational differences, is important to get a good picture of the object in a benchmarking study. Public sources of information, such as company facts, presentations, papers etc were used to get the basic facts about the company and general goods flow etc.

The interview could then focus on more specific aspects such as:

- Background and overall organization.
- Process: What is the scope of process standardization? What is the efficiency and effectiveness of this process?
- Organization: How is the company currently organized to control and perform the particular processes?
- Knowledge: What visibility is there to key data and intelligence required to manage the process?
- Technology: What level of automation has been implemented to support the process? How is the automation integrated and aligned? System-environment interaction and barriers for real time action
- Performance: What kind of performance indicators that are used and why.
- Roles and distribution of responsibilities between planners, operators and the WMS
- Human-system Interaction and interface
- Their experience of system-directed work
- User acceptance and user involvement in the development
- System integration and technical solutions in the area of real-time discrepancies, support and exception handling.
- Strategies for warehouse processes and feedback of the output

During the visit at the terminal I got the possibility to interview their IT manager, Louis Stevens. He was the man who had planned, simulated and organized the terminal before it was built in 2001 and have been working continuously with the development of processes, WMS interface and technical solutions ever since. The visit also included a round-trip at the terminal and the warehouses for a closer look at the warehouse design, working processes, interfaces and so on.
3.4.3 Criticism to the benchmarking method

It is not optimal to only have one day to visit the Benchmarking object. It is not possible to go very deep into problems and the process is not continuous resulting in insufficient follow up on issues and missing information. Another aspect is that companies are competitors and not totally open to each other, and therefore more detailed information regarding problems and solutions is hard to get.

3.5 Validity and reliability

Reliability and validity is about critically examine the methodology used in collecting data to determine if the information gathered is reliable and measures what it intend to do (Bell, 2000).

Reliability is the way to assess to what extent the approach can achieve the same results if it were carried out at a later moment, but under the same conditions. To reiterate a previous study, careful documentation is of great importance. (Yin, 1994) If a person participates in the same survey on two separate occasions the response may vary widely. In a quantitative study this will mean a low degree of reliability, while this is not necessarily the case in the qualitative study. The reason that reliability need not be considered low in the qualitative study may be due to the respondent changed its mind, is given new insights and skills. The interview could also be of a different nature, for example the respondents state of mood. In qualitative studies the reliability should be assessed on the basis of the specific occasion of the interview (Patel, 2003).

Validity determines whether a question describe or measure what it is intended to do (Bell, 2000). The concept of internal validity is used in conjunction with descriptive and causal studies. A causal link is created so that the search for events will lead to other events. If the examiner finds a causal link between two events but miss an additional event that has impact on the phenomenon the internal validity may be adversely affected. If the patterns coincide between empirical findings and theory this will strengthen the internal validity of the survey result. The external validity put focus on determining if the result can be generalized from the cases included in the case study (Yin, 1994).

3.6 Implementation

In an early state I saw some problems of defining productivity and efficiency, measure it and relate it to a not yet existing way of working. Warehouse simulation is one possible, but in this case complex way of addressing the problem. A lot of assumptions have to be made, not only assumptions of the environmental factors and resources, but also the choice of what assignment algorithm to use, efficient zoning- and positioning solutions etc. But this is not only a question of getting the system algorithms right. Implementing a WMS and system directed work in an existing environment give rise to a lot of other issues that are equally important. Since my task isn’t to find an optimal algorithm – but still say something about what there is to gain in productivity – I have chosen a more qualitative and exploratory way of approaching the problem.

The opening period of the study was conducted at the terminal in Tunadal. To get a good orientation and a more complex understanding of the problem observations and discussions with actors at different positions within the warehouse and the IT department was held. With the intention to get input from different perspectives, interviews were conducted with end-users, foremen, administrators and people on a managerial level.

During this period I started the search of reference literature, case studies and theory in the fields of Logistics, Organization, Management and Cognitive Work Analysis that could fit to this kind of study. The key literature used is; Effektivisering av Materialföden i Supply Chains by Stig-Arne Mattson (1999), Cognitive Work Analysis – Toward safe, productive and healthy computer-based work by Kim J. Vicente (1999) and The benchmarking handbook, Andersen (1996). The theoretical framework used in the study will be presented in the chapter Theory. Because of the scope of the study no single model will be used. It is a framework of theories that the
analysis will be referring to. As the context of the thesis is a Logistic system some theory regarding terminal flows, efficiency and productivity provided by Mattson will be used. Vicente present many important issues related to IT-supported work flow, as well as a method for analyzing work environmental and cognitive constraints in order to design IT-systems - also with focus on productivity.

3.7 Disposition
The Empirical framework include three parts. The first part will give a brief introduction to the WMS system, functionality, future prospects and current implementation.

The second part is a description of the current state at the Tunadal Terminal based on observations and interviews with the terminal managers, planners and operators. The focus is on issues and obstacles related to the WMS implementation and system directed task assignment that have come up during the interviews.

The third part is a report from the findings of benchmarking study at the Stora Enso terminal in Zeebrügge.

The analysis includes findings from the benchmarking studies regarding solutions that may be advantageous for the Tunadal terminal are critically discussed. Argumentations based on analysis of data from the current work and the interviews will be presented.

The report will end up with conclusions and recommendations for future organization- and system development.
4 Theory

Logistics is about controlling and managing flows of products and information in an efficient way. The following chapter will look into theory regarding efficient logistics, supportive systems, cognitive work analysis and some important models and concepts will be highlighted. The chapter will end with a discussion regarding perspectives on efficiency, flexibility and productivity.

4.1 Managing warehouse processes and flows
The main purpose of a warehouse or terminal is to balance the variance of inbound and outbound flow. The terminal is a node in the logistic system, and its efficiency is in its possibility to create value by connecting different modes of transport. As there is not always possible to cross dock incoming and outgoing goods a warehouse is needed for housing. Other value adding activities often performed at the terminal are for example consolidation, sorting or breaking of goods in a way that makes transportation and distribution more agile and cost effective (Mattson, 1999).

4.1.1 The flow of goods
In a terminal or warehouse three logistic phases can be distinguished; Inbound, Internal warehousing and Outbound. If the inbound and outbound flow coincides the goods can be cross-docked. Otherwise it has to be put into storage until it is ready for shipping or pre-loading (Mattson, 1999).

Registration of incoming goods, put-away, inventory moves, cross docking, picking and shipping, are all examples of internal logistic processes. In figure 4 are these presented as arrows connecting the different logistic phases.

4.1.2 The flow of information
Information is a very important part of an efficient logistic system. Information flows between actors and links in the supply chain (Lambert, Stock, Ellram, 1998). The flow of information must efficiently support and administrate the physical flow. There are three main reasons to why correct and punctual information has been a more and more important part of efficient logistic flows (Bowersox, 2002):
The customer is able to track the order and follow up order status, product availability, transportations etc. as a natural part of the customer service provided. The information is not only an important part of a company's competition but also the customer's ability to compete with other actors.

A company's goal is to reduce its lead times. Information can be used in this purpose, especially by bringing visibility into processes and flows and thereby reduce uncertainty. Uncertainty is a big factor to why companies fail to complete strategies and plan future events. Information increases the flexibility regarding how, when and where available resources can be used to obtain strategic advantages. On the other hand lack of information is often the reason to why logistic operations cannot be performed fully without making too much work in vain. It is a balance of doing things in uncertainty and add value or be counterproductive.

Information transfer is one of the most important functions in warehousing and distribution. A well-adjusted and reliable information flow is crucial in order to perform all warehouse activities in a correct and efficient manner (Lambert et al, 1998). Information regarding internal processes and flows is mainly a question of what is measurable and use that information in the best way. More and more routine bound automated data also increase the requirement for the development of functional support for the operator to monitor and understand what is happening in these flows. The division and coordination of work determines what information content actors need to perform their duties. If a group of actors is responsible for a particular level of abstraction in the work domain, the information contained in that level defines the information content that should be presented to that particular group (Vicente, 1999, 254 pp).

The importance of visibility into warehouse operations cannot be neglected. A key enabler of warehouse agility is timely, reliable data that is integrated with the WMS. These requirements must be met in order to get the most out of the investments made. With real-time visibility to activities inside the warehouse managers and planners are able to more effectively balance their workforce and create more cross-operational opportunities for example task interleaving. Best in class companies find that once the data is visible in real-time the focus can then be turned to optimize processes (Aberdeen Group, 2008).

4.2 Decision Supportive systems

Depending on the system's level of automation, if it is a decision-making or decision supporting system, the operator is given more or less the opportunity to influence the process output.

The purpose of automated supportive systems is to create a higher decision quality that result in higher value in relation to manual decision-making (Mattson, 1999, p 189). The system must support the decision-maker and not replace him. The decision support should assist decision makers and increase their ability to make sound decisions. With support from the system, the decision-maker should be able to control the entire decision process. Together with the human judgement, the system provides support in semi-structured and unstructured decision situations (Turban, 2001). The fundamental motive is to uncover and fulfill all the requirements and conditions that must be met so that operators and users can serve as flexible and adaptive problem solvers in the socio-technical system (Vicente, 1999).

If users will perceive the decision support system as favorable, it must be easy to communicate with, robust and easy to control. In addition, it must be adaptive, and complete on important issues that users handle. The decision-maker must be able to quickly confront changing conditions in the business and adapt the system to address these. The system must provide exactly the functionality required to enable operators to fulfill their qualified tasks and confront unexpected events. The operator and the system support must work together in a way that enhances the performance of the system as a whole (Vicente, 1999, p 245 ff). This requires the
decision support system to be flexible so that users can add, delete, combine, modify and restructure parts of the system (Turban, 2001).

4.2.1 Computer-based support in open systems
An open system is generally speaking a system that interacts with its environment (i.e. a system with disturbances). In an open socio-technical system disturbances will always occur. These disturbances will have a negative effect on productivity. Some disturbances are known and can be dealt with if they can be identified.

