COMPETITIVE INTERNAL LOGISTICS SYSTEMS THROUGH AUTOMATION

Anna Granlund

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The growing demand for products and services puts great pressure on logistics performance and enhances the role that logistics plays in determining a company's competitiveness.

This research focuses on internal logistics systems, which includes all logistics activities and processes within the physical limits of an isolated company. Internal logistics is vital for the overall function of many companies. However, despite its importance, this part of logistics has traditionally not been viewed or developed in a strategic way. Since internal logistics activities are often characterized by a high degree of manual handling and hence strongly affect the cost of operations, there is a large incentive for improvements in this area.

One possible way to improve an internal logistics system is with the help of automation. In many areas, automation is a well-known means to increase productivity and cut costs, thus improving competitiveness. However, automation is not commonly used within internal logistics activities, and there is a lack of knowledge and research within this new application area. The main objective of this research, therefore, is to contribute to an increased understanding of how automation can be used to develop competitive internal logistics systems.

Four empirical studies have been performed to investigate how companies perceive and work with their internal logistics systems, specifically in terms of improvements using automation. The empirical studies also aimed at identifying and describing how the studied companies could benefit from automation within internal logistics activities.

From the studies, the importance of assessing and being aware of the current state of logistics performance was discovered as a basic requirement that needs to be fulfilled before conducting improvement work. Further, one of the main overall conclusions from this research is the need for a logistics strategy that includes goals and plans for the operation and development of an internal logistics system. As a result of the research, a structure and procedure for the development of an internal logistics strategy and a framework for conducting an improvement process in internal logistics using automation were developed.
ABSTRACT

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I would like to start with expressing my gratitude to my supervisor Professor Mats Jackson for your encouragement, energy and ever inspiring and helpful ideas. I would also like to thank my assistant supervisor Associate Professor Magnus Wiktorsson for your guidance, co-writing and support along the way.

Further, I would like to thank all my colleges at IDT in Eskilstuna for a joyful place of work and all the members of the research school IPR for an inspiring and instructive research environment. Special thanks go to my closest colleges and friends: Erik Hellström, Anders Wikström, Karin Romvall, Petra Edoff, Dr. Antti Salonen, Joakim Eriksson, Mikael Hedelind, David Akpone, Patrick Phua, Daniel Gåsvaer, Lisa Gustafsson, and Caroline Runius for your constant support and for brightening up my days both at and outside work.

I would also like to thank the members in the research project Lean Automation for inspirational collaboration, and Vinnova through Robotdalen for financing this research. I would also like to express my deep gratitude to all the companies and organizations that have participated in the studies, especially the employees that have contributed with their time and knowledge and hence enabled this research.

Last, but not least, I would like to send my love to my wonderful two families and to all my friends for supporting me in my life both inside and outside the academia, and for making me remember the important things in life. Special thanks to my mother Kerstin and father Hasse for always caring. To my sister Åsa for your inspirational drive, and to my nephew Alec for being my little ray of sunshine that always make me smile. Thank you to all my friends for giving me a place to, when needed, forget about work. Finally, my warmest gratitude goes to my dear Christian for your endless support, comfort, love, and understanding. Jag älskar dig!

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Eskilstuna, May 2011
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Eskilstuna, May 2011
This thesis is based on the work presented in the four publications listed below. The author of the thesis initiated and had the main responsibility for the writing of all appended papers. The papers are appended in full, and are referred to in the text by Roman numbers.

Granlund, A. and M. Jackson (2008) 
Logistics Automation - an Enabler for Competing. 
In Management in Logistics Networks and Nodes, the Proceedings of Hamburg International Conference of Logistics 2008, 4-5 September, Hamburg, Germany.

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Resource Efficiency in Internal Logistics: a Survey on Objectives and Performance. 
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In the Proceedings of the 42nd CIRP Conference on Manufacturing Systems, 3-5 June, Grenoble, France.

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Reducing Environmental Impact from Manufacturing: Three Industrial Cases for the Manufacturing of "Green" Products. 
In the Proceedings of the 42nd CIRP Conference on Manufacturing Systems, 3-5 June, Grenoble, France.
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**Paper II**

**Paper III**

**Paper IV**

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This chapter introduces and describes the background of the research area. The objective of the research is presented, and the research questions are listed along with the delimitations of the research. The chapter is concluded by presenting the expected results in the form of practical and academic contributions.

Today's technical development, expanding markets and growing population increase the demand for products and services. This demand requires an increased focus on logistics since it puts great pressure on the logistics performance in the form of, for example, just-in-time supply of material, efficient material handling within operations, and on-time delivery of finished products. Therefore, the role that logistics plays in companies' industrial performance and competitiveness is great. Or, as Christopher (1997) has expressed it, "it is supply chains that compete, not companies".

The logistics field is vast and contains many subparts, activities, and tasks. One way of narrowing the field down is by separating its activities into external or internal logistics activities. The focus of this research is on the internal logistics system, which includes all logistics activities within the physical walls of an isolated organisation, for example, internal transports, material handling, storing and packaging (Jonsson, 2008). Hence, the internal logistics system is part of the overall logistics area and their contexts overlap to a large extent.

The internal logistics system (with the internal logistics activities) constitutes a necessary and vital part for the overall function of organisations in a wide spectrum of lines of business. In the manufacturing industry, the main task of the internal logistics system is to provide necessary supplies to the company's operational units. A failure in the flow of materials or adherent information can result in costly downtime, which clarifies the significance of a well-functioning internal logistics system for the functioning of all operational units (Schulze and Wüllner, 2006). In other lines of business, such as the healthcare sector, the need to have the right materials and information in the right place in the right time is even more critical since it can influence the possibilities to perform proper care.

Despite the importance of the internal logistics it has previously, especially in the manufacturing industry, been viewed as purely a cost of doing business (Mentzer, 1991; Olavarrieta and Ellinger, 1997). This most likely derives from the fact that the cost of logistics activities often constitutes a large part of the overall cost for businesses (Rouwenhorst et al., 2000). Average logistics costs usually represent between 10 and 30 percent of sales turnover for a typical producing company (Gattorna et al., 1991). The main reason for these large costs is that logistics activities in general are very resource-intensive. Internal logistics activities in particular are often characterised by a high degree of manual handling; hence, they have a high degree of labour usage, which strongly affects the cost of these operations.
1. INTRODUCTION

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1.1 Background

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The importance of keeping costs low in order to stay competitive is ever increasing, and companies are forced to look into every part of their organisation for possible improvements. Tomkins (1991) lists cost competitiveness as one of the aspects that needs to be addressed when undertaking research in the logistics area. Due to the large impact on the overall cost, internal logistics plays an important role in determining a company’s overall competitiveness. Also, the previously mentioned pressure to improve logistics performance and productivity is closely connected to competitiveness. This is because a company not able to efficiently utilise its resources in creating value for its customers will not survive in today's tough business environment. Therefore, there is a strong need to improve the internal logistics. But it is known that logistics, as compared to other parts of the organisation, has not received the same attention, especially when it comes to strategic improvements (Gupta and Dutta, 1994; Rubinovitz and Karni, 1994). Therefore, improving this area in a wide variety of organisations should be of great interest and possess great potential.

In order to successfully improve internal logistics activities, there is a need to change how this area and function is viewed. Traditionally, the internal logistics function in a company is seen as only a support function, or a function among others within the firm (Kihlén, 2007), and its influence on the overall business performance is not fully recognised. However, according to Mattsson and Jonsson (2003), a well- formulated and correctly used internal logistics system increases a organisation’s efficiency in many ways. As pointed out by Stock, Greis et. al (1998), in this competitive environment, logistics must be accorded a high strategic priority and cannot be viewed merely as a cost of doing business or as a separate entity whose activities are distinct from other functions in the firm (Olavarrieta and Ellinger, 1997). Rather, since the essence of logistics is the management of the flows of material and information, it is to be viewed as a strategic task, and not as an operational function (Gattorna et al., 1991). Logistics could very well be a future means of competitiveness since it represents a powerful strategic source of competitive advantages (Olavarrieta and Ellinger, 1997).

One possible way to improve competitiveness within operations is with the help of automation. Within the manufacturing industry, for example, automation is a well-known means of improving productivity and efficiency within, e.g., assembly or machine tending operations; hence, it cuts costs (Frohm et al., 2006). The manufacturing industry is one of the sectors most closely connected to using automated equipment. However, automation is undergoing a transformation in scope, and the range of applications is increasing. New, emerging application areas include logistics, healthcare, and retail. Today, automation is already frequently used in some specific areas of logistics, such as automated storage and retrieval systems, especially in large warehouses (Baker, 2004). However, generally speaking, automation does not commonly occur in internal logistics activities in other businesses, and it is hence viewed as a new application area.

The potential benefits of using automation in internal logistics activities (such as within internal transport or materials handling) are great since they often are characterised by a large amount of manual work, both time-consuming and often physically straining.
Logistics costs vary depending on the degree of automation in the logistics processes (Groover, 2008). However, the application of automation could also have other advantages, such as increased performance and improved work environment. It is most likely that automation could be a key point in the development and optimisation of internal logistics (Schulze and Wüllner, 2006). But, as with any other tool or technology, there is a need for knowledge regarding how to use automation to best benefit from it. As confirmed by Baker and Halim (2007), there has been relatively little previous research into the area, despite the fact that automation can be quite important in internal logistics. As a result, a lack of knowledge exists.

1.2 Problem statement and research objective
As stated in the background section, a well-functioning internal logistics system is crucial to the overall function of many organisations. Despite its importance and possible contribution to strategic competitive advantage, internal logistics has been neglected to a large extent and not improved in a structured way. In other areas, automation is a well-known means of improving performance and cutting costs. However, it is not commonly used in internal logistics. The potential benefits of automation in internal logistics activities are great. This is due to the large amount of manual handling and its strong impact on the overall business cost. However, in spite of automation’s potential significance in logistics, there has been relatively little previous research into this new application area. Therefore, a lack of knowledge and understanding of how automation can be used to obtain competitive internal logistics systems exists. Thus, the main objective of this research is to:

“contribute to an increased understanding of how automation can be used to develop competitive internal logistics systems”

1.3 Research questions
In order to fulfil the objective, the following two research questions have been formulated.

RQ 1: What critical factors need to be considered when creating a competitive internal logistics system?

The first question aims at building an understanding of the goal of the internal logistics system and its performance. Success factors, important performance criteria, critical resources, and other factors will be investigated in order to define what characterises competitive internal logistics and how the performance of the internal logistics system should be evaluated.

In this question, the main focus is placed on the system and its inputs, deliveries and performance.
RQ 2: What challenges are there to using automation as a means of improving the internal logistics system?

The second question aims at analysing how organisations work with improvements and automation in the internal logistics system. The question considers what specific areas in the system need improvement and why, and what challenges in the way of working need to be overcome in order to reach the goals revealed in research question 1. Hence, the question covers operative and strategic aspects of improvement work, as well as actual and potential applications of automation.

The main focus in this question is on the way of working with internal logistics systems in general and, specifically, with regards to improvements and automation.

1.4 Delimitations

The focus of this research and the unit of analysis is the internal logistics system, where the system boundaries correspond to the physical limits of an isolated company. Internal logistics thus involves logistics activities such as transports and material handling within the physical walls of an organisation. Both the physical flow and the connected flow of information are studied. The strategy and way of viewing, organizing and improving the internal logistics system with its adherent activities and resources are also of main interest.

During the research, organisations in three lines of businesses have been studied: companies in the manufacturing industry, hospitals from the public healthcare sector and warehousing and distribution companies. The focus here is not on the specific business in itself. Instead, the internal logistics system and its activities, a common feature of all three, are in focus. The reason for choosing different study objects is to study the same system and activities in different settings where the experience of automation differs. The main objective is not to rank the businesses, but to compare them to one another and try to see similarities and differences in order to transfer knowledge from one business to another.

The automation perspective used in this research takes it stance in automation as a means of improving operations. The studies have focused on identifying possible application areas for automation in logistics activities today performed manually. The focus is, therefore, on how to use automation as a possible tool to achieve competitive internal logistics, and not on the automation technology itself. The research does not attempt to define or predict the most appropriate type or level of automation; it analyses how automation could and should be integrated in the logistics strategy.

In the research, a user perspective on automation is adopted in the sense that the result aims at aiding the user of logistics automation by developing the area.
1.5 Expected results

The research presented in this thesis is expected to generate both a scientific contribution to the research community and a practical contribution to solving the industrial problems targeted.

The expected scientific contribution is to enhance the knowledge of how the internal logistics system could be viewed and developed as a strategic resource in companies, and contribute theoretical and empirical conclusions in the area of automation in logistics. The research aims at contributing to the body of knowledge in logistics research by using a research perspective not traditionally associated with all lines of businesses studied. Therefore, another scientific contribution is a transfer of knowledge between different lines of business.

The expected practical contribution of this research is to provide organisations with an increased ability to use the logistics system as a competitive means. The aim of the research is to increase the knowledge of how automation can be a means to achieve efficient internal logistics systems. Another practical contribution is increased knowledge about automation as a tool in lines of business not closely connected to and familiar with automation.

To ensure a practical relevance, the research is based on the findings and the industrial needs that emerged during the initial studies in this research.

1.6 Outline of the thesis

Chapter 1 introduces the research area and the objective of the research, along with the research questions and delimitations. Chapter 2 presents the research methodology in terms of the view and methods applied, along with a description of the studies conducted. In Chapter 3, the theoretical frame of reference is presented. Chapter 4 then provides an overview of the data and results from the empirical studies. In Chapter 5, a framework for developing competitive internal logistics through automation is presented and discussed. Finally, Chapter 6 presents the overall conclusions and research results, discusses the research quality and fulfilment of the research objective, and suggests future research.
This chapter presents the research methodology applied. The chapter begins with a discussion of the scientific view in the research, followed by an explanation of the research approach and a presentation of the four conducted empirical studies. The chapter is concluded with a discussion regarding the quality of the research.

There are different epistemological views or traditions which form researchers' fundamental perceptions of the world, specifically regarding science and knowledge.

The objective of this research is to contribute to an increased understanding of how to develop competitive internal logistics systems using automation. In order to fulfil the objective, the researcher must be able to explain the system without influencing it. Therefore, the author has studied the internal logistics system from a passive outsider position in different real life settings. A positivistic, rather than a hermeneutic, view is thus adopted, since positivism is associated with explanatory knowledge where the researcher has an objective role (Wallén, 1996). The positivistic view is usually associated with natural science and aims for universally applicable explanations (Lantz, 1993). A fundamental feature in the positivistic view is that the knowledge should be empirically verifiable (Wallén, 1996), and this has influenced the research process and selection of empirical studies.

Connected to the view of knowledge, there are, according to Arbnor and Bjerke (1997), three different research approaches: the analytical approach, the systems approach and the actors approach. The research approach used in this research is the systems approach, which aims at finding, explaining and understanding relationships in a comprehensive system (Arbnor and Bjerke, 1997). The relationship between the above mentioned knowledge views and research approaches can be seen in Figure 1, which also shows the span in which the author has been positioned during the course of the research.