Open systems give rise to context-conditioned variability and workers must adapt in real time to disturbances. A fundamental assumption is that a human agent within his environment has a large number of action alternatives, i.e., to formulate the task, to define the activities, and to control the movements. In order to be able to select a particular sequence of action, a number of explicit or implicit choices and decisions have to be made (Rasmussen, 1990). Unlike normative systems, where users are forced to follow a specific sequence of instructions for achieving a goal, the formative approach give operators the opportunity to "finish the design" of the system, i.e. with their adaptive skills to perform tasks of a complexity level that is difficult to design into the system. The operator’s role is to use his expert ability to create solutions that counters the interference effect (Vicente, 1999, p. 121).

4.2.2 Centralized versus Distributed control – two different principles of control
The fundament of Vicentes argumentation for a formative approach lays in the division between centralized and distributed control (Vicente, 1999, p 126 ff). In the traditional approach to work analysis and systems design a centralized control is adopted. The approach is centralized because decisions about what should be done and how it is to be done are made beforehand by designers, the central authority in the scheme. The designer analyzes the work and, in the extreme, tries to identify the "optimal" way of doing the job. The insights derived from this analysis are then used to develop a plan that is implemented by one or more means, such as: 1) automation that performs the job according to the optimal plan, 2) a computerized work flow that forces workers to follow the optimal plan, and 3) paper- or computer-based procedures that guide workers in following the optimal plan. There is therefore little intellectual work left for workers and alternative actions are minimal.
4.2.2.1 Centralized control

As shown in figure 5, alternative A) present the concept of centralized decision making. In this case the system designers try to anticipate everything from the optimal plan. Optimization requires reliable data. All factors must be measurable for the output to be correct. Computers then mediate workflows and procedures. Operators’ finish the constructors plan or let the automation take over. There is little or no operator influence over the outcome.

4.2.2.2 Distributed control

In case B) distributed control, the system designer identifies a priori predictable conditions and limitations. The system then provide the operator with relevant information. The operator terminates the design through his knowledge, and with input from local information. The role of the operator as an adaptive problem solver is better exploited, of course also with the increasing risk of human error into operations - something that can be mitigated with other solutions such as barriers for unwanted actions.

4.3 Productivity, efficiency and flexibility

Productivity is a term often used but the meaning is not always clear. There are many factors that impact on productivity and some of them are difficult to measure in precise terms. This means that it often requires an extensive process to gain insight into how large their impact on productivity really is. The basis of implementing targeted productivity improvements is to identify the factors affecting the productivity of the business. In logistics the goal is a high level of service to the lowest price possible. In other words, resources (trucks and operators)
must have a high productivity per man-hour. But they must also be efficient, do the right thing that means maximizing value adding and prioritized tasks.

It is important to emphasize the difference between productivity and efficiency in the assessment when new tools have been implemented in organizations and activities. Productivity measures the difference between input and output, enabling the development of indicators for monitoring the specific process or activity. Measuring e.g. number per hour, or the value of output relative to the value of inputs. Productivity is about producing the right way, to perform the processes right. In this way, measuring and steering the organization towards increased output (quantity, value, income, etc.) and reduced input (working hours, resource use, cost). Improved productivity is therefore designed to either increase output with existing resources or to produce a given output with fewer resources. High resource utilization can lead to rationalization (Ewing, Samuelson, 2002, p. 60 ff). It is important to emphasize that high productivity is not a goal for a company in itself but rather it is one of several ways to achieve good profitability. Productivity is only one factor of many that affect the company’s profitability (Mattson, 1999, p 119).

Efficiency is a broader concept. Eklund (1999 p. 36) explains efficiency of production with the resources allocated in such a way that it is not possible to increase the production of a product or service without reducing the production of other goods or services. In summary, we conclude that the effectiveness is about getting done what was intended and that it is accomplished with minimal effort / resources.

4.3.1 Resources and time
When time is discussed in a management perspective two concepts are commonly used, lead time and delivery time. Lead-time can be defined as the time between a need is identified until it is satisfied. The lead-time consists of administrative lead time and physical lead time. The later relate to the time it take to move the physical item. The concept is favorable because it is able to implement in every part of the supply chain (Persson, 2001, p 242).

The time can be divided into three categories

1. Value-adding
2. Supporting (non-value added, but necessary)
3. Non value-adding or unplanned stop time.

The non-value-adding time is the actual (theoretical) productivity potential with the current method of work. In order to increase profitability actors in the system must strive to ultimately fill the time with value adding activity (Mattson, 1999).

4.3.3 Flexibility
Flexibility is a term closely related to both efficiency and productivity. Since flexibility is primarily intended to meet the customer’s needs, i.e focusing efficiency of output, it is an internal aspect, for example the ability to prioritize and move orders or resources between different workflows. In the case of a dynamic warehouse environment flexibility can also be looked at as one of the key factors to an efficient work flow, the ability to adapt to the current situation and still be productive (Kinnander, 2006). In an open system disturbances occur randomly. To cope with these disturbances and satisfy the customers’ requirements, enterprises need to be more flexible and responsive as well as more efficient. This provides more freedom and flexibility in order fulfillment and thus translates into better customer service.
4.3.4 The relation between productivity, flexibility and efficiency

Sushil (2003) discuss the relationship between the two key performance variables of any enterprise, i.e. flexibility and productivity. A normal proposition is flexibility hampers productivity by reduced output and requirement of more input. Normally, it is argued, that as flexibility implies more options, change mechanisms and freedom of choice, it would be hampering the productivity both by way of reduced output and more inputs for more options. Normal assumption is that a dedicated system requires less input and is more efficient. But, a flexible system may better cope with uncertainty of demand leading to less inputs per unit of output. In an uncertain and dynamic environment, the real productivity of a more flexible system is expected to be higher than a less flexible system. This idea is important to understand certain types of flexibility. The first, operation flexibility, relates to the possibility of performing an operation on more than one machine. The second, sequencing flexibility, refers to the possibility of interchanging the sequence in which required manufacturing operations are performed. The third, processing flexibility, which is determined by the possibility of producing the same manufacturing feature with alternative operations, or sequences of operations.

4.3.5 A flexible organization

The traditional way of organizing a manufacturing or distributing company may be characterized by a functional division of work tasks and responsibility. Individuals and departments are expected to perform isolated and specialized tasks. Cooperation among the different departments is often made thru communication by the heads of the departments. The basic principle behind this form of organization is the assumption that it is more effective to specialize in a certain field because the resources of the department may be optimally utilized. This may be true, but in a broader context it may be contra-productive to the total efficiency of the company. This traditional way of organization is characterized by having a function-oriented rather than flow-oriented view. For the individual in the company the head of the department will turn into a more important actor than the customer. The functional organization model is oriented to administrate resources in an efficient way rather than creating efficient value creating flows (Mattson, 1999, p 67 ff).

The drawbacks of traditional function-oriented organization have increased along with a higher proportion of customer order based production, so called Pull. The benefits that the organization have had in terms of efficient use of resources can no longer compensate for its shortcomings in coordination and the increased need for flexibility. Businesses that are customer order driven should have a flow-oriented organization to meet the requirements for flexibility (Mattson 1999, p 69).

When introducing a new IT system in an organization this will create new ways of communication and making decisions - which affect the workflow as well as the existing roles and responsibilities, Some roles may be reduced and other created as a result of the new structure. If the organization does not change accordingly the IT system may not be as effective and vice versa. The introduction of an IT system like WMS with System directed task assignment is a significant change in work flow but also in organization in relation to traditional way of working. Reports show that a successful implementation of system directed warehouse activities require changes in roles supporting this way of working. The Aberdeen report of 2008 conclude that of those companies considered best-in-class 89% have established central monitoring and direction of warehouse processes which provide greater flexibility and agility. Together with increased visibility and more collaborative process capabilities, fluctuations and disruptions inside the warehouse and the companies have have been minimized (Aberdeen Group, 2008). Aberdeen's Research Benchmarks provide an in depth and comprehensive look into process, procedure, methodologies, and technologies with best practice identification and actionable recommendations.
4.3.6 Operator Autonomy - Flexibility

Autonomy refers to the extent to which workers are allowed to improvise or adapt doing their job. When workers are responsible for dealing with unanticipated events they must improvise and adapt because their normal procedure no longer apply in these cases. The worker must then generate an appropriate response based on a conceptual understanding of the work domain. As a result, information system design cannot be based solely on expected or frequently encountered situations. Socio-technical systems must operate effectively even – or especially – under rare events that are not anticipated by workers or designers. This makes the role of computer-based support systems even more important (Vicente, 1999, p 17).

By constraining rather than instructing workers gives the worker more discretion to decide exactly how the task should be performed and not be constrained by the designers assumptions on functionality. A constrained based task analysis is needed to identify the information requirements that will help workers achieve anticipated task goals in a flexible, situated manner. Improve decision latitude by providing workers with the autonomy to make decisions and the opportunity to exercise and develop skill. Thereby better productivity would be expected (Vicente, 1999, p 95). An improper decision system can be likened to a “black-box” that provide limited opportunities for the operator to co-evolve with the system and its goals.

Providing autonomy does also allow workers to develop their skills. Unskilled workers may have difficulties to effectively exercise autonomy. Lack of control over how workers do their job and how they can exploit their skills are the primary risk factors in stress related diseases (Vicente, 1999, p 29). Discretion is not complete freedom, it has to be given within the boundaries of safe and effective operation (Vicente, 1999, p 81). By using these criteria to identify the boundaries of responsibility of different actors, room for flexibility and adaption that are required in socio-technical systems will be left open. Operator involvement in decision-making can directly affect the motivation and ability to develop a sense of their work.

All operators are individuals and they will thus have varying decision behavior. Although "The Firm is a group of individuals", i.e. individuals within the company has its own goals that are not always consistent with the overall objective of the company, which means that they are not effective. It is therefore important to reformulate the company’s overall goals down in the organization at the operational level (Sjöberg, 1996, p 29).
5 Empirical framework

The empirical framework includes three parts that will be the basis for the following analysis; A description of the WMS functionality - how it is supposed to be applied and what has been introduced in Tunadal. A description of the current situation, organization and user groups at the Tunadal terminal. And finally, a presentation of the findings from the functional benchmarking study at the Stora Enso terminal in Zeebrugge.

5.1 Operation support with a Warehouse Management System

A WMS is used to control all the operations in the warehouse – tracking stock movement, managing resources and inventory. This make it possible to support different warehouse operations (e.g. picking, internal moves etc.) by directing warehouse activities from source to destination locations.

Among today's distribution centers there is a growing gap between the "haves" and "have nots" when talking about automation and successful efficiency improvements. On one side there are companies that are highly automated. The daily operations of the warehouse is planned and optimized with advanced WMSs. Tasks are sent wirelessly to operators in the warehouse, they execute the tasks and confirm their actions with bar-code scans. The location of every item in the warehouse is tracked in real-time, and there is no or little administrative work required to operate the warehouse.

On the other side are companies that are operating their warehouses traditionally using manual methods. Managers and planners plan all processes and hand out spreadsheets with instructions to the warehouse operators. The operators work on their own in the warehouse with little or no ability to optimize their work. A lot of data is translated from handwritten reports and processes are carefully checked for accuracy (Aberdeen Group, 2007).

On the surface it would be easy to say that the "haves" perform better than the "have-nots". This is partly true. Among the results in the extensive Aberdeen report of 2007 it is revealed that there is a strong correlation between basic process automation and improved warehouse performance (Aberdeen group, 2007). But the question of how and what to automate is still dependent of the company business, size, technology, organization etc. The strategy required to accomplish this will vary by the nature of each individual distribution center.

The decision to waive the manual warehouse planning for an implementation of WMS are often made in order to improve services, i.e. reduce errors in orders, picking, inventory etc., and to increase utilization of available resources. Tracking stock movement, managing resources and locating inventory are the basic features of a WMS. At all of the Interforest terminals, as well as Stora Enso’s terminal in Zeebrügge, a WMS from the software provider RedPrairie has been implemented to facilitate managing, monitoring and controlling of the warehouse activities.

In order to implement the above mentioned functionalities some basic setup must be installed. In the following sections the necessary basics for a WMS support will be explored as well as the WMS functionality in today's operations at the Tunadal terminal.
5.1.1 System-environment interaction
The most common technique used to mark inventory, locations and carriers are barcodes and RFID. Together with bar-code scanners, fixed on the truck or handled manually by an operator, can all actions be registered in the WMS. As well as all actions will be registered, these technical solutions does also allow the system to validate the operations performed by the operator and make it possible to provide direct feedback to minimize error handling. The use of scanners and RF technique also reduces paperwork, which often is a source for manual errors. Lead time for picking can often be reduced by the use of these technical solutions (Singer, 2007).

There must also be a technical solution for the WMS to communicate with resources in the warehouse. Wireless communication such as RF or Wifi are the most common. Wifi may also be used for positioning of trucks in real time in a terminal or warehouse area. The problem of positioning resources can also be solved by letting the resource “tell” where he is based on what location or zone he currently work in. Identification and positioning of resources are prerequisites for having the WMS distribute assignments to appropriate resources based on their current position.

In Tunadal all inventory, reels and pulp bales, are marked with a bar code, so called license plate. To register a reel in the system the truck operator has to scan it with the scanner fixed on the truck. Currently there is no technique for positioning of trucks - Wifi has been tested but the paper reels in the warehouse absorb a lot of radiation.

5.1.2 The Warehouse structure and capacity modeling in WMS
Every warehouse location, inventory and resource must be mapped in the WMS. This requires a lot of configuration. It is a very important step to configure the basics properly. The information will form the WMS capacity model on which all calculations and optimization are based.

The warehouse locations are assigned values like area, height and other preferences. This information is stored in the WMS and represents the model of the warehouse, its design and limitations. Locations can be divided into storage areas, so called home zones. Home Zones can be grouped into larger Home Zone Groups with specific characteristics that the generation of put-away proposals will be based on. Each product must be associated with a strategy, a routine for how and where it should be placed in the warehouse. For the picking process, home-zones are divided into sections, and sections into pick zones. The formation of Pick zones is often based on picking frequency.

5.1.3 Strategies to direct goods in the put away process
Rules and strategies for how each inventory/item should be handled are set up in the WMS. These decision rules, called strategies, works in the background and are set by the administrator. When an incoming item is registered by the operator the product type is sent to the WMS which, in turn, based on the strategy related to this product, check the associated home-zones, generate and return a proposal to the operator where to put it. An efficient use of the warehouse space requires appropriate configuration of the Home Zones, Home Zone-groups and the setting of strategies for each inventory.

5.1.4 System directed task assignment
The basic requirements are key enablers to warehouse automation and optimization. Once they are integrated and deliver reliable data more advanced process methods can be implemented and the organization can begin to explore more advanced functionalities and high performance capabilities.

Warehouse tasks are movements from a location A to a destination location B within the warehouse. Warehouse orders consist of several tasks. Warehouse orders can be distributed in two different ways. One way is that the
planner manually assigns an order to a resource (a truck and its operator). In this case the supervisor's decision will determine if the assignment is optimal or not, the algorithm efficiency doesn't matter. The second way is to let the system decide what to assign and how (this is the so-called system-directed mode). With a more sophisticated WMS setup the ability to define, plan and prioritize tasks, assign tasks to operators (truck drivers, warehouse staff), and guide operators in the execution.

Figure 6 show the concept of system directed task assignment. Warehouse orders (WOs) ready for processing are released into the WMS order queues by a planner or manager. WOs may also be auto-generated by the WMS or triggered by events in the terminal environment. Generally queues are defined by their warehouse process or zone, for example inbound, internal and outbound queues. Queues could also be set up for orders with different prioritization. Since different companies may have different warehouse layout the setup may vary.

Resources are grouped based on their attributes, technical as well as others. The truck operator will use a “looking for work” menu item as each task is completed. When a resource is looking for work the system loops through the first queue (which is assigned to the resource group) and selects the first open (not locked by other resources) WO and assigns it to the resource. If there is no open WO in the queue the algorithm will check the next queue in the sequence. If there is no more WO in the queue then the resource has to do nothing (Monori, 2008).

This means the overall performance of the software not only depends on algorithms, it relies also on correct customization in order to generate optimal decisions (Monori, 2008). This is only when the distribution of tasks are system directed. Business demands may also require situations when planners must assign orders manually. Therefore it is crucial that the WMS also works as a supportive tool in critical situations and exception handling.
5.1.5 Decision support
With its superior overview, the WMS system is a powerful administrative support and a tool to plan and control activities in the warehouse. Everything that is registered in the system, such as moves, activity, interaction between inventory and operator etc can be monitored in real time and will also be logged. The system database may therefore be an ideal source of information. Under the condition that every interaction is locked to an actor, a location, and inventory on an individual level, the information of what and when actions have or is taking place may be able to track in real time. WMS is therefore a powerful tool to get visibility into warehouse operations. This possibility should be used to support work on all levels, for managers, planners and operators (Fredholm 2006, p 81).

5.1.6 The current WMS operation support at the Tunadal terminal
The internal operational activities in the warehouse are supported by the WMS as follows.

5.1.6.1 Inbound, Handling and registration of incoming goods
Incoming traffic and the orders connected to the vessel is registered in the WMS. This will trigger a put-away assignment. The Put-away process aim include the finding of an appropriate location in the warehouse. The simplest form of put-away is called User Directed Put-away. The truck operator decides where to put the goods and register the move in the system using a RF (radio frequency) device or similar approach. A more advanced form of put-away is called System Directed Put-away. In this case the WMS decides, based on given strategies, a suitable location and directs the operator to put the goods in this location. How this decision is generated depends on the decision strategies that are set up by the administrator in the WMS. The truck operators in Tunadal have a lot of influence on how to direct goods in the warehouse. This is manifested by the override function that is used to override the systems proposal of where to put inventory. The override frequency in the put away process is about 13%. (Appendix 1)

5.1.6.2 Outbound - processes related to the Shipping of goods
Information about transport mode and time of shipment rule how and when the loading process can start. For orders where the shipping time is known and goods and equipment is in place preloading may be applied. Then a manual release of pick tasks into the system can be made. This is applied when to prepare more complicated and time consuming shipments or to balance workload. For other time dependent shipments, as the loading of an incoming trailer or vessel, the arrival triggers the release of a pick assignment in real time.

When an order is ready for processing the planner will release it into the WMS order queue. The WMS will then allocate the goods intended for the order based on allocation rules. There are mainly two ways in which the WMS allocate goods, soft and hard allocation. Soft allocation, is when the system allocates goods on order level. This means the operator is free to select the location from which an item of an order will be picked if the order exists in many locations. The operator can pick any individual as long as it is the correct order. Hard Allocation means that the system allocates on individual level, i.e on specific individuals at specific locations.

5.1.6.3 Stock Movement
Movements and stock adjustment is necessary in the warehouse to “tighten up” the warehouse space and create empty locations. In some cases inventory must be removed because it block an the order that is going to be picked. In manual warehousing, for example in Tunadal, these moves are manually planned, a process that often take a lot of administrative time. The WMS is, with its superior overview, able to generate rule-based movements to ensure high quality decisions.
5.2 The dynamic terminal environment

The terminal facility in Tunadal consist of four big warehouses and sheds for staging cassettes and bulky goods. The warehouses consist of bays and aisles. Each bay is considered a warehouse location. The bays vary in size between one to ten paper reels in depth and up to six reels in height.

The aisles are broad so that trailers, cassettes and trucks can move around and also be staged inside the warehouse. In each aisle areas are marked that are used as staging locations for trailers and cassettes. This approach has both advantages and disadvantages – it enables the planners or truck operators to stage carriers or trailers as close to the pick or put away location as possible. If an order of a trailer shipment exist in more than one location, or in different sheds, the trailer can be moved closer to this location in order to minimize the driving distance of the truck handling the goods. An negative effect is for example the risk of congestion that can occur when there is a lot of activities in an area, something that also increases the risk of damaging goods and inventory.

Neither there is no fixed point for incoming and outgoing goods, as there is for example in warehouses with a dock system. Altogether these factors make optimization of the warehouse activities quite complex.

5.3 Inbound and outbound flows at the Tunadal terminal

There are many everyday logistic challenges that the terminal managers and planners have to deal with such as;

Fluctuations in workload over the various work areas at the terminal, uncertainty due to lack of information that complicates planning and preparatory work, variable process times because of disturbances and inhomogeneous workforce with respect to skills and experiences (Gyllroth, Interview).