Figure 1
The author's view and approach, adopted from Arbnor and Bjerke (1994)
2. RESEARCH METHODOLOGY

This chapter presents the research methodology applied. The chapter begins with a discussion of the scientific view in the research, followed by an explanation of the research approach and a presentation of the four conducted empirical studies. The chapter is concluded with a discussion regarding the quality of the research.

2.1 Scientific view and research approach

There are different epistemological views or traditions which form researchers’ fundamental perceptions of the world, specifically regarding science and knowledge.

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![Figure 1](image_url)  
*Figure 1* The author’s view and approach, adopted from Arbnor and Bjerke (1994)
Situations characterised by rapid change, multiple interests, limited resources, and high complexity are good candidates for a systems approach (Leonard and Beer, 1994). To a great extent, this is the case when it comes to logistics in any industrial or organisational setting. Further, systems theory refers to a system where a group of related components interact and cannot be treated as isolated (Arbnor and Bjerke, 1997). The systems approach therefore explains reality from a holistic point of view.

The internal logistics system studied in this research is a complex system, comprised of several sub-parts and components with adherent connections and relationships. Since the systems approach is applied, it has been important to take a holistic view of the studied system when observing and analysing. The applied view of the internal logistics system, its boundaries, main components and their relationships are explained in Section 3.5.

Other implications of adopting the systems approach are related to the proper adjustments of the research approach. Since the system studied is an actual industrial system with a practical application, the research is of inductive and applied character with the goal of both an academic and practical contribution. This has strongly affected the research approach, which mainly and consists of case studies for collecting the empirical evidence. As an approach, the author has chosen to continuously move between the industrial context and theoretical aspects to study the system from two perspectives. The goal has been to ensure both academic and practical relevance by addressing actual organisational problems while at the same time contributing to increased knowledge. This has in turn affected the choice of methods for gathering and analysing data in the empirical studies.

### 2.2 Methodological approach

This research has been inspired by the Design Research Methodology (DRM) presented by Blessing and Chakrabarti (2009). DRM is a research framework with four stages, each having its basic means for creating knowledge and its main deliverables (see Figure 2).

As indicated in Figure 2, the four performed empirical studies correspond to the first two stages in the DRM framework. The results presented in this licentiate thesis should be regarded as input for the third stage, the prescriptive study, which will follow in the continued research after this thesis.
Situations characterised by rapid change, multiple interests, limited resources, and high complexity are good candidates for a systems approach (Leonard and Beer, 1994). To a great extent, this is the case when it comes to logistics in any industrial or organisational setting. Further, systems theory refers to a system where a group of related components interact and cannot be treated as isolated (Arbnor and Bjerke, 1997). The systems approach therefore explains reality from a holistic point of view. The internal logistics system studied in this research is a complex system, comprised of several sub-parts and components with adherent connections and relationships. Since the systems approach is applied, it has been important to take a holistic view of the studied system when observing and analysing. The applied view of the internal logistics system, its boundaries, main components and their relationships are explained in Section 3.5.

Other implications of adopting the systems approach are related to the proper adjustments of the research approach. Since the system studied is an actual industrial system with a practical application, the research is of inductive and applied character with the goal of both an academic and practical contribution. This has strongly affected the research approach, which mainly and consists of case studies for collecting the empirical evidence. As an approach, the author has chosen to continuously move between the industrial context and theoretical aspects to study the system from two perspectives. The goal has been to ensure both academic and practical relevance by addressing actual organisational problems while at the same time contributing to increased knowledge. This has in turn affected the choice of methods for gathering and analysing data in the empirical studies.

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Figure 2 The DRM framework, adopted from Blessing and Chakrabarti (2009)

The focus on descriptive studies and the deliverables from the first two stages in the DRM framework correspond well with the objective of this research and the applied systems approach. That is because the systems approach involves building models of existing systems and aiming at describing, explaining and understanding them (Arbnor and Bjerke, 1994). Further, Blessing (2002) states that descriptive studies increase our understanding of design in order to inform the development of design support. To reconnect to the objective of this research, the design aspect in this research refers to designing competitive internal logistics systems.

According to Bell (1999), there are many different perspectives and traditions in research. Two of the most fundamental viewpoints are the use of quantitative and qualitative data. The different points of view neither propose nor discard any certain method; instead, the choice of approaches and methods for collecting data should be determined by the type of inquiry and data or information needed to answer these (Bell, 1999). Both qualitative and quantitative data can be used for generating and verifying theories. However, qualitative data is more suitable for studying complex phenomena and processes (Alvesson and Sköldberg, 1994), which is the case in this research studying the internal logistics system. To fulfil the objective and answer the research questions in this research, the author has mainly adopted a qualitative approach, as it is the best approach for understanding the processes through which things take place and are related (Meredith, 1998; Maxwell, 2005). However, in this research, there is also a need for quantitative data to be fully able to answer research question 1 primarily. The fact that this research mainly takes its stance in the qualitative approach will be reflected in Section 2.4, where the quality of the research is discussed.
2.3 The research process

The research presented in this thesis is based on two main parts, a theoretical review and four empirical studies. The theoretical review is aimed at creating the theoretical frame of reference of theory and previous research that is presented in Chapter 3. The frame of reference provides direct input into answering the research questions and a base for the empirical studies.

The empirical part of this research consists of four studies (Study A – Study D). Table 1 below shows how the studies correspond to the different DRM stages (where RC stands for Research clarification and DSI stands for Descriptive study I) and how they contribute and give input to the two research questions (RQ 1 - RQ 2). An X indicates a contribution, and a bold X indicates a strong contribution. The table also shows which paper is connected to which study.

<table>
<thead>
<tr>
<th>Study</th>
<th>DRM-stage</th>
<th>Research question</th>
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The four empirical studies are presented in the following sections. The aim and objective of the studies are explained, the sampling and study objects are presented, and the applied methods for data collection and data analysis are described and motivated. For more information regarding each study, the reader is referred to the appended papers connected to each study.

2.3.1 Study A: Logistics and automation in SMEs

Study A was a case study of eight SMEs (Small and Medium sized Enterprises). The aim of the study was to gain a deeper understanding of how SMEs work with their internal logistics systems, especially with regards to automation. The case study approach was chosen since it is suitable when a “how” question is being asked about a contemporary set of events in a real-life context over which the investigator has little or no control (Yin, 1994). This was in line with both the aim of and basis for this study.

This study was equivalent to the research clarification stage in the DRM framework. Therefore, it mostly used an exploratory and inductive approach (Arnbor and Bjerke, 1994). The aim was to structure an initial model of the research area based on the empirical findings and to pinpoint industrial problems that would form the basis and help plan for the coming research. The study therefore intended to cover the following issues: (1) to what extent SMEs apply automation to internal logistics activities; (2) the interest, knowledge and needs for improving the logistics and material handling; (3) problem areas and difficulties for SMEs concerning logistics and automation, and (4) future industrial needs.
The reason for concentrating the study to SMEs is that they represent the main part of companies in Sweden, as well as in the whole of Europe. Their needs and conditions should therefore be representative of those of the majority. This was preferred at this research clarification stage since, in order to direct the research, the results would be generalised to be valid for a larger mass than the sample. The sample in this study consisted of eight companies. The sampling frame consisted of SMEs (less than 250 employees and annual turnover less than 50 million Euro) situated in the region of Mälardalen in Sweden (since this was the geographic focus area for the organisation financing the study). Thereafter, the selection was based on line of business in order to achieve a spread in the sample that would represent the dispersion of companies and lines of business in the region studied. Out of the total of eight participants, five companies were within the manufacturing industry, while the remaining two were classified as warehousing or distribution companies. More information about the participating companies can be found in Paper I.

As a research method, case studies often consist of several methods for gathering information. According to Yin (1994), the most common are: documentation, interviews, archival records, direct observation, participant observation and physical artefacts. In Study A, three main methods for data collection were used: direct observations, interviews and a questionnaire. The different methods were used partly to gather different types of information and partly to triangulate collected information.

All participating companies were visited for observations of their internal logistics systems. Real time observation is an appropriate but very time-consuming and highly selective method (Yin, 1994). The use of observations is necessary to secure valid results. However, it also limited the possible sample size due to time constraints. During the observations, a guide highly acquainted with the organisation and its internal logistics system (often the production/logistics manager or plant manager) was used to give a tour, hence providing a holistic overview of the system. Unstructured interviews without pre-formulated questions (Bryman, 1989) were conducted with the guide during the tour to complement the observations. Unstructured interviews were used since they are informal and allow the respondents considerable latitude in their answers. These features increase the possibility for an “unpolished” view of the system, which corresponds well with the actual situation.

At each company, semi-structured interviews with the person strategically responsible for the internal logistics were conducted. A self-administered questionnaire (Bryman, 1989) was distributed to the interviewee after the interview. The questionnaire partly covered the same aspects as the interviews, to enable the triangulation of data. It also allowed for different kinds of questions of a quantifiable nature (Yin, 1994). The questionnaire mainly contained structured questions, where the respondents were asked to choose from a set of alternative answers. However, a few open questions, in which the respondent could freely formulate his or her answers, were included.

To strengthen the quality of the research (further discussed in Section 2.4), two people took notes during the observations and interviews and afterwards individually
documented the collected data. The data was then compared to verify concordance before it was compiled, reduced (Miles and Huberman, 1994) and coded (Maxwell, 2005). The data was thereafter categorised (Merriam, 1998) according to: previous and future improvement measures and their causes; how the company worked with development work within internal logistics; and general thoughts and views regarding logistics and automation. The data was searched for reoccurring patterns (Yin, 1994) and trends among other examples connected to the line of business and the size of the company.

The answers from the open questions in the questionnaire were clustered using categories (Merriam, 1998). Meanwhile, the answers from the structured questions (with answer alternatives) were compiled for each question and then searched for reoccurring patterns (Yin, 1994).

The author’s role in the study was to have the main responsibility for the planning of the study and the compilation and analysis of the findings. Only the gathering of data was divided between the two people. During the study, an outside observer role was used to increase the understanding of the current state, pre-requisites and needs for applying logistics automation at the case companies.

2.3.2 Study B: Survey on objectives and performance in internal logistics

The aim of Study B was to show how manufacturing companies work with and perceive their internal logistics systems. Different types of data (both qualitative and quantitative) and, consequently, different types of questions were necessary, making a survey an appropriate method for data collection (Yin, 1994). A survey was preferred since it is faster and gathers information from a larger sample with less means than, for example, case studies or interviews do (Bell, 1999).

The survey's general topic was how the internal logistics system is perceived and developed in industrial settings. The more specific area of interest was to investigate what vision and goals the responding companies had set for their internal logistics system and what factors and resources were considered as most important and critical for its success. In addition, the survey set out to explore not only which performance criteria were most important, but also which performance measurements were used to monitor the internal logistics. Improvement areas (from both a long and short term perspective) were also covered, along with responsibility aspects.

A self-administered questionnaire (Bryman, 1989) with a total of 14 questions was used for this study. The questionnaire was divided into two sections. The first, opening part was comprised of questions regarding the respondent’s role, the number of employees, etc. The second part contained both open questions (where the respondents could freely formulate their response) and structured questions (where the respondents were asked to choose from, or rank, a set of alternatives).

The questionnaire was sent by mail to 300 manufacturing companies in Sweden, directed to the person responsible for internal logistics. The sampling frame was based on business affiliation (SNI codes 25-32, including varying manufacturing industries),
having a minimum of one employee, and having a contact person responsible for internal logistics. The sampling was random thereafter, performed by the company providing the business information (contact name and company addresses). The aim of this survey was not to receive a fully statistically secured result. Therefore, the selection of respondents cannot be seen as fully representative of all the organisations in the sampling frame. Instead, this study was intended to give an outlook of current situations, views and trends from a sampling of respondents.

Of the 300 questionnaires sent out, 47 usable responses were received, resulting in a response rate of 16%. In addition, five companies declined participation, citing lack of time, ceased or relocated operations, or being unsuitable candidates. Another three companies responded, but without completing the questionnaire. Information about the respondents and their companies can be found in Paper II.

The answers from parts of the open questions were analysed using pattern matching. In it, the empirical data was examined for patterns and compared with predicted ones (Yin, 1994). The answers from the remaining questions were coded to facilitate comparison between similar answers (Maxwell, 2005) and then clustered using categories by sorting the coded answers into groupings that had something in common (Holme and Solvang, 1997; Merriam, 1998). The results from the questions with answer alternatives were compiled and presented as number/share of responses and ranking averages for the different alternatives. As a result, the answers were treated as statistical data. However, the main use of the results was not to display statistical results; rather, they were used as input to be analysed for trends and so on. As such, this data constitutes the quantitative data mentioned in Section 2.1 that was needed, despite this research in general being classified as qualitative.

2.3.3 Study C: The use of resources and automation in healthcare internal logistics

Study C was a multiple case study focused on the healthcare sector. The reason for studying healthcare is that it is a line of business with an extensive internal logistics system and a great deal of internal transports and material handling, activities far from the main function and core competence of the organisation. Another reason for selecting the healthcare sector as a study object is the fact that it is a sector traditionally not associated with the use of automation. Therefore, it helps to, from a validation point of view; achieve diversity in the different studies, which will increase the generalisability of the results.

The objectives of Study C were to (1) examine and analyse how hospitals in different aspects work with internal logistics activities and (2) conclude how automation can be a tool in improving hospital internal logistics systems. In order to reach these objectives, the following aspects are covered: qualitative and quantitative analyses of resource usage, ways of working with improvements, areas in need of improvement, and possible applications of automation in hospital internal logistics systems. The case study approach was chosen since it is an empirical inquiry that investigates a contemporary phenomenon within its real-life context (Yin, 1994) and therefore suits
both the objective and descriptive approach of this study. Case studies can also be based on any mix of quantitative and qualitative evidence (Yin, 1994) that is coherent with the data needed to cover all aspects of the study.

In order to fulfil the wide objectives, Study C was planned and executed as a multiple case study consisting of three cases with different purposes, aims and approaches, individually described below. The main logic of conducting a multiple case study was to build a comprehensive understanding, where the findings from the different sub-studies together build a total knowledge mass of critical aspects. Thus, the three sub-studies were selected in order to complement each other. Case c1 is the most comprehensive and was the base of the study. Following Case c1, two sub-studies (Case c2 and Case c3) were included to cover a wider range of hospitals with different pre-requisites and levels of applied automation. The three sub-studies are separately explained below, followed by a section with general information for the entire Study C.

The base of Study C was a case study at a Swedish hospital with 400 beds. Case hospital c1 was chosen since its physical and organisational conditions represent a typical Scandinavian hospital in terms of size, age, and constraints in technology management. The research questions during Case c1 were (1) how is the internal logistics system structured and how are logistics activities carried out and (2) what improvement areas are there and how could automation be used to improve these?

Three main methods for data collection were used in Case c1: observations, interviews (open and semi-structured) and archival records/documents. Through the direct observations at nursing wards and the transportation department, the study could cover events and their contexts in real time and also make observations that the personnel involved in the activities daily do not notice. Activities that were time-consuming, ergonomically flawed, or in need of improvement based on other aspects were identified during each observation and then compared and compiled after each occasion. During the analysis, the observation notes were scanned for general themes mentioned and compared with the results from the following interviews.

Twenty-three semi-structured and open interviews were conducted with nurses, the respective heads of three nursing wards, the director of the ward division, the hospital coordinator, the supervisor of the transportation department and employees in the transportation department. Most interviews were conducted with one interviewee, but there were interviews of discussion character with several informants. The interviews covered current practice, routines and time estimates, improvement areas and visions of a future for hospital logistics. Interviews are a commonly used technique in case studies when collecting qualitative data. According to Ejvegård (1996), they are also an appropriate way of doing research when the researcher is looking for answers about views, feelings, opinions, knowledge (i.e. qualitative data) and so on within a population, which was the case in this study.
Information material, reports and other internal documentation were studied in order to triangulate or further investigate aspects that emerged during observations and interviews. According to Yin (1994), the strength of using documents as a source of evidence during a case study is that they are: stable and can be reviewed repeatedly; exact, detailed and can supply quantitative data; and, able to cover a broad span of time, events and settings. Hence, reviewing documents was a good complement to the interviews and observations since it enabled covering several aspects not otherwise possible. Among others was a time study performed at 13 nursing wards. During the study, the nurses mapped activities every ten minutes, day and night, over a period of 14 days, using a form with 30 pre-defined activities. The material was compiled to describe which activities were most time-consuming. During the analysis, it was compared with the results from the other parts of the study.

The second case, Case c2, was a focused study concerning the topic of improvements within the logistics system at a large dual-site hospital. Case hospital c2, one of Europe’s largest hospitals with 1,680 beds over two sites, was selected, since it actively works with improving its internal logistics system. One of the ways it does so is through automation. The hospital is also in the process of planning and designing its new, future site. The research question was: how can and should automated improvements of hospital internal logistics systems be structured?

Case c2, being a descriptive study, mainly used observations and interviews to gather data for analysis, in line with Blessing (2002). The two current hospital sites were both visited once, each time for four hours. During the visits, the researchers observed and were guided through the way of working by the supply manager. Areas studied were related to material handling and internal transports of both patients and goods. Semi-structured interviews were conducted with the manager of supplies and the people responsible for the automated systems to cover the way of working with improvements on the current logistics system. The project manager for the logistics system in the new, future hospital was also interviewed in order to cover how the hospital works strategically with designing a new internal logistics system. Besides observations and interviews, information material, reports and other internal documentation were gathered and studied in order to verify or further investigate areas discussed.

The third case, Case c3, aimed at being a role-model, describing a possible future in hospital logistics. Case hospital c3 was inaugurated in late 2008 and was selected since it is a new hospital (it had been operating for eight months when visited) with a high level of automation. The hospital calls itself Europe’s most modern hospital with regards to the level of technology and the way of working. The research question was: what is the state of practice of modern hospital internal logistics systems in terms of technology and automation?

Case hospital c3 was visited once for five hours, during which time the researchers were guided through the hospital and introduced to the way of working and technology used. The guides were the person responsible for coordinating the user needs during the construction, the manager of the Information, Communication and
Technology department and the manager of the Service and Technology department. Open and semi-structured interviews were conducted during the visit and information material and internal documents were gathered and studied to complement the observations and interviews.

With its three sub-cases, Study C was a comprehensive study that included many aspects and resulted in a large amount of collected data. Therefore, a main focus during the data analysis was on data reduction, the process of selecting, focusing, simplifying, abstracting, and transforming the collected data (Miles and Huberman, 1994). Data reduction is a form of analysis that sharpens, focuses, and organises data in such a way that conclusions can be drawn and verified. According to Miles and Huberman (1994), it is also a continuous process throughout the life of any qualitatively oriented project.

The data was mainly analysed by building an explanation about the case by identifying and describing the casual links within and between the sub-cases. This method of analysis is by Yin (1994) and is referred to as explanation-building.

Since Study C was a multiple case study, there were two stages of analysis – the within-case and the cross-case analysis (Merriam, 1998). During the within-case analysis, each case was treated as a comprehensive case in and of itself, and data was analysed to learn about and describe each case from its context. The cross-case analysis, on the other hand, aimed at building theory across the cases in an attempt to build a general explanation for the study. Since the sub-studies were selected in order to complement each other, the focus during the cross-case analysis was two-fold: find what is common across the cases and focus on the differences, a perspective encouraged by Stake (2006).

Since more researchers than the author were involved in this study, there is a need to clarify roles in the study. In Case c1, the author, together with two other researchers, was responsible for the planning of the study and analysing collected data. However, the other two researchers had the main responsibility for gathering data. The same three researchers performed all the steps in Case c3 to guarantee a well-covered data collection despite a short timeframe. In Case c2, the author was solely responsible for the planning, data collection performed and analysis of the results. For Study C in general, the author had the main responsibility for data collection and analysis when it came to employing a perspective that will help answer the research questions at hand and to fulfil the objective of this research.

### 2.3.4 Study D: Automation through a Factory-in-a-box solution

Study D was an exploratory case study (Yin, 1994) that aimed at increasing the awareness of automation and how it can be a means to develop and improve operations at new users and be used in activities and environments not traditionally associated with automation. Thus, the objective of the study was to develop an automated solution for the case company’s specific needs and demonstrate it at an open event.
The study was conducted at a small manufacturing company with a profile of craftsmanship and small production volumes. The case company was selected since it represents many SMEs that have special needs and inferior conditions in relation to larger companies and therefore needs help and tools in order to improve their business. Many SMEs face a lack of financing and difficulties in exploiting technology (OECD, 2000), and this study therefore addresses new ways for companies to use automation to stay competitive. The case company also showed a strong interest in participating in this type of exploratory research, which was necessary since it demands close cooperation and full access to the company.

From a methodological view, the study consisted of three stages: data collection, solution development and implementation. The research question during the first stage was: how can parts of the production at the case company rapidly be automated? The aim in this stage was to identify the parts of the production system where automation would be most beneficial and further investigate the requirements to do so. A thorough process mapping was to be used. During the first stage, the main parts of the collection of data were made using interviews, direct observations and process mapping/measurements.

During the interviews, the two employees were asked to describe the way of working, what areas were perceived as difficult, time-consuming, straining, and so on and their wishes and requirements for potential improvements and solutions. The interviews with the founder and owner of the company were aimed at identifying the company’s core values, basic requirements and the vision, future plans, goals, etc., for the company. During the direct observations, the way of working was carefully studied to complement the information from the interviews. In the process mapping, all activities were identified and described, lead times and distances were measured, the capacity was calculated, and so on.

From the results of the first stage, the second phase was initiated. It aimed at developing possible ways for the case company to use automation to increase its competitiveness. Information and data was collected though benchmarking and interviews with actors in both the same line of business and other business areas. System suppliers were also interviewed. The suitability of the different developed solutions was analysed and evaluated based on the information that emerged during the first stage of the study.

During the third and final stage, the selected solution was implemented and demonstrated. As a result, the study shares many similarities with a design or realization process, since a problem was discovered and analysed and a possible solution was identified and then tested.

Even though this study from the start did not have a clear objective of solely improving the internal logistics system, it does fill a purpose in this research, and this for two reasons. First of all, it addresses general problems when improving industrial systems and using automation in particular. Secondly, it demonstrates possible ways of
using automation to improve competitiveness where internal logistics activities are one aspect covered.

This study was performed by a group of researchers and personal from Mälardalen University. Therefore, its results are not only a part of the research presented in this thesis. The author was however in different roles involved throughout the entire course of the study. During the first stage of the study, the author had the role of supervisor for the person performing the work. In the second and third stages of the study, the author was part of the team/reference group when developing the solution and conducting the demonstrator.

2.4 The quality of research

Determining the quality of the conducted research is an important but difficult task, especially when, as in this research, the results are based on qualitative data (Corbin and Strauss, 2008). The two most commonly used terms when judging the quality of research are validity and reliability.

2.4.1 Validity

According to Gummesson (2000, p. 91), validity refers to “the extent to which researchers are able to use their method to study what they had sought to study rather than (often without being aware of it) studying something else”. When studying complex systems, as in this research, this could be a problem: the systems consist of many parts and relationships that can make the results difficult to judge. To prevent this, there has been focus on describing the view of the system studied in a successful way, what parts and relationships it consist of and how they relate to and effect each other. Other measures in order to secure the validity of this research mainly consist of continuously assessing and reviewing the methods used, assumptions and conclusions during the research process and continuously being open to revise the results and methods used. As pointed out by Maxwell (2005), it is also important to acknowledge that the analysis process often starts during the data collection. Reading and thinking about interview transcripts and observation notes, writing memos, and the like are all important types of data analyses. Therefore, what is first seen as pure data might be a conclusion or an interpretation of the data. It is important to be able to separate the two.

The choice of methods is strongly connected to validity. That is because it is of primary importance to use an appropriate method that will best contribute to answering the research questions at hand. One alternative approach to the selected and conducted empirical studies in this research (for example, to Study C) would have been a longitudinal study, following every step in an improvement process in which automation was the selected solution. This would have made it possible to study the entire chain of events and analyse the situation both before and after the implementation. Due to practical reasons, this alternative was not possible. The reasons included first finding a case where the outcome was relevant and second being both allowed and able to follow it within the existing timeframe. In the case of Study C, a multiple case study was also preferred since, compared to a longitudinal study, it made
it possible to study a larger sample and hence receive a more holistic view than a single study would have enabled.

In several of the empirical studies conducted, the quality aspect of validity has also been addressed by involving more than one person during the data collection. This is to increase the possibility of covering all information available and not miss any important aspects of the system studied. However, the involvement of several people in data collection can be a disadvantage if a clear unit of analysis and routines for the processing of gathered data are lacking.

Validity can itself be divided in two types: internal and external (Merriam, 1994; Ruane, 2006). Internal validity is associated with whether the conducted studies really indicate causal relationships in the cases where they exist. That is if the researcher can prove that changes in one variable are dependent on the change in a different variable (Ruane, 2006) or, in other words, whether the results are valid for the reality studied (Merriam, 1994).

When studying complex systems such as the internal logistics system, causal relationships could easily be misinterpreted. However, through the use of the systems approach, a holistic view of the system and all including parts and relationships has been sought. The connections and causal relationships discovered in the system have been described in order to strengthen the internal validity and, based on the theoretical and empirical findings, try to eliminate other possible causes of the effects and changes studied. Longitudinal studies would have been a preferred approach to strengthen internal validity. However, due to limited timeframes and access to the study objects, this was not possible.

External validity, on the other hand, is related to the width of the results and whether it is probable that the results can be applied in other situations or at other occurrences than the ones actually studied (Ruane, 2006). A common criticism of case studies as a scientific method is an inability to generalise from their results. This is addressed by Gummesson (2000), for example, who covers the difficulties of generalising from a limited number of cases and also the fact that generalisation is closely related to validity.

To cover the generalisation aspects of validity, a spread has been sought when it comes to the studies conducted, both when selecting several lines of business to study and also in terms of electing representative samples in the different studies. However, the results are based on a limited number of empirical studies and cases that will affect the possibilities to generalise from the results.

2.4.2 Reliability
Reliability has to do with the reproducibility of the research and the extent to which two or more researchers studying the same phenomenon with similar purposes could reach approximately the same results (Gummesson, 2000). There has been a great deal of discussion regarding the reliability of research based on qualitative data. This is because, by nature, it is much more dependent on the researcher's own interpretations. Independent of the kind of research at hand, reliability aspect can be strengthened by
careful attention to how data and information is gathered, analysed and interpreted (Merriam, 1994).

During the research, the reliability aspect has been addressed by carefully documenting every step in the empirical studies. This was done by in full describing the limitations, pre-requisites and given circumstances during the studies, as well as all the steps in the process of collecting and analysing data. Here, the aim was to show how the results were reached and how the conclusions were drawn. The reliability of Study D is somewhat weak, this since it was an explorative case study whose outcome to a large extent was affected by the specific conditions in the case company and the result is strongly influenced by the competencies, knowledge and ideas of the people conducting the study. However, for this research in general, the benefits of using the results and lessons from Study D are considered greater than the quality weakness.

There is a critique that case studies lack statistical reliability. This is discussed by Yin (1994), who states that the general way of approaching the reliability problem in case studies is to make as many steps as possible operational and to conduct research as if “someone were always looking over your shoulder” (Yin, 1994, p. 37). As a result of the preparation for the research the author underwent, the importance of a case study protocol has been fully understood. The research protocol has been used to secure the quality of the research and facilitate the research work, especially where several people were involved in the studies.

2.4.3 Other quality aspects
According to Maxwell (2005), theory is a statement about what is going on with the phenomena you want to understand. A theoretical study is, therefore, a natural part of any research project. In order to develop new knowledge and unique deliverables to the research society, existing theories and conducted research in the area must be thoroughly investigated. The theoretical study has been ongoing throughout the research process to some extent, but with strong connection to the earlier phases when the research area was targeted and formed. The theoretical study in this research is also in accordance with the DRM framework aimed at giving input on and a base for all the studies and the research questions. According to Maxwell (2005), there are two common failures during qualitative research that are related to the way the researcher makes use of existing theory by either not using it enough or by relying too heavily and uncritically on it. It is of importance to have a well-described frame of reference (which, for this research, is described in Chapter 3) as a base for the empirical studies. Since this research is of applied character, there has continuously been a movement between the theoretical aspects and organisational context. This has provided the possibility to verify and adjust the theoretical framework and support and complement it with empirical findings.

Other quality aspects of research include the relevance and applicability that is associated with an academic and practical contribution. Since this research is mainly of descriptive character, the author's role is to a great extent associated with, as objectively as possible, describing situations and current phenomena not previously covered. After
that, an important step is how the author, still objectively, analyses and presents the results. From the results, conclusions are drawn that aim to provide knowledge and support development in both academic and organisational or industrial contexts. One way to achieve this is to clearly state the deliveries of the results to the different societies discussed in Sections 6.3.1 and 6.3.2.
This chapter presents the frame of reference and theoretical background to this research. The frame of reference is constructed around the following topics: logistics systems, performance in logistics, design of and improvements in the internal logistics systems, and automation within logistics. The chapter is concluded with a short discussion of the presented material.

When conducting research, it is always important to describe the frame of reference, since that is the foundation upon which the research is built. This chapter includes a theoretical overview of relevant topics and the results and conclusions from previous research related to this research area. The aim of this chapter is to discuss and explain the applied view of different concepts that are the foundation of this research and present what research has previously been performed within the related areas. The frame of reference is also intended to provide input and a base for answering the research questions and fulfilling the research objective.