The terminal has a traditional function oriented organization with different departments that focus their work on separate processes of the terminal. The departments are; *Inland transport* – loading and unloading of inbound and outbound trailers, *Railroad* – loading and unloading of inbound and outbound trains, *Container loading* – loading of containers, and *Quay* – loading of cassettes for system vessels and conventional vessels.

Inbound, The production rate at Ortviken is normally close to 100% so the pace of incoming goods is steady and predictable. The planners keep track of the current production at Ortviken to foresee the incoming orders. The time lag from production until the goods arrive with trailers to the terminal is a couple of hours. Fixed resources handle unloading of inbound trailers (Johansson, Interview).

The outbound flow is more fluctuating, uncertain and time dependent. Trailers are expected certain days but the no exact time of arrival can be given. Loading of trailers is easier because the trailer can move around in the warehouse to the location where the goods are stored. If the goods is spread out among warehouses the trailer will be moved around.

The time of arrival and workload for system vessels is well known and predictable. Goods that are planned on the system vessels can start to load on cassettes as soon as the goods have arrived from the mill. Loading of cassettes is an activity that can be performed during low activity hours.

What fluctuates most is the outbound workload and specially the loading of conventional vessels. The quay uses a lot of extra resources to adapt to the current capacity need (Granberg, Interview). Loading of trains and conventional vessels is more time dependent. The time trains and vessels can be in loading is often restricted and loading time should be minimized. High service is important to satisfy customer demands on fast loading to minimize stop time and time in port.
The workload of picking activities, when goods is taken from the warehouse with a carrier, conventional vessel, trailer or railway wagon as shipping destination, vary a lot during the day. Some of the activities are just performed during daily hours. Figure 7 show the work performed during one day for each of these picking activities. The number of active truck operators vary from hour to hour - but the fact that the total output vary a lot not just during the day but also from hour to hour is typical. Balancing workload and resources more flexible to avoid heavy peaks would lead to a more steady work tempo as well as better use of resources. The question that follow is how work should be distributed most efficiently, and if operators are able to move and be used where they are currently needed in a cost efficient way.

![Chart showing the number of picks for different shipping destinations over 24 hours (7th July 2009).](image)

Figure 7. The chart shows the number of picks for the different shipping destinations seen over 24 hours (7th July 2009).

The pattern is typical for picking activities during a day.

Resources can not always be moved from one activity to another without changing clamps or solely change truck. If there is work to perform in one area of the terminal and an available resource in another area there is not always cost efficient to move the resource because it take extra time in transportation an to change the technical setup of the resource. Today, this decision is on the planner that have insight in the coming planned work. The decision to move a resource may not be economically optimal but due to the requirements of service, situation dependent priorities is a must.

### 5.3.1 Unbalanced workload among the Terminal departments

The following sample data is taken from the WMS log and it shows the workload over a five day period. The different picking processes are all represented. The total output and the internal levels do vary, but for all weekdays the pattern looks about the same. Most activity 8 to 16, and also big differences in workload among the modes of transport and departments of the terminal.
Figure 8. shows the fluctuating workload during peak hours for a three day period. Loading of cassettes (System Vessel, SV) is an activity that can be used to balance workload and use the resources to produce other more prioritized tasks, something that would decrease lead-times and strengthen service levels for other activities.

Time efficient task completion is important for most loading and unloading operations in order to keep a high level of service. The loading of cassettes by picking reels from the warehouse is an activity that isn’t time dependent in the same extent and could be less prioritized in most situations. The charts in Figure 8 show that low prioritized picking tasks, for example loading of cassettes (SV), is often performed during peak hours even though more prioritized tasks are present.

Inventory movements are sometimes necessary to organize the shed and create empty locations. Move tasks are mostly not prioritized and could be performed during low activity periods to balance workload.
The data in Figure 9 is taken from the WMS log and represent the moves performed during a five day period. From this sample about 50% of all inventory moves is performed during peak hours, 8-16. Most of these tasks could probably be assigned to resources during low activity hours to balance workload and/or prevent slack in resource utilization.

5.4 Resource planning
A resource planner has the responsibility to calculate the resources needed for every day. The inbound flow is quite smooth over the day but the outbound flow is more unpredictable with heavy and irregular peaks. For example, when a conventional vessel is to be loaded extra personnel is needed during the loading period. Truck operators are called in to perform this object related task. The calculated workforce for each object is based on earlier performance. If a vessel has been loaded by four people in eight hours this outcome will set the standard for the next coming loading of the vessel (Byström, Interview). If the work is finished faster than calculated the workers may go home, but they still get paid for the hours they were called in for (Granberg, Interview).

Available resources that are not exploited will result in slack of capacity and unnecessary costs. A goal is to minimize this slack with better planning, but today it is mostly a question of finding proper tasks for the resource during that can fill up slack time. Such tasks could be inventory moves or other low prioritized tasks. Moving truck operators to other activities is not always possible because of mismatch in operator task competence or because the truck doesn’t have the proper equipment (Johansson, Interview).

As earlier mentioned does the process times often vary. There are big differences in task completion time due to disturbances and varying performance among resource. Altogether these factors make it hard to predict and match resources to workload resulting in capacity slack etc.

5.5 User groups
There are two user groups working in the WMS. The planners, that feed the warehouse operations with tasks, and the truck operators that execute the tasks on the floor, and register the activities in the RF (the WMS extension in the trucks).

5.5.1 Planners - Load planning and balancing of orders
There are planners working at each department of the terminal. The main planning and resource planning is centralized but each department get their resource group for each day. The main tasks for the planners are load planning for example making specifications on how to load cassettes or containers, administrative tasks connected to vessel or trailer arrivals and loadings, administrative support for truck operators and warehouse
related problem solving. Beside the WMS the planners use three other systems for planning, order management, support etc.

All releases of warehouse orders to the system are made by planners. The warehouse orders should be released as they get ready for processing, but this procedure isn’t always followed. One example is the release of outbound trailer loading tasks. These are often made in the morning for all outbound trailers of an order, not in the sequence they actually arrive. As a result the truck operators experience trouble with allocated reels in the warehouse. According to the planners they do not have time to work on the principle of real-time because this requires continuous attention and takes time from other tasks (Jönsson, Interview).

Another administrative task that the planners have to deal with, and that often have been mentioned in the interviews as a problem, is re-allocation of reels in the WMS. Planners as well as operators are experiencing lack of flexibility in the WMS, especially when moving and reallocating goods. One example, as it is often necessary to rearrange vessels along the quay to make room for more prioritized shipments. The procedure results in totally different loading conditions because the relation between closest located goods and loading destination change. Hard allocation is applied in the WMS meaning that the truck operator is restricted to pick orders from the locations where the goods is allocated. This is a configuration in the WMS. The planners need to reallocate goods manually in order to optimize the loading procedure (Johansson, Interview).

The offices of the planners are located outside the warehouse facilities so that the quay, the gates and rails can only be partly viewed. The direct visual overview of the terminal is limited, and there is no ability to overlook the activity in the warehouse from the planner’s position. They have to rely on the interface of the WMS and the communication over com-radio to control and follow up work. The possibility to track every truck in real-time thru the WMS is a standard functionality, but currently there is no complete overview of the current state of the warehouse activities presented in the interface. There is a lot of communication over the com-radio to direct resources to take prioritized tasks and to check their current work status. The approach result in a lot of communication over the com-radio - something that many think is disturbing (Johansson, Interview).

As some internal processes performed by truck operators include more than one handling step this will create a chain of actions performed by many resources - but the RF is only used by the operators in the warehouse, only a part of the active resources are therefore registered in the WMS. At the current moment it is not possible to register the actions of, or instruct, these resources through the RF/WMS. It is not possible to supervise or control the trucks outside the WMS, only via radio communication, spreadsheets or on-site direction (Gyllroth, Interview).

5.5.2 The truck operators

The truck operators’ main task is to execute the planned tasks in the terminal, warehouse orders that the planners have released to the WMS. The truck operators does also cope with a lot of supportive and secondary activities such as reporting damage, moves, cleaning, minor problem solving and so on. The experience of working with computers and competence using the RF and dialogues differ a lot among the users.

Today the operators get instructions on spread sheets on what there is to be performed during a shift. The operators are working in groups and one of the operators have the responsibility to inform the other in the group what to work with. Instructions on spread sheet made up and distributed by the planners is telling the operators what and how to stuff goods on cassettes and trucks. In the WMS, that connect the resource via the RF in the truck, the operators choose what to work with and register the actions performed.
The own developed RF dialogue was implemented to fit the old way of working and it hasn’t significantly changed any of the processes on the floor. But there are many work related issues that came with the new system and RF dialogue that turn up in interviews with truck operators. The WMS interface and the own developed RF dialogue have received a lot of criticism for its lack of usability. There is a lot of dissatisfaction among the users with too much clicking in menus, lack of information (that is accessible but not presented), incorrect use of monitor space etc. This issue hasn’t got much attention during the roll out period. No user studies or usability guidelines have been used during the development of the RF dialogue in the trucks. Neither has the standard interface gone thru any changes although certain problems are perceived as restraining and affect the productivity (Johansson, Interview). In interviews with truck operators some mention that with the current RF dialogue some processes that used to take 30 minutes to fulfill now can take up to 45 minutes to complete just because of the interface dialogues and lack of information.

Another issue that came up during the interviews was that when the new RF was introduced there was no obligatory education in the new interface or the developers vision of the system. Some key users were educated and these was supposed to educate the rest of the staff. There has been a lot of ‘learning by doing’ that has resulted in the creation of sub routines in operations. One example that often occur in the put away process is that truck operators scan the first reel of an order to get a proposal of location from the WMS where to put the reel. This procedure is supposed to start with the scanning of one or two reels and end with the operator hitting F8 on the keyboard when he has put away the reels in the clamp at the proposed location. But, instead of doing this the operator scan the first reel and, gets a location, skip to push F8 to tell the WMS that a put away has been completed and goes back to pick up a new reel. In this way the WMS only give one proposal to the operator and not to each individual reel that is scanned. The sub-procedure have many side effects, for example won’t the WMS ability to optimize each operation be fully utilized, the WMS register the move as one move instead of many (if there are 340 reels there it will be registered in the log as for example one move of 340 reels that take 2 hours instead of the natural procedure where there are 340 moves during 2 hours). The actual handling don’t differ, but as the system work today the latter example cause a discrepancy between the actual process and the systems model that make real time monitoring of the process impossible.