The topics of interest for this research come from breaking down the objective and research questions (stated in Chapter 1) into different theoretical areas. The main research interest is in the area of internal logistics, which, as illustrated in Figure 3, is a part of logistics. The first part of this chapter is intended to introduce the logistics area, with a focus on internal logistics systems. The research aims to find ways to obtain competitiveness, and the goal of the internal logistics system in terms of performance is of interest in the first research question. The area of performance in logistics is the second part presented in this chapter. Further, the objective of the research is related to how logistics competitiveness can be improved using automation. Two additional areas of interest emerge. The first is how to design and improve the internal logistics system, and the second is automation, with focus on improvements of internal logistics. Figure 3 shows how the different areas presented below are positioned and relate to each other.

Since internal logistics is a part of the whole logistics area, much of the information presented in this chapter is related to logistics generally. However, it is also of interest for internal logistics specifically.
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![Figure 3 The theoretical areas of interest for the research](image-url)
3.1 Logistics systems
The area of focus in this research is logistics, which is a part of a bigger concept, the supply chain (Christopher, 2005). This section introduces the area of logistics, from the overall holistic concept of the supply chain down to defining and describing the internal logistics system and its components and resources.

3.1.1 Supply chain and supply chain management
Although the phrase “supply chain” is widely used, it is slightly misleading since it implies a linearity that is often not the case (Jonsson, 2008). Rather, the concept represents a network of organisations working together to control, manage and improve the flow of materials and information from suppliers to end users. As a result, the term “supply network” would be more suitable, but it is not as widely accepted and used (Christopher, 2005). Regardless of viewing it as a chain or as a network, one of the most important success factors for the supply chain is to view it as one single entity (Gattorna et al., 1991), not scattered and divided over organisational and functional boundaries.

An essential part of the supply chain is the physical flow and all related activities (Öjmertz and Johansson, 1997). However, information is the “glue” that holds the supply chain processes together (Harrison and van Hoek, 2008). The concept of supply chain management is therefore related to managing the flow of material and information through the entire network and all its processes (Harrison and van Hoek, 2008). In order to manage these two flows, supply chain management is a strategic task that also includes many aspects of organisation and planning. Vaaland and Heide (2007) summarise the essence of supply chain management into five components: work flow/activity structure, organisational structure, product flow structure, communication and information flow structure and planning and control methods.

The purpose of supply chain management is to efficiently and effectively manage all the chain's entities and operations (Christopher and Towill, 2002) with the goal of improving performance and increasing efficiency through the elimination of waste and the better use of capabilities and technology (Tan, 2007). As such, supply chain management aims at creating competitive supply chains and constantly improving them. According to the author, when it comes to the logistics field, it is mostly on the overall level of the supply chain that this important part of the organisation is recognised as a competitive and strategic means. Unfortunately, this view has not filtered down in the structural hierarchy to internal logistics.

In this thesis, the supply chain is defined as the network of all organisations, functions, activities, and processes connected to the flow of materials and information from suppliers to end users. Meanwhile, supply chain management is defined as the task of strategically organizing, planning, managing, checking, and improving the supply chain.
3.1.2 Logistics

Logistics is about satisfying demand. Its mission is to ensure that the right things are in the right place at the right time (Gattorna et al., 1991). In order to guarantee this, the essence of logistics is to manage two distinct flows: the material flow of the physical goods and the information flow that enables the material flow to be planned, performed, and controlled (Harrison and van Hoek, 2008). Therefore, logistics management is quite similar to the concept of supply chain management. At the same time, it is rather an important part of supply chain management, primarily concerned with optimizing flows within the organisation (Christopher, 2005).

Logistics is a wide concept that includes many aspects. In addition, the term logistics can be interpreted in a number of ways and on different levels. That is because the same word is used for both the logistics activities and the organisational function. When it comes to activity level, logistics has been seen as a functional activity. However, it is rather a framework (Gattorna et al., 1991) or an approach where the term is used for a number of activities and processes (Jonsson, 2008). When it comes to logistics as an operational function, it is more and more being recognised as a strategic task (Gattorna et al., 1991), although not to the same extent as the entire supply chain is.

In this thesis, logistics is defined as the framework of all activities and processes connected to managing the flows of physical goods and information within an organisation. The term logistics system is used to denote the system that includes and enables these flows and, hence, all related activities, processes, and resources.

3.1.3 The internal logistics system

In line with the view of logistics as a framework or an approach consisting of several parts and aspects, it is often described as a system, which is the view used in this research. According to Jonsson (2008), the logistics system is always open and in a state of exchange with its surroundings. However, the system boundaries and the subsystems and components included vary depending on different perspectives.

The system studied in this research is the internal logistics system, where the system boundaries correspond to the physical limits for the company being studied. Internal logistics thus involves logistics activities within the walls of an organisation, for example internal transports, material handling, storing and packaging (Jonsson, 2008). An internal perspective of the logistics system is, according to Jonsson (2008), limited to an internal supply chain, with the aim of creating efficiency and minimizing sub-optimisation within the company as a whole. Further, suppliers and customers are external components in the internal logistics system's environment since they can influence the logistics system but cannot control it (Jonsson, 2008). The internal system is based on internal conditions and goals that dictate how the system's resources are utilised.

According to Rouwenhorst et al. (2000), there are three different angles from which logistics operations may be viewed: processes, resources and organisation. These aspects
can all be seen as parts of the logistics system, as the flow of goods and information is handled through a number of activities and steps called processes. Further, resources refer to all means, equipment and personnel needed to perform the processes. Finally, organisation includes all planning and control procedures needed to run and manage the system.

3.1.4 Logistics resources
The logistics resources are one component in the logistics system. As such, they are an important aspect to consider when the performance is assessed (discussed in the next section). It is the resources that enable the flow of information and goods, since they perform the logistics processes and activities. When discussing resources in logistics, physical resources (such as equipment) often come first. However, since information handling is an important part of logistics, IT-systems are an important resource (Kihlén, 2007). Other logistics resources include space and labour (Hackman et al., 2001; Gu et al., 2007) and material and energy (Tangen, 2004).

Specifically labour constitutes an important and critical resource since logistics activities are often characterised by a large amount of manual work: therefore, the system's performance largely depends on the availability of personnel (Rouwenhorst et al., 2000). However, all the resources needed and available for performing the logistics process are an important variable that influences decisions concerning the design of the logistics system to a large extent (Johansson and Mathisson-Öjmertz, 1996). Finding the right amount of resources whose costs are justifiable is to a large extent a balancing act. But a firm's resources are also the result of a developmental and learning process, that process is affected by the firm's decisions and by environmental changes in technology and consumption habits (Olavarrieta and Ellinger, 1997).

The use of the available resources is also a key aspect when assessing the efficiency (and, hence, the performance) of the logistics system. This will be covered in the following section.

3.2 Performance in logistics
Performance is a key aspect when discussing competitiveness. Thus, it is an important area to address during this research, since the objective and first research question are strongly related to competitive internal logistics. The goal of this section is to discuss what performance is from a logistics perspective. In order to do so, the term performance is first explained, followed by the connected concepts of productivity, efficiency and effectiveness. Ways to measure and assess performance are then addressed. Finally, the concept of logistics performance is discussed.

3.2.1 Performance
Performance is a key term for companies to consider since it is very closely related to both competitiveness and excellence of operations. In this thesis, performance is used as an umbrella term for all those concepts that consider the success of a company and its activities (Tangen, 2004). Therefore, performance is the function of resources utilised and results achieved compared to standards and goals (Mentzer, 1991). As such,
it has strong connections to efficiency and waste reduction, as well as organisational strategy and objectives.

A central part of performance is cost. However, according to Tangen (2004), the performance concept also involves almost any other non-cost objective of competition. Examples include dependability, flexibility, quality and speed. There are evidently many different performance criteria, of which productivity (further discussed below) is one of the most important for competitiveness.

Productivity
The meaning of the term productivity is debated in both industry and academia, and there are a vast number of definitions and descriptions. The view of productivity applied in this research is adopted from the field of industrial engineering. There, productivity in general is defined as the relation of input to output (Tangen, 2004). This apparently simple quota of input and output is, in reality, often a complex matter. In manufacturing terms, productivity can be explained as how much and how well one produce from the resources used (Bernolak, 1997). Productivity is therefore closely related to the use and availability of resources and strongly connected to the creation of value (Tangen, 2004). Translated to logistics, the applied definition of productivity refers to the amount of created value in the logistics system in relation to the amount of resources put into it.

As confirmed by Tangen (2004), productivity is vitally important to a company’s competitive ability; a company not able to efficiently utilise its resources in creating value for its customers will not survive in today’s competitive business environment. However, according to Bernolak (1997), despite the importance of productivity, most managers do not know what productivity really means, how to measure and analyse it, what factors affect it, and how to improve it. For example, productivity is often confused with or mistaken for performance, but is rather one aspect of it. Industrial managers often talk about the importance of improving productivity, but actually refer more to cost cutting activities or other terms with similar meanings like profitability or efficiency (Tangen and Johansson, 2000; Tangen, 2002).

Efficiency and effectiveness
Both performance and productivity are strongly related to, and can be broken down into, the concepts of efficiency and effectiveness.

Efficiency is linked to the utilisation of resources. It mainly deals with the input of the productivity ratio (Tangen, 2004). Efficiency, therefore, reflects the internal performance of the studied unit (Öjmertz, 1998). Effectiveness, on the other hand, is output-oriented and related to offering the customers what they demand (Johansson and Mathisson-Öjmertz, 1996) and can be linked to the external performance (Tangen, 2004). Stated simply by Sink and Tuttle (1989), effectiveness is “doing the right things”, whereas efficiency means “doing things right”. The concepts of efficiency and effectiveness are well-illustrated in a model by O’Donnell and Duffy (2002), seen in Figure 4.
For purposes of this thesis, efficiency is defined as a measurement for the internal performance (i.e., how well the expended resources are utilised). Meanwhile, effectiveness is defined as a measurement for the external performance (i.e., how well the desired output is achieved).

![Efficiency and effectiveness model](image)

**Figure 4 Efficiency and effectiveness model modified from O’Donnell and Duffy (2002)**

Although efficiency is a measurement of how well spent resources are utilised (Mentzer, 1991), there is no point in having a high degree of efficiency if the resources are used to achieve something not connected to the goal of the organisation or system studied (in other words, high effectiveness). It is the combination of high efficiency and effectiveness that leads to high performance. Thus, the concepts of efficiency and effectiveness need to be considered simultaneously (Kihlén, 2007). This should hence preferably be one aspect considered in and a part of the logistics operations.

### 3.2.2 Performance measurements

One way to analyse or assess the efficiency and effectiveness of taken actions and performed tasks is by using performance measurements (Neely *et al.*, 2005). Performance measurements can be used to assess both the overall performance of a system and single aspects of performances in different activities or processes in the system. Therefore, performance measurement is an instrument of control. It is also an instrument that informs the organisation what efforts are rewarded and can thereby steer a company’s direction (Maskell, 1991).

There are many motives for using performance measurements. One frequently used argument, which, according to Tangen (2004), cannot be ignored, is simply “what gets measured gets attention”. According to Fawcett and Cooper (1998), performance measurement is critical to the success of almost any organisation. That is because it creates an understanding of the performance of the organisation. However, measurements alone do not suffice. It is important that the performance measurement used actually measure what the company needs to know. It is also important that the
measurements are followed up upon and evaluated in relation to the companies’ goals (Mentzer, 1991). Finally, it is also important to decide what possible actions need to be taken to improve the organisation, depending on the results of the evaluation.

There is an abundance of both cost-related and non-cost related performance measurements. What should be measured, however, differs from company to company, depending on their needs and goals. Most companies create their own unique performance measurement system, which is a set of performance measurements combined to get a complete picture of the performance of a company. In order to design a successful performance measurement system, it is vital that the key-factors influencing productivity and performance at the company are identified and considered (Tangen, 2004). This is done for two reasons: to avoid the overflow of irrelevant information and to guarantee that what is important gets attention.

### 3.2.3 Logistics performance

When reviewing literature in the logistics area, the importance of measuring and, more so, attaining high performance seems indisputable. But very few sources actually discuss what logistics performance is. Unfortunately, there is no one simple answer, as performance is a subjective matter (Fawcett and Cooper, 1998).

However, logistics is about supplying and disposing goods and it is agreed that the key feature to both survival and logistics success is getting the right products, at the right price, at the right time to the right place (Christopher and Towill, 2001). Further, it is said that a perfect order is one that is received, processed, picked, packed, shipped, and delivered on-time without damage and with all of the appropriate documentation (Fawcett and Cooper, 1998). From this, several aspects of important performance features can be singled out, and these are discussed below.

One of the most obvious features is *delivery performance*. This aspect generally has two dimensions: speed and reliability (Stock *et al.*, 1998). Speed is here meant in the sense of having short lead, response and delivery times as well as the flexibility in operations to be able to rapidly adjust the organisation and respond to new demands. *Delivery reliability* (or dependability) relates to the capability to deliver on-time. Meanwhile, another related but more specific aspect is *delivery precision* which could be seen as the capability to assess appropriate delivery dates and to always deliver when promised (neither sooner nor later).

Another (perhaps the most visible) aspect of logistics performance is *quality*. Defects, incorrect quantities and wrong items delivered are symptoms of quality problems in logistics processes (Harrison and van Hoek, 2008). In one sense, quality can easily be measured in the number of incorrect orders. However, there are also many non-quantitative aspects to it related to the running of processes and operations. This brings forth yet another performance aspect: *robustness*. Internally, robust processes help to reduce costs by eliminating errors. They also help to increase dependability by making processes more certain. Therefore, robustness is at the heart of logistics performance (Harrison and van Hoek, 2008).
An additional performance aspect critical to logistics management is the quality of information (Gattorna et al., 1991). As explained earlier, the information flow is one of the two flows that constitute logistics. In addition, it enables the more obvious physical flow. Hence, the availability and quality of data is both pre-requisites to running operations but also critical in the management functions of planning and control (Langley et al., 1995).

There are also economical aspects of logistics performance, such as competing with price of services. But many companies also have internal cost goals for their logistics operations that often derive from the orientation that all logistics functions are perceived as “cost centres” and, thus, the sub-goal for physical distribution is to minimise costs (Mentzer, 1991).

According to Christopher and Towill (2001), the end consumer ultimately determines the success or failure of supply chains. Accordingly, an important part of logistics performance is connected to customer service and being able to respond to their needs and requirements. When it comes to internal logistics, however, the customer is someone in one's own organisation. And when viewing internal logistics as a system, both the service provider and the customer are the same company. As such, the customer’s needs and requirements can be translated to the internal goals. Therefore, internal logistics performance is under the control of the firm, and might provide a more direct indication of the effects of the relationship between strategy, structure and logistics (Stock et al., 1998).