The truck operators have of course a lot of influence over the physical flow of goods as they carry out all warehouse tasks. The WMS do instruct them where to put each order, but to give them some freedom they also have the right to override the system. This functionality is necessary in some situations but it should not be used too extensively. In the warehouse environment the following situation can occur: if several resources, trailers or cassettes are in the same area or in the same aisle congestion occur and the resource has to wait without working. During waiting the time is ticking but there is no effective work and the latest starting time of the other orders will be the same. There must be a possibility to skip an order, or change the execution sequence of the orders, if possible. Congestion, junk data and other disturbances directly effect the operators ability to perform the assigned task. Now and then the operators have to make own decisions due to these obstacles, override the system, or report to planners. Data show an override frequency in the put away process is about 13% (see Appendix 1). The operator influence is significant, but if and how it affect the total efficiency is hard to say.
5.6 The benchmarking study

The following sections will provide a brief description of the logistics system for the reader to understand the context in which the studied terminals are operating. The work environment, the overall organization, the user groups and their division of responsibility, system-environment interaction, automated procedures and the work for continuous improvement of methods will be more closely studied in order to analyze the role and use of the WMS in the operational business. I will also critically look into how they cope with flexibility and autonomy among operators and planners.

5.6.1 The objects of comparison

SCA and Stora Enso are the Nordic region’s two largest forestry companies. They have both big shares of the European pulp and paper market and have several common product types. From their large production of pulp, paper and wood in Sweden, they have developed their own logistics system for distribution of their goods to the European market and worldwide. The logistic systems are developed to optimally manage the distribution of paper reels, a product that in many ways requires special handling to maintain the high quality on their way from the production plant to the customer. Reels of paper are sensitive to moisture, pressure and can easily be damaged if handled without care. Due to these demands SCA and Stora Enso have each developed logistic systems including custom made carriers, system vessels and terminals in order to minimize the handling of individual reels and cargo strains during freight.

5.6.1 In brief – a node in the Stora Enso logistical system

The forest industry group Stora Enso was formed in 1998 with the merger of Swedish Stora and Finnish Enso-Gutzeit Oy. The total sales of pulp, paper and sawn timber in 2006 was EUR 14.6 billion in 40 countries. The group employs 44,000 worldwide (Anttila, 2007). From the Swedish mills, most of the goods is transported via the port terminal in Gothenburg to the terminal in Zeebrügge for onward distribution to the European customers. The terminal in Zeebrügge is operated by Sea-Ro, an external terminal handler considered the biggest Ro-ro stevedore in Europe (Stevens, interview).

5.6.2 The Stora Enso Base Port System

Stora Enso have customized carriers, so called SECUs, Stora Enso Cargo Unit. The carrier is a large container, 3.8 x 3.6 x 3.6 m m, with a carrying capacity of 79.5 tons (Anttila, 2007). Stora Enso are able to transport SECUs on railroads in Sweden, but road and rail transport restrictions are limiting them inside the Stora Enso logistic network (Janson, Nilsson, Östlund, 2003). The loading of SECUs in the Swedish production plants is automated, which means that large parts of the goods have not been handled by truck until they are unloaded in Zeebrügge (Stevens, Interview).

5.6.3 The Goods flow

Figure 10 present Stora Ensos flow of goods from production facilities via their terminals for onward distribution. The Ro-ro system vessels connect Gothenburg and Zeebrügge and calls six days a week. The vessels have two decks and double ramps in each port that allows parallel loading and unloading. Ro-ro traffic is the only inbound flow of Stora Enso goods to the terminal in Zeebrügge (Anttila, 2007). The outbound flow of forest products consist of about 200 trailers a day, trains 3-4 times a week, and about # containers weekly. Nearly 70% of total cargo is cross-docked (Stevens, interview).
Figure 10. The goods flow of Stora Enso, including the production cites and terminal network. The fractions represent the weekly shipments for each connection (Anttila, 2007)

The terminal in Zeebrugge is a receiving terminal, meaning that a lot of storing, planning and balancing of the goods flow have already been made at nodes earlier in the distribution network. The terminal is situated far away from the mills, and when the inbound goods arrive in Zeebrugge the outbound connection is mostly already planned and the terminals planners informed. Another example is the handling of damaged and returned goods that are a lot less prioritized than at nodes closer to the producing units. It is also built from scratch based on Stora Enso’s demands and haven’t inherited any habits from earlier work traditions or organizations.

5.6.4 Terminal history

The terminal was built in 1999, developed specially for Stora Enso and their forest products. The first traffic started up in 2000 and due to the logistic manager it took about two years until the operations were running smoothly reaching a satisfactory production level. Now, the terminal also handles goods for other customers and also other types of cargo for north bound trips such as cars going to Sweden. About 2 million tons of forest products are handled annually, and the capacity will increase with the planning of a new warehouse and additional container handling (Stevens, Interview).

When Stora Enso took the decision to locate a terminal in Zeebrugge, run by Sea-ro, Louis Stevens got the responsibility to simulate and plan the terminal after requirements from Stora Enso regarding traffic, flows and their products. Based on the WMS chosen and its basic functionality, the constraints on how the processes could be carried out were set. Working procedures and organization was created based on these conditions together with a lot of testing and simulation. After the system was built they constructed the facility.

5.6.5 The warehouse environment

The terminal uses a dock system to connect SECUs, containers, trailers and wagons to the warehouse. No staging locations are used as in the Tunadal terminal. This means no activity except trucks inside the warehouse which minimizes congestion, dust and the risk of damaging inventory. All warehouse processes are under roof protected from weather, also a factor that minimizes disturbances and unnecessary breaks.
5.7 The WMS and System integration

The WMS implemented is based on a RedPrairie version and have been customized to the operations in the terminal. The system is only used in Zeebrügge and not in other Stora Enso terminals. An EDI-integrator from RedPrairie is used for integration with the Stora Enso production system. All transactions are made on individual (reel) level. In this way every stakeholder is able to track activities in real-time. Only one system, the WMS, is used to plan and manage all activities at the terminal. This facilitates data-mining, survey and traceability of historic events. All actions in the WMS are logged for one year, after that the historic data is put in a separate database where it is logged for 5 years (Stevens, interview).

The terminal runs in two shifts, 6 am to 22 pm. The night break make it possible to run a database discrepancy check, clean the warehouse and so forth without disturbing the daily routine. Every night the WMS database is crosschecked with the Stora Enso database in order to find discrepancies. In the morning a list of discrepancies is provided and checked by the planners at the terminal. In this way the system database is continuously corrected and junk data is minimized. By cleaning up the system problems become isolated before they can lead to bigger disturbances and productivity losses. Follow up and communication with Stora Enso is a daily activity (Stevens, interview).

The development and integration of the WMS was made together with Stora Enso. Mock-ups of every screen was created and evaluated by Stora Enso before they were implemented.

5.7.1 System development and User involvement

Operators and planners take active part in the development of procedures and user interfaces. Once a week two key users, one planner and one truck operator, and the logistic manager meet and discuss possible improvements and changes of the interface, do follow ups of some key indicators linked to productivity etc. Before a change in interface is implemented it is tested in parallel with live activities and the output is analyzed.

5.7.2 System - environment interaction

The two warehouse facilities are divided into picking zones by wifi antennas in the ceiling. A truck (resource) will get assignments based on the current zone/antenna it is registered by. As in Tunadal, the same system with barcodes and bar code-scanners is used to register actions. Stevens says that a lot of techniques for registration of locations have been tested without any successful alternatives to the manual registration.
5.8 Resources, roles and responsibilities

The organization supporting the system directed warehouse operations consist of three user groups with different responsibilities. The structure differ in some aspects from the distribution of responsibility seen in Tunadal. The user groups are not divided in different functional departments, the planning is centralized while process supervisors are decentralized - situated in the un/loading area of each warehouse facility.

Every day 36 truck operators and 10 planners in average are working spread over two shifts. No extra personnel is needed, only fixed personnel is used (Stevens, Interview).

5.8.1 Planners - Load planning, balancing of workload and problem solving

Every evening, a meeting with Stora Enso takes place on what incoming and what should be shipped during the next day. Information regarding incoming orders is also retrieved and if there are any tightly planned shipments will be prioritized. The planners check the orders ship date -2 days, and decide what they can start loading on the basis of what’s available. The planners will then have a clear overview of how many orders to be picked and how many are available for preparatory loading. All tasks are released into the WMS order queue at the end of the planning (Stevens, Interview).
Load planning takes place one day in advance; the rest is done in real time. Trailers are announced and the only indication planners have is a loading date. The planners aren’t able to tell when a trailer is going to arrive during the day. During the day this date can change or loading can be postponed. Check-in of trailers that triggers the release of an assignment is made in the gate when the trailer arrives. A person currently makes this but they are working on a solution where the driver checks in himself. The check-in of trains is done manually in real-time.

Every evening the planners go through what will happen the following day – during daytime they work solely supportive solving the problems that occurs in operation during the day. This procedure makes the work less stressful and they can fully concentrate on the supportive work during the day.

During the day the planners also create relocating tasks to tighten up the warehouse. These tasks are released in the system to balance workload during calm periods.

5.8.2 Distributed Process control
A planner supervises all docks, including pre-load areas and checking locations. The supervisors responsibility is to plan preparatory loadings, overlook the ongoing loading and control service times. In other words he has both direct visual control and system support to manage the active and coming warehouse orders that the planners have released to the warehouse order queue. The supervisor work in the WMS and have all the information regarding the processes of finished, started, ongoing and upcoming orders in one screen. If the loading process takes too long he can assign another resource to help. If no one starts to load within a certain time he can manually distribute the warehouse task to a resource.

![Figure 12. Overview of the warehouse and loading area. The process supervisor have both direct visual overview and monitor the loading processes and resources in the WMS.](image)

The problem of prioritizing orders due to situational demands have been solved by letting the planners regulate the WMS order queue. The planners are prioritizing orders manually by putting all other warehouse orders in the queue on Hold, and thereby restricting them from being distributed for a period of time. For example may all released orders be put on hold until the urgent ones are un/loaded. This is how prioritized orders get priority on the floor - the planners manually control what should be distributed by the WMS by putting all other assignments on hold. The planners can drop priority assignments and tasks on unit-level, location-level and also to certain resources. 2-3 trucks can work on the same trailer at the same time.
5.8.3 Autonomous truck operators

All operators have to perform a certain tonnage per day. This capacity measure is not cut in stone but it is a good way of keeping a steady work pace and predict process times. Truck operators know what they have to perform and the planners can make good assumptions when planning resources. As the system is directing the tasks during normal work the combination of tasks may vary a lot. All truck operators are well educated and familiar with all tasks and working with the RF/WMS. Stevens say that no one is stressed up by the flow of different tasks they are fed with as “they know they can work in a steady tempo and are all well educated to use the RF menu in all situations”. The way that exceptions are handled, such as problems regarding damaged inventory etc put the operators off the pressure of handling exceptions, situations that otherwise affect their productive time.

If the truck operators experience a problem with an assignment they will instantly report this to the planners. They will put the assignment on hold, solve the problem and release it again when the problem is solved. The truck driver continues directly with a new assignment to keep active. In this way the problem is isolated. No unnecessary time is taken from the operational work.

The truck operators are able to override the system proposal - it is important to get them to reflect and think about the system’s decision, says Louis. But, the override frequency is linked to individuals and continuously measured, both per operator and in total. The level of acceptance is lower than 12% of the total amount of tasks. This is an indicator that is surveyed by planners. Too many overrides are seen as an indicator of problems and is basis for investigation.

5.9 Process Support

In the interview and observations at Zeebrügge the focus was on getting a picture of the flexibility and operator autonomy behind the warehouse processes.

5.9.1 Put away

For each product there is a Put away strategy even though the planners can direct goods to certain locations if needed. The basic rule is finding a suitable location for “big orders far into the warehouse and small orders close to the dock” (Stevens, Interview). The WMS direct the truck operators where to put the goods but they are also aloud to override the system proposal as previously mentioned.

5.9.2 Picking

All warehouse orders are released in the WMS in its respective queue. The WMS algorithm will check for locations where the order exist and propose the location that best fit the current amount of goods. The location that contains least reels will be emptied first otherwise the location that best matches the amount will be proposed. When a truck become available it will get an assignment that matches the zone or area where the truck is located.

Allocation is always made on order level (Soft allocation). When an order is spread out over a number of locations the allocation is always made on order level and not per location. The algorithm used for allocation will search for the correct amount of items on a location or as close to the requested amount as possible. The proposal direct the operator to this location, but as allocation always is made on order level, the truck operator can choose if he wants to pick from another location where the order exist. The information of where the order exist is provided in the GUI. This makes the picking more flexible and insensitive for disturbances because the truck operator can choose which location to pick from as long as it is the correct order. The system will count down so on the allocated amount so that the correct number of reels is picked. This solution creates flexibility for the truck operator to decide where to go and how to go there. The WMS will do calculations that are hard for
the operator to perform and present the result as a support to the operator's decision. Based on local information, such as disturbances like congestion in the aisles etc the operator is free to follow the systems proposal or not. The proposed location may not be the closest so the operator is free to choose a closer location if possible.

5.9.3 Warehouse handling

If a truck operator handles a damaged reel the reel is directly lifted to a check location. A serviceman (in some cases the same person that is positioned at the loading area) at the check-location takes care of all the damaged reels and checks them against a list if they have been reported earlier. If not, he will make a report based on what the damages look like. By doing it this way Louis says that the reporting of damaged goods have got more reliable. No one feels guilty to report a damaged reel and a more objective judgement of what has happened to the reel can be made. The check location also handles stripping and relabeling of damaged reels.

There are also some examples of barriers for non-wanted actions in the warehouse handling. If a reel that doesn’t belong to the current assignment is scanned the operator will be warned and a move-assignment will automatically be created. The operator may then move the reel and register this. This procedure is done to prevent the operator to make moves "outside" the system without registering actions.

In order to tighten up the warehouse and create empty locations the WMS will auto-generate an assignment if a large location with few reels is found. The operator will then be instructed to move these to a small location. This will happen only if less than 4 reels and no more reels of the order are registered as incoming in the WMS.

5.10 General experiences of automation and system-directed work

Stevens commend clean processes. Truck operators spend almost all of their time in the truck, carrying out their assignments. As many supportive process steps as possible have been lifted out from the critical line of flow. As the WMS is used to optimize resources, the resources that are connected to the WMS won’t perform any supportive tasks in their workflow, except inventory moves. The result is stable and predictable process and lead times. Stable pace resulting in a more predictable capacity planning – he points out that the steady and high utilization rate of trucks is the result of the division of responsibility in problem-solving between planners and operators.

As disturbances appear randomly, and when they do they affect productivity negative, it is important to minimize the ones that you can do something about.

Stevens says that all operators have worked in a system directed way from the beginning so they aren’t experiencing any stress in the work due to the automation. Both operators and planners take active part in the development of the WMS interface and this is also why changes are widely accepted. He also think that user acceptance comes from routine-bound evaluations and changes based on an open dialogue between users and developers. This is the main reason why they have very few, or no, complaints about the interface or process routines from the users, Stevens say.

5.11 Performance Indicators

I did not get the chance to see any detailed performance measures at my visit to the terminal. But the types of performance indicators used was discussed. The type of indicator and why they are measuring it is also a way of understanding the processes, surrounding problems and goals (Parmenter, 2007). Some of the indicators that are used in the daily activities are;
- Response times i.e. time between a WO is released to the first activity is registered. This is considered an important service indicator that reflect how well the 

- Override frequency. As an indicator of the strategy's configuration etc.

- Timeframe from the opening to closing of a wagon, trailer, how many trucks used and so on.

- Number of trucks per warehouse order and time.

The indicators say something about what the terminal managers think is important in the operations, and what is critical for a good result and efficient performance. They are also indicators of how the strategies work out during different conditions and situations.
6 Analysis

**In the following sections the findings from the benchmarking study and empirical material will be analyzed and critically discussed.**

An organization must have roles that match these requirements and can deal with challenges to achieve its goal in an efficient way. When changes in IT support is made this will affect the organization. A change in information flow will affect roles and responsibilities as well as working procedures.

The benchmarking study and data from other Best-in-class surveys show that companies that successfully implemented WMS and a system-directed task assignment have:

- Succeeded in creating reliable real-time data that creates visibility into processes
- Create reliable data through barriers that hinder corrupt input, especially in real-time dependent processes.
- Central control and monitoring of processes, in Zeebrügge also with on-site monitoring
- Clean processes – supportive activities have been removed from the operational critical line of flow
- User groups are taking an active part in the development of interfaces and process procedures.
- Active manual sequencing and balancing of warehouse orders by planners/process supervisors.
- Adaptive operators are allowed to make decisions and react to disruptions in operations

There are also other things that have come up during the study that I will return to in the coming sections. Some aspects of these factors are more relevant than other in the case of the situation at the Tunadal Terminal, so, how can this be applied to SCA Transforest’s situation to increase efficiency and flexibility?

### 6.1 Identification of productivity potential

The empirical data sample presented in 5.3.1 show the imbalance in workload between the terminal departments. There are possibilities to balance the workloads with the support of a WMS - if its functionalities to monitor work in real time as well as distributing warehouse tasks are properly utilized. Move tasks could be auto-generated by the WMS and be released by planners. Manual product handling time can be reduced helping to optimize workforce and cut down on non-value adding inventory movements. By having the WMS to generate move-assignments etc that can be released to warehouse operations during low activity periods. In that way workload can be balanced over the day. If the tasks are released by planners and not automatically released by the WMS, the control lies upon the planner. These are tasks that could be performed during low activity hours to create a more balanced workload, but also a higher service rate for other activities. With a central control of the warehouse order queue, and ultimately the task assignment, balancing and prioritization of tasks would create a more efficient workflow.

The empirical data in Figure 8 showed the imbalance in workload between the terminal departments over time. Based on the observations at the Zeebrügge terminal and the current technical solutions of mapping the warehouse the balancing of workload cannot solely be conducted by the WMS through distribution of assignments. The WMS will only search for available trucks in the current zone, if there is no work in queue in...
the current zone the WMS will check another zone. The risk of sending a resource to another shed is at stake. If truck capacity is to be distributed over the whole terminal to different areas of function the WMS cannot solely balance this. The macro balancing must be performed by planners based on the current situation and prioritized tasks. These decisions are highly context dependent, which advocates good visibility, centralized decision making and direction of processes. The situation gives reason to argument for centralized direction of work. Someone must monitor and control the terminal activity and take the decision to move a resource from one area to another.

6.1.1 Central control and direction of work
As discussed earlier, efficiency is very much a question of flexibility in the dynamic terminal environment. Agility lies in the ability to easily move resources and orders between flows, reallocate and move orders in time. As many of the reports and observations points out, it is not possible to fully rely on the WMS to balance and direct the workflow in the warehouse. Controlling the warehouse order queue and supervise processes is of high importance to meet the demand on flexibility and service.

Balancing resources to the current workload must be seen in two levels using zone dependent distribution of tasks. The WMS will be able to find appropriate resources within a zone, but balancing or moving resources between zones and tasks must be overlooked by planners. The distances at the terminal, the different truck setups, resources working outside the WMS etc are factors that highly risk resulting in unreliable system decisions. To make priorities based on local information, business demands and a correct overview of current work impose this to be a planner’s decision. The supervisor must therefore have the appropriate information upfront when making these decisions.