To summarise, there are several aspects of logistics performance that among others relate to delivery, quality, robustness, information, cost, and customer service. But it is also important to consider that it is the combination of high efficiency and effectiveness that leads to high performance (Stock et al., 1998). As pointed out by Jonsson (2008), performing efficient logistics activities alone does not suffice. To create competitiveness for the company, it is essential that the right type of logistics activities be performed and the right performance variables be given priority. There is no point in being good at something not internally or externally appreciated. However, as discussed by Finnsgärd (2009), there is a lack of standardised ways of dealing with requirements in internal logistics that influences logistics performance.

Ultimately, the most important aspect of internal logistics performance is to (1) have a clear understanding of the most important requirements and performance aspects and (2) make sure the requirements and related goals are reached in the most efficient way possible. Hence, the prioritised performance aspects become the starting point when establishing the goals of logistics and are, therefore, the basis of a logistics strategy (Jonsson, 2008).

### 3.2.4 Performance measurements in logistics

Numerous logistics performance measurements exist. Wen and Wang (2007) have created a performance measurement system for the quality evaluation of a manufacturing enterprise's logistics system. Many others such as Gattorna et al. (1991),...
Mentzer (1991), Fawcett and Cooper (1998), and Shepherd and Günter (2006) list or present taxonomies of measurements of supply chain and/or logistics performance. Far from all of these measurements are directly connected to internal logistics. However, Swinehart and Smith (2005), who studied internal supply chain performance in the health care sector, concluded that many traditional external logistics measures, potentially, are equally insightful and may provide more directly usable information when applied to internal customers.

As with all performance measures, the suitability of logistics measures differs depending on the situation and purpose (Mathisson-Öjmlertz, 1998). Generally, good measurements should cover all aspects of the process measured and be appropriate for the situation. However, the main emphasis of the measurement is that it reflects the goals of the firm and truly captures the essence of organisational performance (Gunasekaran et al., 2004). But this is however not always the case. Hackman et al. (2001), for example, present frequently occurring performance measurements in warehousing activities and discuss their flaws and what they are not good measurements. The lack of good measurements to assess logistics performance is also supported by Mentzer (1991), who states that refined measures for the evaluation of logistics have not been rigorously developed.

However, the problem is not limited to a lack of appropriate measurements but the fact that few companies actually measure their logistics performance at all, especially in terms of resources used compared to the goals achieved (Mentzer, 1991). A study by Fawcett and Cooper (1998) investigated the use of performance measurements in a vast number of companies. The results showed that the area with the least improvement (comparing the state in 1989 and 1994) involved traditional logistics productivity measurements. The same study also showed that nine of the ten measurements most often available still focus on cost measurement and control. Fawcett and Cooper (1998) concluded that this emphasis on cost derives from the fact that logistics has traditionally been viewed as a support activity and evaluated as a cost centre. According to the author can another underlying reason be the fact that it is difficult to assess the value of internal logistics and hence knowing what is important performance features that also needs to be followed up upon.

Some good news, though, came from the above mentioned study: overall, logistics managers are attempting to use measurement to help them design and manage more efficient and customer-effective logistics systems (Fawcett and Cooper, 1998). Identifying the value of internal logistics and its critical performance criteria might be one way to aid this development.

### 3.3 Design of and improvements in internal logistics systems

Many state that a well-designed and correctly used internal logistics system increases the efficiency of an organisation (eg. Öjmlertz, 1998; Mattsson and Jonsson, 2003). The design of the internal logistics system is hence one aspect that strongly influences the competitiveness of the system and is, thus, related to the objective of this research. This
section deals with important aspects when designing a logistics system and possible ways to improve existing systems.

### 3.3.1 Design of logistics systems

It is generally accepted that the concept of “one-size-fits-all” does not apply to the design of logistics systems (Christopher and Towill, 2002; Baker, 2004). That is because it is highly important that such systems fit the unique needs and requirements of each organisation. Before beginning to structure the logistics system, it is necessary to formulate all performance objectives and their targets (NEVEM-workgroup, 1989), which is discussed in the previous section.

In a literature overview, Baker (2006) identified and summarised five elements to be considered in the final design of distribution centres, and they are largely transferable to the design of internal logistics systems. The five elements, explained further below, are:

- **Building design**
- **Equipment**
- **Systems**
- **Staffing**
- **Process design**

**Building design** refers to physical features such as ceiling height, placement of doors, floor flatness, and so on. Many of these features are only possible to influence when constructing new facilities since it often requires a large amount of rework or could be impossible to change in an existing facility. However, it is possible to change certain features and, for example, adjust the layout in an existing facility to improve the logistics flow. One motive for changing the layout could be a change in the space needed for different logistics activities. One example of this could be materials supply, when manufacturing companies introduce new products. Space, therefore, is one of the main characteristics to consider when designing the layout of internal logistics systems (Johansson and Mathisson-Öjmertz, 1996).

**Equipment** mainly refers to the physical equipment for the handling of goods and information, and ranges from automated equipment to manual, more labour-intensive equipment types. **Systems** include software and IT-systems needed to support and manage the planned operations. (Baker, 2006)

**Staffing** considerations include the use of permanent and temporary staff, multi-skilling, ergonomics, and health and safety issues (Baker, 2006). The labour resources needed and available for performing the process are important restrictions that, to a large extent, influence decisions concerning the next element, **process design** (Johansson and Mathisson-Öjmertz, 1996). In the design of the logistics system, as in the organisation as a whole, resources, such as space, labour, and equipment, need to be allocated among the different functions. Further, each function needs to be carefully implemented, operated, and coordinated in order to achieve system requirements (Gu et al., 2007).
According to Rouwenhorst et al. (2000), the main design objectives for logistics systems are low investment and operational costs. However, there are other performance criteria that unfortunately might be neglected due to the difficulty to quantify them. Examples include environmental and ergonomic conditions. Many companies even have problems defining important quantitative performance objectives such as delivery/throughput time, delivery reliability, and inventory level (NEVEM-workgroup, 1989). The first threshold to overcome is hence to specify what performance aspects are important and try to specify target values for these. The second step is to rank these in comparison to each other (in other words, what is more important/more critical than the other). As stated by Rouwenhorst et al. (2000), there is a need for further research in the area of trade-offs between costs and operational performance.

Due to the vast amount of parameters to consider and the high number of possibilities that exist in each step of the design phase, it is acknowledged that the design of logistics systems is highly complex and it may not be possible to identify the optimum solution (Baker and Canessa, 2009). Several researchers who have performed extensive literature reviews state that there is a need for more research on strategic design problems since no comprehensive, systematic method or model for designing logistics operations currently exists (Rouwenhorst et al., 2000; Baker and Canessa, 2009).

3.3.2 Improving the internal logistics system

The main design of a new internal logistics system is made and decided during the construction or planning of a new facility. However, improvements in the system and its design are (or, at least, should be) a continuous process. One important part of supply chain management is to improve the supply chain and all its parts and activities. Logistics and the internal logistics system are included in this category (Tangen, 2004; Tan, 2007). As in many other areas, there is a need in logistics to constantly improve and develop operations in order to maintain or improve competitiveness. The goal is to achieve a competitive advantage through both cost reduction and service enhancement (Christopher, 2005). These two objectives of reducing costs and improving performance sometimes go hand in hand in the sense that one leads to the other but that is not always the case, though. It is rather, as mentioned in the previous section, a question of tradeoffs between cost and performance. Cost reduction is what traditionally has been in focus when discussing important improvements of logistics systems, while future challenges are more connected to improving performance features, such as shortening lead times (Baker, 2004).

When initiating an improvement project, it can be difficult to know where to start. Frazelle (2001a) has developed a methodology called Logistics Master Planning, characterised as a road map for redesigning logistics systems. The methodology, further described below, is divided into three phases:

- Phase 1: Investigate
- Phase 2: Innovate
- Phase 3: Implement
During the first phase, investigate, it is important to:

- Profile current logistics activity
- Measure current logistics performance
- Benchmark performance and practices

Regarding the first two points, the importance of clarifying the most important aspects and measuring them has been covered in Section 3.2.2. When it comes to benchmarking, a study by Fawcett and Cooper (1998) investigated the relationship between companies' degrees of benchmarking and their own performance assessment for 32 specific capabilities. The study showed that firms classified as non-benchmarkers indicated the highest levels of performance for the majority of the capabilities. Firms classified as limited benchmarkers considered themselves to be the highest performers for half of the investigated capabilities. Meanwhile, companies with extensive benchmarking programs claimed to be the best performers for only two capabilities. Although this finding might be used as evidence that benchmarking does not improve logistical performance, the most likely explanation is that companies that actively benchmark have a more realistic view of their own performance (Fawcett and Cooper, 1998).

The goal of the second phase, innovation, is to determine and create the most appropriate design for each logistics activity. Therefore, it is important to (Frazelle, 2001a):

- Simplify, by eliminating and combining work activities
- Optimise, with decision support tools to determine optimal resource requirements
- Apply “world-class” practices (in other words, tailor the best logistics practices to the particular setting and circumstance)

For logistics, the prime objective is to move the goods as efficiently and safely as possible. This often involves minimizing the amount of handling and movement (i.e., reducing all waste). This is accomplished by performing only “necessary” movements and combining operations wherever possible (Gattorna et al., 1991). Hence, a well-designed materials flow also gives the opportunity to lower the work-load dose (Öjmertz, 1998).

For some time, logistics has been tackled on a piecemeal basis. Further, the tuning of logistics activities has either not been undertaken or undertaken insufficiently, which has led to sub-optimisation (NEVEM-workgroup, 1989) and poor performance. One improvement in a materials flow system might have a negative impact on other components of the performance of the system (Öjmertz, 1998). Therefore, it is very important to not only have a vision for the logistics system and a set of goals for optimal resource usage, but also to measure and follow up the systems, in order to actually know how it performs and be able to see how improvements or changes affect it.
Reaching world-class is neither possible nor desired in every situation. Nonetheless, the emphasis on finding the most appropriate design and solution for the situation is always valid.

Frazelle's (2001a) third phase, implement, includes the following steps:
- Systemise, develop and document detailed procedures
- Automate, justify, select, and implement appropriate systems
- Humanise, design, populate, and develop organisation plans for human resources

It is important to systemise operations, for at least two reasons. Doing so not only makes a conscious design decision for the system, but also ensures that the activities and operations are carried out as planned to guarantee the desired output.

Automation could be a tool in improving logistics activities. Since this is one of the main focuses of this thesis, an entire section (3.4) is dedicated to further elaboration on the topic.

One important aspect in the humanising step is to involve the people working in the system. Since they are involved with the task on a daily basis, they often have a good understanding of the system, improvement areas and potential solutions. The step also includes both ergonomic improvements and team/personal developing programs (Frazelle, 2001b).

### 3.3.3 Logistics planning and strategy

Designing and improving the internal logistics system involves making decisions on different levels, such as the strategic, tactical and operational levels. As such, it involves both long-term planning (strategic) and short- and medium-term planning and control (managerial) aspects (Harrison and van Hoek, 2008). A well-functioning internal logistics system demands involvement and an understanding of the system on all levels. Logistics professionals must be equipped with the necessary expertise in the critical functions of their own enterprise and fully understand how they affect the entire value chain (Tan, 2007). Supply chains are faced with the situation where they have to accept uncertainty but need to develop a strategy that enables them to still match supply and demand (Christopher and Towill, 2001).

In general, it could be said that a strategy is about planning, as distinguished from doing (Harrison and van Hoek, 2008). A strategy consists of those plans or patterns of actions that integrate an organisation’s primary goals, policies and activities into a coherent whole. Thus, a logistics strategy consists of those plans or patterns of actions that relate to the flow of materials. A well-formulated strategy helps to utilise all the resources of an organisation and create value based on its internal competence and shortcomings with respect to the external environment (Jonsson, 2008).

It is however of great importance that both the logistics function and the logistics strategy is integrated into and aligned with the organisation’s other functions and strategies in order to create competitiveness (Tan, 2007; Jonsson, 2008).
From the above presented findings, the importance of a logistics strategy is evident. However, few sources discuss or present guidelines for how a logistics strategy should be developed or include details on what it should include.

3.4 Automation in logistics

This section introduces automation, its driving forces and possible challenges, both generally and with special regard for its use in logistics. Commonly occurring areas of application in logistics are described, as well as the process of automating.

3.4.1 Automation - definition and driving forces

According to Groover (2008), automation can be defined as the technology by which a process or procedure is accomplished without human assistance. The definition used in this thesis is somewhat more general, embracing all applications of devices and techniques that involve any degree of self-action (Amber, 1962).

Just as the essence of logistics can be separated into two flows (physical goods and information), automation can be divided into mechanisation and computerisation (Frazelle, 2001b). Mechanisation mainly relates to the automation of and in the physical flow of goods, while computerisation refers to the automation of and in the flow of information. It can also be seen as computerised technology deals with the control and support of mechanised technologies (Frohm et al., 2005).

There are different types of automation, especially within mechanised automation. The types range from fixed and programmable to flexible automation (Groover, 2008). The level of automation is a concept often used when discussing automation. One common usage of the term is when assessing the degree of automation (in other words, to what extent a task is automated or performed manually). The level of automation can be described as a continuum, ranging between totally manual and totally automatic (Frohm, 2008). It can also be described as three broad levels: manual handling, mechanical handling (manual power supplemented with mechanically powered devices), and automated handling (Gattorna et al., 1991).

Automation is a known tool for improving competitiveness, especially in the manufacturing industry. There are many reasons that justify automation, according to Groover (2008), some of them are:

- To increase labour productivity
- To reduce labour cost
- To mitigate the effects of labour shortages
- To reduce or eliminate routine manual and clerical tasks
- To improve worker safety
- To improve product quality
- To reduce lead time
- To accomplish processes that cannot be done manually
- To avoid the high cost of not automating

To avoid the high cost of not automating
These reasons are general and should, under the premises of proper use and implementation, be valid regardless of the activity being automated.

In a study by Frohm et al. (2006), the major expected benefits of using automation in manufacturing was (according to the respondents in the study) to generate; (1) cost savings, (2) possibilities for higher efficiency, (3) increased competitiveness, (4) increased productivity and, (5) an improved working environment.

A similar study from a specific logistics perspective was performed by Baker and Halim (2007), who investigated the reasons for automation in warehouses. There, the three main factors that brought about the need for automation were the requirements to: (1) accommodate growth, (2) reduce operating cost and (3) improve customer service. Other factors mentioned were to: reduce staffing level, consolidate inventories, improve accuracy, increase stock rotation and improve image. In addition, other, similar studies showed that the major motivations for automating the warehouse were to: (1) reduce material handling; (2) increase accuracy levels; (3) improve service consistency; and (4) improve speed of service (Dadzie and Johnston, 1991).