The role of the planner is to plan and release orders to the warehouse floor. Central controlling introduces another area of responsibility – to monitor and manage resources and the orders released for processing. The Aberdeen reports as well as the benchmarking study at the Zeebrugge terminal show that successful control of the terminal activities, together with real-time data support from the WMS, may be achieved by a centralized control and direction of processes. The main flexibility and efficiency gain lies in the visibility of the terminal activities, with the total workload planned for a day visualized in the WMS and the ability to move resources between zones and order queues. To be able to prioritize and rearrange orders and manually assign orders to resources.

The observations made at the benchmarking study in Zeebrugge show something else. The planning is centralized as the support during working hours. But supervision of the processes is made on site in each docking area with both direct overviews of the dock area (loading and unloading) and by a WMS real-time support. The supervisor have the finished, started and planned warehouse orders presented in the same screen, control of each resource so he can control prioritized tasks to be executed fast. The solution distributes responsibility and work between process supervisors and planners that create more concentrated administrative time for planners, who can focus on load planning and support.

6.2 Task and process control
There are many aspects to task and process control. First of all, discrepancy between the actual process and the system model must be minimized so that processes can be monitored in real time. Second, non necessary non value adding procedures should be lifted out from the critical line of flow. If a process standard is created the ability to identify disturbances and succeed in rational process improvements will be possible. On the other hand must the organization and system support innovative problem solutions to some extent.
6.2.1 Clean processes – predictable lead times

The WMS directed warehouse activities can be seen as the crucial production line, and according to Mattson (1999) one should strive to remove unnecessary non-value adding activities from it. As seen in Zeebrugge the critical line of production is clean and all processes have been highly isolated. Therefore the outcome of each procedure can be measured and monitored without pollution from other work, supportive actions etc. The ability to analyze work activity over time especially during episodes of high activity, troubles or unforeseen events is an important source of data for further investigation of possible improvements. The terminal may consider the solution of introducing a work quote that each truck has to perform during a day. This will create a steadier pace even if some resources might work more or less in relation to the current level.

SCA Transforest should also consider the opportunity to use the WMS and RF in a way that gives each operator more feedback of the current performance. A WMS with real-time data enable direct feedback on performance. After setting a standard for each process the WMS can communicate how close to standard operators are performing for each task. Presenting this information for the truck operator could be one way of getting a more stable work pace. (Aberdeen Group, 2008)

The WMS can provide visibility, load balancing and optimization of events within the scope of its control, i.e.; within the scope of the equipment it is provided. WMS doesn’t take into account other factors than what its capacity model includes and it works only with the assignments that have been established. Every action can’t be in the WMS, and shouldn’t be there. Therefore a clear division of tasks between WMS-directed tasks and other activities is necessary if the system will be used in a productive manner. The activities that the system isn’t intended to direct and optimize must be lifted out of its "arena". A lot of supportive activities, like cleaning of cassettes, damage report etc is today performed by operators. In Zeebrugge the critical line of flow is cleaner. Supporting activities have been sorted out from the processes so that the truck operator can focus on the system directed tasks and perform productive work. When a problem occur this will instantly be taken over by another actor. The operator still have to identify problems and disturbances visually but solving the problem is someone else’s responsibility. This has led to a higher utilization of the truck resources and also to a more reliable information flow on what kind of problems and damages that occur in the warehouse.

Isolation of processes to get reliable lead times – this will facilitate planning and manual balancing of work. The activities in Zeebrugge show a high isolation of different processes and procedures. This has created a high precision in lead-time due to Stevens, but equally important – the quality of data output is high and a reliable source for productivity measures.

6.2.2 Controllability and the quality of input

System directed work might be productive as long as the input is correct and purposeful. The warehouse activities will be directed by what is in the WMS order queue and therefore it is crucial that these orders are accurate. First of all, in order to successfully introduce system directed functionality into operations one must strive to secure and control the release of warehouse orders into the order queue. Barriers should be implemented for real time dependent releases to prevent unwanted allocation of reels in the warehouse. One good example, used in Zeebrugge, is the release of picking orders, triggered in real-time on the arrival of trailers when they are checking in at the terminal gates. This solution takes this responsibility from the planners, and they may in turn concentrate on other work.

Controlling the active order queue in the WMS is crucial when operating a warehouse or terminal with system directed task assignment. As soon as a warehouse order has been released it is enabled for distribution to resources. The orders that are released into the order queue and are open must be executable and add value.
As the Zeebrügge study implicates the responsibility of balancing orders in the queue and keep it clean from corrupt orders is made continuously by planners or supervisors.

System directed task assignment put extra responsibility on the planners. A practice that has a devastating impact on system directed task assignment, as well as task interleaving, is flooding the WMS work queue with future work. Putting work into the active queue too early results in an imbalance of task priorities. Similar tasks enter the work queue with the same priority even though, as illustrated in the example above, the required completion time is what determines the true priority of a task. If an order must be released in advance, for allocation reasons etc they should be put on hold so they don’t interfere with current work.

Compared to the todays manual way of working SCA Transforest must find other ways to control and distribute information. To exploit the system for information transfer is more efficient in the long run than the use of spreadsheets and com-radio. WMS functionality is not used today for control after the orders placed in the system. An example that is used in Zeebrügge is how the planners manually regulate the available orders in the system for distribution by using the Hold functionality on warehouse orders in the WMS. This is a flexible method because all business demands and situational dependent priorities can be made without losing the systems ability to distribute tasks optimally to available trucks. This procedure will demand more attention from a planners, or supervisors, perspective.

**6.2.3 Improving visibility and data in the information flow**

By a more efficient use of the information provided by the WMS's visibility into warehouse processes can be achieved. Reliable real time control requires high quality data with low discrepancy in time and stock. The basics are a necessity to be successful and reach the real productivity improvements. Everything should be kept as close to natural procedures as possible. Today there is no restriction in the system of the number of scanned reels a truck may carry. Extracts from the WMS log show operators that have far more than 2 or 3 reels in the clamps. The configuration does not match with the actual course of action. It is necessary to change these setting if the processes are to be monitored in real time.

SCA Transforest should strive to get all available resources and activities registered in WMS, not just the work performed in the warehouse. The planners would get more use of the WMS as a supportive tool and get a much better overview. Without clear end-to-end visibility, processes improvements and decisions will be made in the dark; ultimately hurting other supply chain operations. If all activities, even supportive activities as cleaning, can be separated and registered as tasks in the WMS, the actual work activity can be measured more accurately.

With the creation of transparent activities problems that take down productivity will be put into light and analyzed. The benchmarking study of the Zeebrügge terminal show an flow oriented organization where the WMS is the fundament in the production system. The division of roles around the critical line of flow is clear, and all supportive activities are sub processes to the main processes. This has contributed to a high predictability in lead times that facilitates planning decisions. The main parts of the operational activities are pull driven and smooth mainly because the functions are created with the real-time demands in focus. RFID-tags on all SECUs, check-ins and checkouts of trailers at the gate and visual overview of the activities in the docks are some of the barriers that uphold the plea on real-time interaction with the WMS. A minimum of spreadsheets is used in the operations. This reduces the risk of growth of problems in operations and a result in a minimum time waste.

**6.3 Productivity potential from a planners perspective**

All double typing of data, distribution of spreadsheets, communication over com-radio are administrative tasks that could, and should, be fully or partly automated as a step in streamlining the processes and the flow of
information. There is a great ability to reduce the manual work and automate some of the tasks that is now performed by the planners. Real-time triggered tasks, such as the arrival of trailers, could easily be automated. In Zeebrugge is the arrival of trailers handled as they pass the terminal gates. This is a solution that has many advantages. It prevents warehouse orders to be released into the WMS queue on beforehand, something that would significantly reduce disturbances in the warehouse operations. The pressure on planners to handle arrivals would also decrease and it would get them extra time to focus on other administrative tasks that strengthen the service level. The time frame between the trailers registration in the gates and its positioning in the warehouse would also increase, giving the planners extra time to prepare or administrate the loading/unloading.

Some of the tasks that the planners are performing today can be automated, resulting in higher decision quality and more time to concentrate on other administrative tasks. Move tasks that could be performed during low activity periods could be auto-generated and put in a separate list. The planners could then release these tasks or manually distribute them to specific resources to balance workload during the days.

6.3.1 Usability issues effect the administrative time
The usability issues that planners and operators experience must be taken seriously, and is a prioritized improvement. It is a question of efficiency and long-term productivity that the different user groups get the support they need and not feel restricted by the interface. The user interface must be customized through user studies; this will increase the current productivity by reducing the administrative time put on each order. It will also improve the output quality of the administrative work. How much time that is spent on non value adding activities today is not known. But the issue is extensive and if user studies are conducted and proper actions are taken the performance of the planners will increase a lot and give many positive effects. The errors that rise from lack in usability may blur some of “the real” problems in the terminal operations and risk the outcome of future improvements.

6.4 Truck operator autonomy and productivity under system directed task assignment
During normal work the truck operator perform tasks and when completed he will use the “looking for work” menu item. The WMS will feed the operator with suitable tasks and the operator don’t have to examine an order list by himself or make own priorities of which order to work with. This might result in less administrative time for the truck operator and also reduce the risk of performing low prioritized, non-value adding tasks. System directed task assignment require that all warehouse orders that are released into the WMS queue must be ready to be executed. As truck operators will be fed with more diverse assignments the knowledge and capability of executing different terminal tasks is an important factor of flexibility. The kind of flexibility that this work approach can result in requires a homogenous workforce with respect to process knowledge (including using the RF), technical setup and work tempo. In the end it is the individual that maintain productivity. Motivated personnel should be part of the future development. Motivation that rise from involvement should neither be underestimated. Therefore continuous education and user involvement is highly important to succeed in future development.

One of the basis in this thesis is the notion that system directed work not only is a way to instruct people how to work, it should be a support in all operations and strengthen productivity. The other way around should the operator not be restricted in productivity by the design of the system, its interface and presentation. The RF must support the operators to take good decisions in situations when it is needed. The operators are experts and cannot be excluded from information about the goods flow. Information regarding the task and goods flow keeps operators in the loop, a prerequisite if the operator should be able to compensate for the systems shortages and take good decisions when needed.
Once the process constraints are set the operators must take active part in the development of the interface. The interface should contain the type of information that supports decisions and strengthen autonomy – not just instruct them on what to do. As the operators are using the dialogues every day, they are process experts and need to continuously be part of the development. Process improvement is an ever-changing activity and user involvement is an important part of getting acceptance for changes. Operators must have the same idea of the process goal as planners, system administrators. This is achieved by training and education, but also by letting users and operators take an active part in the system development.

The current self-developed user interface is not very informative and the screen area could be used much more to show more data in each screen. This would reduce a lot of clicking in deep menu systems. Resource productivity is primarily measured in number of lifts per hour. The truck operator’s administrative time must be minimized. SCA Transforest should consider performing extensive user studies with the goal to reduce the interaction with the RF.

6.5 Automation and Control by awareness

WMS can be used automate processes to reduce extra work that is done today. With WMS indisputable overview of the warehouse the system should be able to auto-generate assignments to clear locations, a productive task that otherwise would be planned by the planners, or truck drivers. These tasks take time and require a lot of extra work. If the WMS continuously create proposals on stock movements within the warehouse to create empty compartment without risk of counter-productive decisions, this is a clear efficiency gain. Planners or supervisors could for example, get a list of auto-generated assignments, which they can then distribute to appropriate truck operators during low activity periods. The system should provide the planners with the information of what is happening in the automated procedures to show the rationale behind the system decisions or proposals.

The WMS can be used to alarm on specific states. When service time is too high, operators have been idle for too long etc. The interface could also present the standard tempo and compare in real-time the performance of each operator to give feedback to both the operators and planners.

6.5.1 The potential of advanced picking methods

A question worth discussing is whether the alternative to continue the manual work really is an alternative. System directed work is necessary step to implement more advanced warehouse methods, a step that could leverage the real productivity gains.

While task interleaving can provide improvements in productivity by reducing travel time, the limitations of such systems must be kept in mind. As noted, a terminal warehouse must put a high priority to service incoming cargo. Furthermore, every warehouse must place a high priority on prompt service to customers, even when there is some sacrifice in efficiency. Whenever these prioritized tasks are occurring or when there is an urgent need to complete one task as quickly as possible the advantages of the interleaving system are degraded (Gilmore, 2005)

As noted, the problems of implementing this kind of system automation are well known and supervision and control can not be left open. Prioritizing tasks and balance workload in complex situations must still be a planner’s decision. Task interleaving does also put extra responsibility on the planners. The most successful task interleaving depends on a balancing act involving the number and kinds of tasks in the WMS work queue. When the work queue is full enough and include as many complementary tasks as possible the opportunity to interleaving tasks will be greatest. Too many tasks in a queue is not the right approach, quantity is not the same as quality when interleaving is applied (Rose, 2003).
Having a good balance of complementary tasks is another key requirement for effective task interleaving (Rose, 2003). If there are fairly equal numbers of each type of move, i.e. a balance of complementary tasks, interleaving may be a productive method. Not all tasks are suitable though. Tasks must also have the same importance, add value etc. Therefore, matching the proper tasks also plays a key role in being able to carry out a interleaving successfully.

The productivity potential of task interleaving depends on three factors; the combination of complementary tasks, the travel time in relation to the process time in total, and a flexible workforce. Considering these factors, the possibilities of a successful implementation of task interleaving at the Tunadal terminal is probably low. There is no fixed in- and output point in the warehouses that could be focus in the planning process, so the number of two way complementary tasks is low. One must also consider higher service time for each object and the complexity put into operations that follow with this method.
In this chapter I will discuss the result of this report - as well as the things that I for some reason found hard to tackle and analyze.

During the work with this thesis I have found it very hard to find a way to analyze and compare the actual productivity potential for the concept of a system directed work approach in relation to the manual work procedure. As the system directed approach demands a significant change in organization, decision procedures information quality and so on, and also relate to a certain technological maturity a lot of assumptions would have been required. In the beginning of the study my aim was to calculate, or simulate, the potential efficiency gain and translate it into costs, but the scope of this comparison showed to be very complex. Simulation of the terminal activities is hard, mainly because of the dynamic warehouse environment. The warehouse layout in Tunadal does not match the normal warehouse layout, with aisles and fixed in- and output points. There are many studies, theories and models of simulating these common warehouses. But, as this study show, there are a lot of other things that directly affect the productivity and efficiency, obstacles that are hard to cope with in simulations and calculations. Usually simulation and logistic calculations concentrate on the physical transport, factors that are easier to measure. But transports are usually only 20 percent of the total logistics cost. The remaining 80 percent can be allocated to stock, management, administrative costs and other accompanying charges. By focusing exclusively on finding the absolute lowest transport rates the risk of sub-optimization is at stake, missing the opportunity to do savings in other parts of the value chain. The administrative time put on each order is hard to measure, but it is usually in these routine operations that a lot of improvements can be made.

The value of an IT support in an organization will be significantly reduced if the end users are excluded from the development process. As many of the interviews indicate a lack of user involvement and serious issues with the usability of the system in operations this cannot be neglected. The user interface must be customized through user- and usability studies. Such an adaptation could increase the current productivity by reducing the administrative time put on each order as well as improve the output quality of the administrative work. From a planners perspective, the administrative work will probably increase with more system directed activities and automation in the terminal. It is a question of productivity that they get the support they need and not feel restricted by the interface.

7.1 Test and measure for process improvement

I think that the best way of approaching the implementation of system directed task assignment is to test the different WMS functionalities and configurations on a smaller scale, at a less complex terminal or at a separate department where the technical truck setup is the same and complementary tasks are common. By testing at a less complex level, improvements and configurations can be made step by step. It is important to start loose and then tighten up the system. If starting too tight a lot of problems will arise and it will be impossible to identify the source to certain problems. Instead, tighten up bit by bit and investigate what problems arise and deal with them. To test, measure and analyze the output would become more valid and reliable. When looking deeper to a problem like this surely more problem areas will be found and some that are mentioned in this thesis might not be an issue.
7.2 Centralized control

Making decisions requires speed, agility, and visibility to critical data. The Aberdeen report conclude that the most efficient companies have one person as a single point of contact in managing key processes. This is an ideal state and may be hard to achieve. In Zeebrügge all planners sat together, but the control and direction of processes was made on site in each warehouse. What solution that result in best control of the total workload for the terminal should be discussed and be considered in future development.

7.3 Flexibility and shorter lead times with Soft allocation?

The argumentation that is presented by Vicente impose that the level of restriction – or instruction based action – have to be set into relation to the openness of the system. An open dynamic work environment must be formative i.e. more flexible than a system with less disturbances. External disturbance factors such as fast changing customer demands, urgent order insertion and order cancellation, and internal process disturbances occur rather frequently. These unforeseen disturbances invalidate the plan and schedule at an operational level. To cope with these disturbances and satisfy the customers’ requirements, the terminal activities need to be flexible, responsive and efficient. This provides more freedom and flexibility in order fulfillment and thus translates into better customer service. It is hard to have the system make these context dependent priorities. It is a question of how hard the terminal activities can be directed by a system, what level is the most effective balance between system directed and manual decisions to streamline the terminal output? The level of user involvement in the generation of output must be exploited to compensate for the system’s shortages.

A necessity for the truck operator to perform flexible he must be able to pick a reel from any location, as long as it is the right order. The freedom is necessary if the operator should be able to adapt to local disturbances. Today this is restricted by the tight allocation rule (Hard allocation). SCA Transforest should consider applying soft allocation to give the operators more freedom in operations. The operator must therefore be presented the proper information so he can execute the task under these circumstances. The RF could present one suggestion but show all alternatives on the same screen so the operator can make a decision immediately without a lot of clicking. Soft allocation would also reduce the administrative time planners spend on reallocating goods, setup times for orders decrease which improve flexibility and reduce lead times.
8 Conclusions / Recommendations

To successfully implement system directed work procedures and increase productivity and efficiency SCA Transforest should strive to:

- Implement barriers for realtime dependent processes and use auto-generated tasks that create more efficiency in the warehouse and help drive down operating costs without sacrificing service levels. By introducing barriers for realtime dependent processes – such as registration of arriving trailers – administrative time for planners could be reduced and more reliable data would be provided.

- Create central control and direction of processes that allows for the addition of performance-driven services and flexible order prioritization. Central direction and control of processes could probably solve many of the problems that the terminal is experiencing. This would provide the terminal a flexible balancing of warehouse orders and resources. As seen in Zeebrugge, the planners release the orders ready for processing, a supervisor on sight control the internal processes and moderates the queue so that the orders are getting the correct priority and are efficiently executed. The WMS can provide fast and agile decision making based on a complete overview of completed, started and planned warehouse orders - and function as the user centered IT support that increase the decision quality. The solution will add value by preventing low prioritized work to be performed when more prioritized tasks are active.

- Leverage investment in technology that can provide automation and visibility to create more flexibility and agility in the warehouse. Anyhow, the first step should be to improve the usability of existing software and interface for both operators and planners. The interface in the RF must be more informative and support the operator in critical decisions. SCA Transforest should consider implementing complementary tools and support to manage order planning and balancing. Visual planning tools can make it easier for a planner to manage the daily workload and resources.

- Utilize auto-generation of tasks with high quality - for example move assignments - that can be controlled and released by planners to balance workload during low activity periods.

- Examine the possibilities of implementing Soft allocation. A change in configuration that would provide operators with the flexibility and autonomy they need. It would also result in less administrative time spent on reallocation of orders, faster order setup time and a decrease in lead times.

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Louis Stevens, Business Analyst/Programmer, Sea-Ro Terminal N.V. Zeebrügge, April 2009

Peter Gyllroth, Terminal manager, SCA Transforest AB

Peter Eriksson, Logistics manager, SCA Transforest AB

Tomas Granberg, System owner, SCA Transforest AB

Christian Johansson, Cassette- and load planning, SCA Transforest AB
Rolf Byström, Resource planning, SCA Transforest AB

Martin Barkman, IT Consultant, SCA Transforest AB
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Gustav Rydeman, Uppsala 2009
Appendix 1

För perioden 9/4 00:00 – 22/4 11:00

Totala antalet gånger man har kört Genmove: 10304
Totala antalet gånger man har tryckt "F5 - Override": 1127
Totala antalet gånger man har tryckt "F1 – Investigate Option": 2359

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