The results from these tree studies mentioned above are quite similar, with one exception: ergonomics was not cited as a main reason for automation in warehouses. Automation can be successfully employed in areas that involve tasks with physical strain or awkward environments in order to improve ergonomic working conditions (Echelmeyer et al., 2008). Since logistics often involves a large amount of manual handling, heavy lifting, and long transportation routes, ergonomic benefits are one of the biggest potential gains from automation in logistics activities.

Finally, other potential benefits of automation in logistics not mentioned in the studies above are, based on Naish and Baker (2004):

- Better use of floor space and buildings
- Less reliance on staff

### 3.4.2 Possible challenges with automation

As with any other technology, there are difficulties and potential challenges to using automation.

Several studies have investigated the most common concerns or problems associated with automated equipment in logistics operations. Below is a compilation of them, based on results from three studies (Dadzie and Johnston, 1991; Naish and Baker, 2004; Baker and Halim, 2007) and listed in their order of appearance:

- Lack of flexibility
- High cost of equipment/financial justification
- Reliability of equipment
- Software related problems, such as poor documentation
- Integration of equipment into existing systems
- Lengthy implementation and potential dips in service level during this period
- Maintenance cost/maintenance parts
Poor user interface and need of training to operate systems

According to Dadzie and Johnston (1991) and Baker and Halim (2007), other potential obstacles to implementing automated equipment not connected to the automation technology were related to the following:

- Lack of commitment from top management
- Issues concerning the change in culture
- Internal politics
- Worker acceptance of automation/transition from manual to automated procedure

Implementing automation in logistics activities often enables a redistribution of resources in a organisation (Echelmeyer et al., 2008). Since the implementation of automation often affects efficiency positively, it often leads to a reduced number of logistics staff. One danger of this is the risk of losing important information exchange needed to uphold tacit working skills and knowledge (Frohm, 2008). Increasing the degree of automated equipment might also change the demands on the skills and knowledge of the staff in order to properly operate the equipment. The operator’s role as problem-solver or decision-maker might also increase. As a result, the need for competent professionals might increase when automating (Frohm et al., 2003).

As when effecting any type of organisational or operational improvement plan, there is a risk of disruption and service level failings during the implementation and operational start-up of an automated system before the designed benefits are achieved (Baker and Halim, 2007). However, the risk and level of disruption depends on several aspects, such as the extent of the change/implementation, the degree of preparations and planning, and the experiences of dealing with similar projects and technology.

**3.4.3 Automated applications in logistics**

There are numerous possible automated applications and pieces of equipment that can be used for improving logistics activities. Below is a compilation of the most commonly occurring applications and types of automation presented in a selection of publications (Dadzie and Johnston, 1991; Öjmertz, 1998; Frazelle, 2001b; Baker, 2004b; Rushton et al., 2006; Baker and Halim, 2007; Echelmeyer et al., 2008):

- Automated loading and unloading systems
- Automated guided vehicles (AGVs)
- Automated storage and retrieval systems (AS/RS)
- Bar code systems
- Conveyor belts
- Conveyerised sorting systems
- Fork-lift trucks for mechanised handling
- Industrial robots/robotics
- IT systems for planning, managing operations and systems, etc.
- Item picking devices
• Lifting aids for manual handling
• Mechanised palletizing
• RFID-systems
• Sorting or screening systems
• Various forms of information automation for communication, data handling, monitoring, etc.
• Vision systems

Automation of certain logistics activities, is reasonably commonplace, but mostly in large warehouses (Baker, 2004) and not in internal logistics overall. Though the development of automated equipment, generally speaking, has advanced very far, there are still many fields in which the automation of logistics processes is not achieved with standard solutions (Echelmeyer et al., 2008). This often leads to unnecessarily high costs for automation technology and long development projects since new solutions must be created. However, as mentioned in the process for the design of internal logistics systems, the benchmarking of automated applications in other lines of business could be very valuable in developing the area of automation in logistics.

The sales of automated materials handling equipment have been growing steadily during the last decades (Baker and Halim, 2007; Echelmeyer et al., 2008). Further, according to the Materials Handling Industry of America (2010), the outlook for coming years is a continued growth in material handling equipment orders. But parallel to this growing trend has the degree of automation in production processes increased in an even faster way (Echelmeyer et al., 2008).

A study by Frohm et al. (2006) investigated to what extent different activities were automated. The results showed that logistics activities (such as material handling, material supply, and packaging) were all automated to a lower extent than other production activities, such as machining, change-over, and maintenance.

Some of the most likely reasons for this comparatively slow adoption of automation in logistics include the following points: top management neglect the logistics function; the unique environment in logistics is not commonly understood in terms of productivity and quality improvements; and, it is believed that the results of the logistics activities cannot be measured effectively (Dadzie and Johnston, 1991).

3.4.4 Automation decision, process and strategy
When initiating an automation project to investigate whether and how automation can improve logistics, there are many factors and aspects that need to be considered; hence, there are many steps in the automation process. By studying automation projects of internal logistics in warehouses, Baker and Halim (2007) have created a model of the generic steps in an typical warehouse automation project (see Figure 5).
Before considering automation, it should be understood that automation will not automatically achieve a turnaround in a company’s fortunes unless it is part of an overall strategy that takes into account the whole internal logistics system (Naish and Baker, 2004). It is important to connect the automation decision to the performance goals and then find the appropriate level and type of automation for the company’s needs and pre-requisites, and not the other way around. Since there are numerous parameters and performance indicators to consider if the company wants to have an

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**Figure 5** Typical warehouse automation project steps adopted from Baker and Halim (2007)

Unfortunately, since this model was not intentionally created as a guideline, it does not thoroughly describe the steps in the process. However, it does provide an idea of which phases and steps there are in an automation project. Another downside is that this process is mostly based on and adjusted for large scale automation implementations of complex and extensive automated systems. Automation in logistics however covers a wide range in the scale of the implementations, starting with small scale projects involving implementations of single pieces of equipment/systems and for these might not all steps (for example board approval) be relevant but instead confusing. Thus, there is a need for a more detailed process description that also suits small scale automation projects.

Nonetheless, it is pointed out that most companies do not conduct all steps in the process by themselves. Rather, they often take help from consultancy firms, equipment suppliers and/or a system integrator to complete many of the steps in the process (Baker and Halim, 2007).

The theoretical review led to some important conclusions for the research which are

- “A holistic view of the internal logistics system has been applied in this research. The view of the system was created based on the findings during the literature review. The main characteristics of the internal logistics system are described below, as well as
- of some key terms previously presented in the chapter.

- The number of pre-requisites that affect the automation decision could be the number and diversity of the products handled. Other pre-requisites could be physical constraints in the building design. The decision to automate is therefore viewed as an early decision within the logistics design process.

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- Before considering automation, it should be understood that automation will not automatically achieve a turnaround in a company’s fortunes unless it is part of an overall strategy that takes into account the whole internal logistics system (Naish and Baker, 2004). It is important to connect the automation decision to the performance goals and then find the appropriate level and type of automation for the company’s needs and pre-requisites, and not the other way around. Since there are numerous parameters and performance indicators to consider if the company wants to have an
optimised and effective system, Fasth et al. (2007) conclude that companies need to be increasingly aware of the parameters affecting their systems before automating to increase the potential of successful outcomes. Also, one of the main reasons that an automation project ends in failure is unrealistic or undefined objectives (Frohm, 2008). Thus, more time should initially be invested into the process of describing the requirements of the overall system before automating (Frohm et al., 2003).

Pre-requisites that affect the automation decision could be the number and diversity of goods to be handled (Frohm et al., 2006; de Gea Fernandez et al., 2007) or a fast changing product base that influences the flexibility requirement for the automated equipment. Standardised mass goods have a high potential for being automated (Echelmeyer et al., 2008). That is because it is relatively easy to find a standardised automation solution at a reasonable cost when product volumes are high and demands for flexibility are low (Tangen, 2004). One of the most common arguments against automated equipment is that it is generally considered inflexible. However, this depends on the type of automation, since there are many different types of automation, ranging from fixed to flexible. Depending on the pre-requisites and intended area of use, the suitability of the different types differ. Hackman et al. (2001) also conclude that inefficiencies in highly automated logistics systems, in addition to the lack of adequate system maintenance and the difficulty of reconfiguring the systems to meet changing requirements, often depend on inappropriate selection of system types. This while, at the same time, highly efficient facilities with high levels of automation generally make very targeted use of the automation.

Other pre-requisites could be physical constraints in the building design. The decision to automate is therefore viewed as an early decision within the logistics design process (Rouwenhorst et al., 2000). In other words, it is a strategic decision that will have a long term impact on the system (Baker and Halim, 2007). This is especially true since investments in automation often involve a high capital cost which, in turn, has to be justified by savings in running costs. This implies a certain payback period; hence, a medium to long-term view must be taken (Naish and Baker, 2004).

3.5 Discussion on theory and definitions
The theoretical review led to some important conclusions for the research which are presented below. The section is concluded with a summary of the applied definitions of some key terms previously presented in the chapter.

A holistic view of the internal logistics system has been applied in this research. The view of the system was created based on the findings during the literature review. The main characteristics of the internal logistics system are described below, as well as visualised in Figure 6.
The system boundaries for the internal logistics system are the physical walls of an isolated organisation. The system, however, is open and therefore affected by other systems outside the studied system (external influences) and outside the scope of this research. The system is also closely integrated with other systems and processes in the company, such as the manufacturing or assembly processes in a producing company or the care processes in a hospital.

The main feature of the system is the physical flow of goods and products and the flow of information associated with it. These flows are comprised of a number of logistics activities and processes performed with the help of resources such as the humans (and their skills and competence) and the physical equipment and IT-systems in and a part of the system. The flows and all resources are in turn managed, controlled and affected by the organisation, the logistics strategy and planning.

The view of and focus on internal logistics in literature are much different from the ones connected to the overall level of the supply chain. This is to some extent

Figure 6 A holistic view of the internal logistics system
Figure 6

A holistic view of the internal logistics system. The system boundaries for the internal logistics system are the physical walls of an isolated organisation. The system, however, is open and therefore affected by other systems outside the studied system (external influences) and outside the scope of this research. The system is also closely integrated with other systems and processes in the company, such as the manufacturing or assembly processes in a producing company or the care processes in a hospital.

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The view of and focus on internal logistics in literature are much different from the ones connected to the overall level of the supply chain. This is to some extent expected. However, there are still many valuable lessons from the view of the supply chain that are valid and could easily and advantageously be passed down to the internal logistics system.

There are many aspects of performance covered and presented in the literature. The importance of clear goals in terms of performance is also often mentioned as a key aspect for both designing and evaluating the internal logistics system. There is, however, a gap in the literature: very few, if any, observers give any direction as to how a company can generate these performance goals. Many refer to the logistics strategy as the solution, but there is little written on what a logistics strategy includes and how it should be created.

Definitions

Based on the discussion and theories presented in this chapter, the following definitions are used in this research:

*Automation:* All applications of devices and techniques that involve any degree of self-action.

*Efficiency:* A measure for the internal performance, i.e. how well the expended resources are utilised.

*Effectiveness:* A measure for the external performance, i.e. how well the desired output is achieved.

*Internal logistics:* All logistics activities and processes connected to managing the flows of physical goods and information within the physical limits of an isolated organisation.

*Internal logistics system:* The system that includes and enables the internal logistics flows and, hence, all related activities, processes, and resources.

*Logistics:* The framework of all activities and processes connected to managing the flows of physical goods and information within an organisation.

*Logistics system:* The system that includes and enables the logistics flows and, hence, all related activities, processes, and resources.

*Performance:* An umbrella term for all aspects and criteria that consider the created value and success of a company, function or activity compared to the goals.

*Productivity:* The amount of created value in relation to the resources expended.

*Supply Chain:* The network of all organisations, functions, activities, and processes connected to the flow of materials and information from suppliers to end users.

*Supply Chain Management:* The task of strategically organizing, planning, managing, controlling, and improving the supply chain.
This chapter presents the most important findings and conclusions from the empirical studies in this research. For a more detailed description of the studies, the reader is referred to Section 2.3 as well as the respective paper.

The empirical part of this research consisted of four studies, Studies A-D. The studies, their objective and the course of action are presented in detail in Section 2.3. In the following sections, the most important findings from each study are presented, discussed and connected to the literature review. Each section ends with some conclusions from the study. A more detailed description of the findings is presented in the paper connected to each respective study.

Study A was a case study of eight SMEs with the aim to gain a deeper understanding of how they work with improvements in internal logistics, especially with regards to automation. Study A and its findings are more thoroughly described and discussed in appended Paper I.

The results from the questionnaire, interviews and the direct observations performed in Study A are compiled below, presented and discussed with regards to the following four themes:

• The importance of internal logistics
• Improvement areas and their causes
• Way of working with improvements
• Automation of logistics activities – extent and difficulties

The importance of internal logistics

In the survey, the respondents were asked to rank the importance of effective internal logistics and materials handling in their business and also in relation to their core competence. The answers can be seen below in Tables 2 and 3, where the roman number indicates the number of replies in each category (from the seven case companies that completed the survey).

Table 2
The importance of an effective internal logistics

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Table 3
The importance of effective internal logistics compared to the core competence

It is our core competence

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4. EMPIRICAL FINDINGS

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4.1 Study A
Study A was a case study of eight SMEs with the aim to gain a deeper understanding of how they work with improvements in internal logistics, especially with regards to automation. Study A and its findings are more thoroughly described and discussed in appended Paper I.

4.1.1 Results
The results from the questionnaire, interviews and the direct observations performed in Study A are compiled below, presented and discussed with regards to the following four themes:

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Table 3 The importance of effective internal logistics compared to the core competence
The results in Table 1 and 3 show that an effective internal logistics is considered (very) important but, as expected, not as important as the core competence. The two companies that rated internal logistics their core competence was the two warehousing companies.

The survey also covered what share of last year's conducted investments and improvement measures were related to internal logistics and the desired future share. The results are presented below in Tables 4 and 5, where the roman number indicates the number of replies in each category (from the seven case companies that completed the survey).

**Table 4** Share of last year's conducted investments and improvement measures related to internal logistics

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**Table 5** Desired future share of improvements and investments related to internal logistics

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The result in Table 4 shows a wide spread in how much effort and money have been put into improving the internal logistics at the case companies. However, a pleasing trend can be seen when comparing Table 4 and 5: that the desired share of improvements and investments related to internal logistics is higher than the current.

The organisational responsibility for logistics was also investigated during this study. In general, the responsibilities were much more distinct the bigger the company and the larger part logistics played for the company’s overall function. In the participating warehousing companies, the responsibilities were clear, well-spread out over many functions and several positions. This was not surprising since the core function is related to logistics activities. In the producing companies, the responsibility for internal logistics often rested on the production manager or a similar and relatively high position in the company. This was particularly common the smaller the company, since such companies often did not have a separate logistics department, while some of the medium-sized companies did.

**Improvement areas and their causes**
Study A covered already implemented improvement measures in the company’s internal logistics. Below are examples of the most recent improvements and their main causes in six of the companies:

1. Implemented a robot cell for materials supply to processing machine and two robot cells for materials handling (one that mounted boxes and one that closed and sealed boxes).
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1. Implemented a robot cell for materials supply to processing machine and two robot cells for materials handling (one that mounted boxes and one that closed and sealed boxes).
   Main cause: Free up expensive labour for other tasks, improve work ergonomics and quality degree in operations.

2. Introduced a “milk run” for materials supply.
   Main cause: Improve order and work structure of materials supply function. Reduce travelled distance for operators to collect material, thus also shortening lead times.

3. Introduced a new MRP-system.
   Main cause: Improve/enable planning of the operations and introduce a warehouse system.

4. Mechanised lifting aid for lifting goods to a conveyor belt.
   Main cause: Free operators from heavy and repeated lifts.

5. Robot cell integrated with conveyors for materials supply and storage between two processing machines.
   Main cause: Free staff to perform other tasks, remove ergonomically unsound steps (including repeated and heavy lifting), remove several process steps (in other words: shorten lead times), shorten setup times, and reduce amount of work in progress inventory.

6. Introduced a new MRP-system.
   Main cause: Achieve better control, order and clearer responsibilities. Also, reduce a substantial number of manual steps in planning.

During the interviews, all the respondents agreed that their company needed to further improve their internal logistics system. Most could also state several identified areas within internal logistics they desired to improve. The most mentioned area related to changing and improving parts of the materials handling, especially where a large amount of manual handling was required today. The materials flow, especially in aspects of materials supply to workstations, machines, and so on, was also a reoccurring improvement area, along with desired changes in the layout. Many improvement areas also related to information handling and implementing IT systems for planning and control. For the improvements desired in both the physical flow of goods and the information flow, many of the respondents considered automation to be the most likely or desired solution.

The reasons these areas needed improvement related to:

- Freeing up staff for more value adding tasks/more advanced tasks and assignment
- Improving work environment regarding ergonomics
- Utilising equipment and/or space better
- Reducing cost
- Increasing control over processes
- Improving worker safety
- Reducing lead times
• Decreasing risk of disturbances in the process
• Standardise the way of working
• To clear out areas of responsibility
• Ease planning
• Increase quality, make sure all orders are correct
• Improve organisational structure
• Improve reputation/attract new and younger staff

The first five reasons reoccurred the most. In general, most respondents expressed a desire to utilise all the available resources better, by using different terms such as productivity, efficiency/effectiveness and focusing on different performance aspects or resources.

**Way of working with improvements**
Approaches varied a great deal regarding the way the companies worked when conducting the above mentioned implemented improvements and how they planned to tackle their current areas in need of improvement. Some of the companies chose to execute all the steps in the improvement projects on their own. Others performed the greater part of the work themselves but turned to consultants or system suppliers in a few of, as they saw it, the most complicated steps (ones that demanded high technological skills, for example). A number of the companies turned to consultants or system suppliers for complete solutions, while others chose to work in teams with representatives from the company, system suppliers and consultants. The most reoccurring steps in improvement work the companies chose to do themselves were to identify problems or possible areas of improvements.

According to the answers from the survey and the interviews, many of, especially the first steps, in the improvement process were considered difficult. The following steps were considered to be difficult by the majority:

• Drawing up investment calculations
• Evaluating solutions and decide on most appropriate one for the future
• Identifying problems/possible improvements
• Developing specification of requirements

The consequences of the poor ability to draw up investment calculations and proper requirement specifications were considered to be unnecessarily expensive and overly complicated solutions.

It was also considered difficult to find an appropriate level of cooperation with systems suppliers. Some experienced that they could take too much control over the project, risking ending up with a solution that did not fit into the rest of the system or that the company could not handle after the implementation. Some also experienced problems during collaboration regarding who owed and were responsible for the implemented solution, and the like.
However, in the end, the main reasons for why the company was stopped from improving its internal logistics system were considered to be a lack of time for improvement work and a lack of competence of how to do it.

Automation of logistics activities – extent and difficulties
During the survey, the respondents were asked to assess the extent to which different activities were automated. In general, all logistics activities related to the physical flow of goods were automated to a low or very low extent and not to the same extent as the production processes (where applicable) or the information handling. The logistics activity with the highest degree of automation was internal transports. Nonetheless, there was generally a low degree of automation at the case companies.

When asked what have stopped the companies from automating logistics functions to a larger extent, many different reasons emerged. Many related it to a lack of competence, the demand for flexibility mainly due to the variety of goods, the high investment cost or the company’s priorities. Some also mentioned a lack of support from management. Most respondents concurred that the automated technology needed to improve their internal logistics most likely was available on the market today, but that it was rather a question of having the time and knowledge to search for it and being willing to pay for it.

Regarding what types of activities were experienced as difficult to automate, many mentioned quality controls and inspections, especially those today performed visually. Several of the respondents also mentioned material supply, picking and packaging as difficult to automate due to low volumes and a wide variety and non-uniformity of goods.

The respondents were also asked if they saw any obstacles towards automation in general and of logistics activities in particular. The doubts that did come up mostly related to the automation technology, such as the level of flexibility when automating and the reliability and robustness of the automated systems. One respondent had experienced that previous automated equipment did not work properly, which had created a resistance among the operators towards automation in general. Some respondents also had concerns about the operators’ lack of knowledge and willingness to learn how to operate new equipment in order to utilise new solutions to their full extent and handle them in the right manner. Finally, several of the respondents had experienced that problems had occurred with previous automated equipment, mainly due to incorrect handling.

In general, however, there was a positive attitude towards automation in logistics. Many wanted to automate extensive parts of their businesses, especially activities that were repetitive include heavy lifting or other ergonomically unsound activities. One respondent also expressed the goal of “a black factory” (i.e., a fully automated factory, and therefore not needing lights).
4.1.2 Conclusions
The conclusions from Study A are:

- There is a need and willingness to improve the internal logistics at the case companies. Some areas of improvement are well-known to the company (others not), and they could also specify why these desired improvements were necessary and the potential benefits of correcting problems.

- Many of the conducted improvements involved automation. Also, many of the current problem areas and desired improvements and their underlying causes could be solved with the help of automation. Therefore, there is clearly a market/need for automation in internal logistics.

- There were reoccurring trends among the different companies' conducted and planned improvement measures (i.e., what some had already implemented several were planning to do). There is hence knowledge and experience regarding many automated solutions for areas desired by several, and it should therefore be possible to develop some form of standard solutions that many can benefit from without expertise knowledge or extensive investments.

- The low degree of automation in logistics activities does not mainly depend on a lack of existing technology; rather on a lack of knowledge about how to find it, see the potential benefits of it, economically justify it and use it properly. However, the demand for flexible solutions was also considered a hindrance.

- None of the respondents considered the actual implementation of automated equipment to be the most difficult step. This while in literature (as presented in Section 3.4.2) the risk of disruption and service level failings during implementation was mentioned as one of the main downsides to automation.

- There are trends in what type and what areas the case study companies chose to automate. One company had several robot cells for materials supply and handling and aimed at implementing five new cells the same year. They had apparently found a type of automation they found suitable and strove for a higher degree of automation in the materials handling. In contrast, almost all information, planning and communication was done manually.

- The companies studied very much depend on system suppliers and integrators when conducting improvement projects in general and when using automation in particular. They need help with many steps in the improvement process, especially in the early phases (for example to identify problems and mainly identify and determine potential/appropriate solutions).

- Almost all companies in the study chose to identify problem areas themselves. This was interesting since this was one of the steps in the improvement process they felt they needed the most help with. Due to a lack of knowledge, they often do not even see how their logistics activities could be improved. They are
aware that there probably are automated solution they could benefit from. However, they do not know what they are and, hence, what is possible to improve.

- The result from the assessment of the degree of automation in different activities is in line with previous research e.g. (Frohm et al., 2006) that concluded that logistics activities are automated to a lower extent than typical production activities. However, the degree of automation in general at the case companies was low.

- There is a big difference on the perceived level of the importance of and focus on internal logistics as a function, especially when it comes to improvement efforts and budget. Not surprisingly, logistics is of high importance for the warehousing companies in the study. There, logistics can be seen as the core function, which is reflected in a more systematic way of working with and improving the system. In the case of companies from manufacturing industry, responsibility for internal logistics is not often clearly assigned. Instead, it was one small part of, e.g., the production manager's areas of responsibility, a phenomenon more common the smaller the company was.

Since Study A figured as the research clarification, the results from this study influenced the rest of the research process. For example, Study B was initiated to reveal what performance aspects are most important for the internal logistics system. This information can help when developing requirement specifications and choosing the most appropriate improvement solution which was considered as difficult. Study C studied potential areas of use for automation in logistics activities in other lines of business; hence, it constituted benchmarking for available technology and potentially new application areas for SMEs. Finally, study D also targeted an SME, focusing on the company's problems that emerged during this study and showing one potential way of using automation in an SME.

4.2 Study B

Study B was a survey study with the aim of showing how manufacturing companies work with and perceive their internal logistics system. The detailed results from the survey are compiled and presented in appended Paper II. Below is a discussion of the most important empirical findings and their implications, followed by some conclusions from the study.

4.2.1 Results

The results from the survey in Study B are compiled below, presented and discussed with regards to the following six themes:

- Vision and strategy
- Success factors
- Important performance criteria
- Critical resources
- Development of the internal logistics system
- Performance measurements

**Vision and strategy**

The great majority of the responding companies do not have a clearly stated vision of or strategy for the internal logistics system in their organisation. Seventy-nine percent of the respondents answering the question clearly answered no vision; in addition, five did not answer the question at all.

Of the few respondents that did answer the question, none separated their answers into both a vision and a strategy or stated whether their reply was to be interpreted as the company vision or strategy. Further, several of the answers provided did not typically express a vision/strategy. For example, “maximum five days lead time” is a means or a goal rather than a vision/strategy.

Of those stating a vision/strategy, many answers were connected to the Lean production paradigm and its terminology and methods (such as minimise waste and use pull and Kanban systems). However, none explained the strategy as seeking to achieve a “lean logistics system”.

**Success factors**

When asked for the most important success factors for a well-functioning internal logistics system, the three following areas was almost equally as much referred to: (1) performance factors, such as delivery precision, stock levels and lead/delivery times, (2) information factors, such as information systems, communication and information precision, and (3) flow and process related factors, such as a good and balanced flow.

The performance aspect can partly be viewed as output from the system but also refers to internal performances (such as delivery precision for internal transports) that need to be fulfilled to guarantee smooth running operations. Possibly the most distinguishing result category is the one related to the humans in the system, which was the fourth most commonly mentioned category. That category contained many personal features (such as commitment and responsibility) and the competence of the people working in and with the system.

**Important performance criteria**

When ranking important performance criteria from the internal logistics systems, the three criteria that reoccurred the most and had the highest ranking average were the following: (1) delivery precision, (2) service degree towards customer, and (3) delivery dependability. The first and third criteria are very closely related, and 39 of the 44 respondents chose at least one of them. If their occurrence were combined, it would have been by far the most important criterion. But many respondents do separate them. Seventeen of the 39 respondents that choose at least one of the two ranked both criteria as one of the five most important deliveries, but the remaining 22 only chose one of them.

The results are very much in line with the ones from a similar study in four different industries, where the following were considered the most important logistics service
attributes: accuracy in order filling, consistent lead time, and the ability to expedite emergency orders (Stock and Lambert, 1992).

The fact that service degree towards customer is ranked very high is totally in line with the classic expression that in order to succeed one should only do what the customer is willing to pay for (and nothing more) in order to keep the cost down. But an interesting feature is that all cost and economical aspects (such as total logistics cost, operational and administrative cost, and return of assets and payback from investments) are ranked very low. This suggests a shift in focus from the traditional view of logistics as only a cost toward other performance features being the most important.

Another characteristic feature partly mentioned when presenting the results is that the criterion with the highest number of top scores by far and the highest average was ergonomics and staff safety, which in the total compilation placed as low as number six. Thus, those respondents that considered it an important aspect found it very important.

**Critical resources**

The most critical resources, both referring to the organisation in general and to logistics specifically, were, in decreasing order, competence, manpower, equipment and space. Despite competence being viewed as the most critical resource, only one respondent specifically listed it as a success factor. But as described in Section 5.2.3, human aspects were the fourth largest category when listing success factors. One possible explanation can therefore be that the resource competence does not solely relate to the staff’s knowledge. Instead, it includes having the right type of staff with the desired personal features that emerged when listing success factors (such as commitment and responsibility).

The resulting order of importance for the ranked resources turned out the same for the organisation in general and for logistics specifically. However, only 26% of the respondents ranked the critical resources in the same order when it came to logistics as when it came to the organisation in general. Therefore, it can be concluded that logistics often has other requirements than other functions in responding companies. But when reviewing the compiled results, no clear trends emerged, since the differences often evened each other out. One could possibly claim that equipment is regarded as more critical in the organisation as a whole, and space more critical when it comes to logistics, but the differences are not fully evident in this relatively small sample.

**Development of the internal logistics system**

When the respondents were asked to state how the internal logistics system should be structured or how it needed to be improved to better utilise the company’s resources, the four most common aspects the answers concerned were layout, planning (through information systems), space, and competence.

One interesting observation is that the areas in future need of improvement poorly correspond to the ranking of critical resources. For example, space was considered the least important resource, but emerged at top three when it came to improvement areas.
Manpower was the second most critical resource, but only one respondent mentioned a need for more staff. The most critical resource, competence, however, was listed as the fourth most commonly sought after improvement area. One possible explanation for this poor match can be that the companies do not measure or follow up on the use of resources; hence, they may not be aware of which resources are the most critical.

When comparing improvement areas with the listed success factors, many similarities can be seen and most aspects and areas appear in both listings. For example, information and planning, layout and flow, and various performance aspects reoccur. One reason for this is that both questions were open, leaving the respondent free to answer whatever came to mind first, and what most regarded as important for success was also, not very surprisingly, something they wanted to improve.

Two respondents answered that their internal logistics system worked well today and that no improvements were necessary. It is rather difficult to believe that such an optimal internal logistics system has been achieved that no possible improvements can even be imagined. As strongly promoted by the lean paradigm, continuous improvement is a necessity for a successful corporation, and the constant drive to want to develop one's organisation is an important success factor. When asking about areas currently being improved or highly prioritised/planned to develop, several did answer that they continuously worked to improve their operations. Somewhat more alarming is that 31% answered that they currently did not have any prioritised, planned or ongoing improvement work connected to logistics, even though they had listed areas in need of improvement.

Only about half (53%) of the respondent companies have a person with strategic responsibility for internal logistics. Even though this is unfortunate, it might not be unexpected. More than half of the responding companies in total have less than 50 employees, and the smaller the company, the lesser the probability of having clear, assigned strategic roles for all departments and functions. Also, smaller companies logically have small logistics departments. It emerged from the information about the respondents and their role in the company that the logistics responsibility many times rests on the production manager and there is no manager solely assigned to logistics. The lack of someone with strategic responsibility vastly reduces the possibilities to manage and develop the internal logistics system. This is because no one has the overall view of the system, its performance, the responsibility for setting visions and goals and following up and planning for improvements, and so on.

**Performance measurements**

In line with the ranking of aspects considered as the most important performance criteria and aspects considered by several as success factors, measurements regarding delivery (e.g., delivery precision and delivery dependability) are by far the most commonly occurring ones among the respondents using performance measurements. Many also used measurements related to inventory, which was listed medium high in terms of important deliveries or success factors. Service degree towards customers and quality degree were other aspects considered as highly important deliveries. Quality
was the third most commonly measured aspect, but only two respondents followed up on customer satisfaction.

In contrast to the importance of using performance measurements (that emerged during the literature review), seemingly few respondents did (only 60% listed any performance measurements used). Further, several respondents that did use performance measurements only used one or two measurements, which does not give a complete picture of the operations.

One danger in not measuring and following up on a company’s logistics operations is that you get a poor general view of the system. This increases the risk of sub-optimisation. If you do not know how much resource your system uses, how it actually performs, and so on, how will you know how to improve it? The results and following reasoning are in line with the results and conclusions from previous studies on the topic (e.g., in Mentzer (1991) and Gunasekaran et al. (2004)).

Finally, the fact that the majority of the responding companies lack a strategy and vision for their internal logistics system is one aspect that presents difficulties when designing a performance measurement system for logistics. This is because there is nothing to connect it to. Also, the common lack of someone with strategic responsibility is another aggravating circumstance, since no one bears the responsibility to design, implement and make sure a performance measurement system is used and followed up on.

### 4.2.2 Conclusions

From Study B, it can be concluded that:

- **Very few companies have a vision or strategy for their internal logistics system.** The downside of not having a vision or strategy is that the company has nothing to work towards in a long term view. A vision or strategy can often give an indication of what is viewed as important values, how the internal logistics system should be managed and in which direction it should be developed.

- **Manufacturing companies in Sweden find the following to be the most important success factors for a well-functioning internal logistics: system performances (such as delivery precision), information aspects (such as updated and supportive information systems), a balanced flow without disturbances, and committed and responsible staff.**

- **In line with the previous point were delivery precision and dependability, together with service degree towards customer and quality degree, the system performance criteria found most important. Meanwhile, various cost and economic aspects were not considered important. The aspect of ergonomics and staff safety was not one of the five most important criteria. However, respondents that found it important found it very much so. Thus, there is a trend towards a shift in focus from only cost to other performance aspects.**
• The most critical resources are considered to be competence and manpower. Nonetheless, future improvement work rarely aims at improving these areas. This might be related to the fact that few measure and follow up logistics performance and are, therefore, unaware of the current situation. This could in turn be linked to the fact that most lack a vision and strategy for their internal logistics system, and many do not have anyone strategically responsible for operating and developing it.

• Swedish manufacturing companies must place more focus and attention on their internal logistics system as a strategic task, rather than only a function. A better understanding of the current state of the system and its performance will help improve its efficiency and effectiveness, thus increasing the possibility to utilise it as the strategic means for competition it has the potential to be.

4.3 Study C

Study C was a multiple case study of three Scandinavian hospitals. The objective of Study C was to examine and analyse how hospitals work with internal logistics activities in different aspects. This was done in order to conclude how automation can be a tool in improving internal logistics systems in hospitals. Study C and its findings is thoroughly described and presented in appended Paper III, below is a summary of the most important findings and conclusions.

4.3.1 Results

Since Study C was a multiple case study, this section first provides a brief summary of the findings from the mapping of the current ways of working at each of the three case hospitals. Reflections and conclusions from each sub-study (Case c1-c3) then follow. The more general conclusions for Study C are presented in the next section.

Case hospital c1: Current state

Case hospital 1 has a transportation department, working as an external party from which the hospital buys services. The department is responsible for all transportation activities that belong to the internal service of the hospital (for example, transports of patients, waste material, laundry, food, pharmaceuticals and all mail handling).

In general, there is a very low degree of automation in the logistics activities that involve a vast amount of manual labour. This is especially true regarding internal transports and material handling. There is also a low degree of automation in the flow information and few/poor tools for planning and communication. One of the implications of this is that the transportation department can only conduct 87% of all patient transports, leaving the nursing staff to perform the rest.

The hospital layout and physical properties are far from optimal. Among other things, this results in long transport routes and obstacles (such as not being able to bring aids as bed pushers and the like in elevators or in culverts). When it comes to equipment used in logistics, the transportation department owns all the equipment they use for internal transports and materials handling. However, since the department is only contracted
with the hospital for two year periods, the manager expressed concerns regarding the ownership of new investments, enabling a long term view.

While the transportation staff’s main task is to perform logistics activities, this is not the case for the nursing staff.

In order to analyse the nurses’ time in detail, a quantitative time study was performed at 13 of the nursing wards. The activities in the time study were separated into four categories: direct care, indirect care, administration, and personal time. Direct care encompasses activities carried out face-to-face with the patient (for example, treatments and examinations). Indirect care is patient-related activities not performed in direct contact with the patient (for example logistics activities and preparing medication and food). Administration refers to administrative tasks that are not directly patient-related (economic planning and education, for example). Finally, Personal time includes all pauses (besides lunch) taken within the regulated working hours for restroom visits, coffee breaks, and so on.

Diagram 1 shows the average time distribution for nurses during the day shifts. The indirect care category is the largest category, occupying 54% of the nurses’ total time. Many logistics-related activities are involved in this time, such as handling of food and supplies and transportation of oneself or patients and goods outside the ward.

![Diagram 1: Time distribution for nursing staff](image)

Diagram 1 Time distribution for nursing staff

In general, as the nurses expressed it, internal logistics was cluttered and disorganised, and they experienced a great deal of “running around”. Through interviews and observations, the following logistics-related areas were found in need of improvement:

- Patient transports made by nursing staff, despite being the transportation department's responsibility. The transports are time-consuming and considered physically straining due to long distances.
There is also a general wish to “professionalize the logistics processes” (Elmfeldt and Kardbom, 2009). The logistics flows, though vital, are too expensive to customise to each ward. A standardised way of working with focus on an efficient flow is desired. Several lean principles are also mentioned as customer focus (part of Total Quality Management), Just-In-Time deliveries and continuous improvements.

Today, the logistics department is an internal department. However, in the new hospital, the property-owner will be responsible for the logistics function (in other words, it will be outsourced).

Case hospital c2: Current state and future hospital logistics
Case hospital c2 was studied in order to complement Case c1 as regards aspects of possible improvement of hospital internal logistics in a larger hospital context.

Case hospital c2 had a number of automated applications in the internal logistics system, such as:

- An IT-system for ordering, planning and managing patient transports.
- Positioning hand computers for all transport staff for planning and communication.
- A pneumatic dispatch system for the transportation of small goods, such as samples, blood, medicine, paperwork, and money.
- An industrial robot cell that handled incoming and returning shipments from the pneumatic dispatch system at the laboratory.
- Automated guided vehicles (AGVs) for deliveries of food, linen, laundry, waste, and goods.

Case hospital c2 is in the process of planning and building a new site, replacing one of its current sites. A major strategic study of the logistics needs was conducted as a step in the planning. The result was gathered in a report (Elmfeldt and Kardbom, 2009), approved by the hospital management as guidelines for the future internal logistics system. The report concludes that automatic transports will be a founding principle for future logistics, due to increasing demands for efficiency, accessibility, shorter lead times, and round-the-clock service. AGVs, pneumatic dispatch systems and air pressured waste/laundry systems are also necessities at the future site. In general, a high degree of automation is sought, by for example IT systems for ordering materials, tracing equipment and staff. Equipment for picking and packing medicine for patients is also to be integrated with the pneumatic dispatch system.

There is also a general wish to “professionalize the logistics processes” (Elmfeldt and Kardbom, 2009). The logistics flows, though vital, are too expensive to customise to each ward. A standardised way of working with focus on an efficient flow is desired. Several lean principles are also mentioned as customer focus (part of Total Quality Management), Just-In-Time deliveries and continuous improvements.
Case hospital c3: Development, solutions and initial problems
Case hospital 3 was studied in order to complement Case c1 as a role-model and a description of what the future of hospital logistics could entail.

Case hospital c3 is a new hospital, inaugurated late in 2008. Prior to planning the new hospital, an analysis of the previous hospital was made. That analysis concerned the nurses’ time usage for the main activities and related bottlenecks. The results from the analysis pointed out focus areas to consider when designing the new hospital. Inspiration was gathered from hospitals in the UK and USA, as well as from the building contractor and the hospital staff. A goal for the new hospital was to own as much of the equipment as possible and be able to perform the majority of the task/services internally.

Prominent features at Case hospital c3 were:
- **The layout** - The aim was that wards and units with many transactions and patient transports should be closely situated. All nursing wards also follow the same layout, including the placement of pneumatic dispatch stations, supply storages, and so on.
- **AGV system** - Extensive and modern AGV system for internal transports. The staff does not order transports; instead, sensors at the pickup positions signal a transport to pick up. When the AGVs leave a delivery in the hallways, the system signals the ward staff by phone.
- **Pneumatic dispatch** - An extensive pneumatic dispatch system for the transport of small goods. When designing the pneumatic dispatch system, the goal was one station per 14 patients. Text messages are used to signal the staff when new deliveries arrive.
- **Industrial robot cell** - Identical robot cell inspired by Case hospital 2 for opening and emptying incoming deliveries at the laboratory.
- **Waste material and laundry** - Chutes for waste material and laundry at each ward. The laundry bags are transported by air pressure directly to the laundry facility in a nearby building and the waste to the waste room.
- **Medicine handling** - High-speed tablet packaging equipment integrated with an automated storage and retrieval system. Automatically prepares all medication to each patient for the next 24 hours based on the prescriptions electronically received. Integrated with the pneumatic dispatch system.
- **Information handling** - Hand computers, cell phones, bar-code system, etc., used for automated communication and information handling.

According to the technical manager, there were several initial problems until all functions ran smoothly (some were still not running properly at the time of observation). Some areas, such as the waste and laundry system, however, were running at full pace earlier than expected. The manager of the Service and Technology department mentioned that the technology in itself worked well, but there were
problems caused by faulty handling of the equipment/systems. The new hospital, with a higher level of technology than before, also places higher demands on the Service and Technology staff, requiring higher competence and more diverse skill in technology and IT.

**Reflections from Case c1**

One of the questions to be investigated during Case c1 was the following: what improvement areas are there and how could automation be used to improve them? In general, much of the technology used at Case hospitals c2 and c3 would also benefit Case hospital c1. A few possible implementations would be the following:

- **Indication for full dumpsters and roller cages** – Introducing a sensor system indicating when the collecting containers for laundry and waste are full would free up a great deal of time for the transportation staff. This while not having to run back and forth to check when dumpsters are full and avoiding overflow from congestions in the pipes, which causes extra work. The sensor system should be integrated with a communications system that sends signals directly to the transportation staff. This would be similar to the technology used at Case hospital 3 for indicating new arrivals from the AGV and pneumatic dispatch system. A more advanced approach is a track with several carriages that automatically pushes the full container away and places an empty one under the pipe.

- **Small goods and mail handling** – A more extensive pneumatic dispatch system would be a timesaver for both nurses and transportation staff in the transportation of small goods, such as mail, samples and blood. However, it is much more costly and a bigger procedure to install a pneumatic dispatch system in an existing hospital building, in this case with partly low ceiling height and thin inner walls, compared to integrating one from the start.

- **Patient transports** – A better planning system (preferably computer-based) for patient transport, similar to the one in Case hospital C2, would most likely increase the share of transports performed by the transportation department exclusively. Additional and better suited equipment for pushing the beds (that, for example, fit in the elevators) would also improve operations.

- **Internal communication and planning** – A better system for internal communication between the transportation staff (through the use of hand computers, for instance) would reduce unnecessary travel to pick up new orders, making it possible to better plan tasks and more efficiently use the staff.

- **Handling of packages** – A software system integrated with barcodes and barcode readers would both decrease the amount of manual handling and increase the possibility to trace goods using less effort.

- **Lifting aids for laundry and waste bags** – The physically straining handling of laundry and waste bags could be relieved with the help of automatic lifting...
equipment or even manual lifting aids. The equipment would be used when transporting the bags and lifting them to throw them down the chutes.

**Reflections from Case c2**

The question during Case c2 was: how can and should automated improvements of hospital internal logistics systems be structured? The process of planning and building the new future hospital involves a massive amount of work and parameters to take into consideration. It is of great importance that all functions, including internal logistics, are involved in early phases when designing the new hospital. The hospital has performed an evaluation of the current way of working to identify improvement needs and created a vision for the future hospital internal logistics system. This is most pleasing and, as the Joint Commission (2008) noted, it is important to help the hospital in meeting the future needs of patients and public. One of the sites at Case hospital C2 was a technically advanced hospital when first built, but the fixed solutions made it hard to upgrade, giving a somewhat obsolete solution. Flexibility and scalability must be key aspects when designing new solutions to fit future needs and demands as well.

**Reflections from Case c3**

For a hospital that calls itself Europe’s most modern hospital, Case hospital c3 has a low degree of entirely new technology. The overall level of automation is high. However, the hospital’s uniqueness is more related to how they managed to combine a large number of existing technologies and the comprehensive view when creating this hospital. By building a new facility, all aspects could be integrated together from start to best suit the demands.

Case hospital c3 performed a benchmarking of other hospitals that inspired many of the applied solutions. Now that same hospital has embraced the role of “role-model” which is manifested in hosting many visitors, exhibiting openness in showing the hospital to the public and revealing problems they have experienced. This benefits the development of the healthcare sector, as there are valuable lessons to be learned and technology to be adapted from others. In the design phase, building constructors, nurses and other functions were involved to discuss layout and function. It is very important and beneficial to gather opinions, ideas and knowledge from many different functions and levels (both inside and outside the organisation) when designing new internal logistics systems.

**4.3.2 Conclusions**

Besides the more case-specific reflections on the logistics activities, a few general problem areas and success factors regarding improvement work and the use of automation in internal logistics systems were discovered. They were related to:

- Division of work
- Overall strategic view
- Setting the target
- Transfer of knowledge
- Ownership
• Physical limitations

Each area is discussed further below.

Division of work
The time study in Case c1 showed that only 30% of the nurses’ time was spent on direct care activities. This was similar to the results from the pre-study performed by Case hospital c3. The result is also in line with the result from previous studies by Hendrich et al. (2008) and assessments from other Swedish hospitals (Johnreden, 2003; Elmfeldt and Kardbom, 2009). The majority of the nurses’ time is spent on indirect care activities, often connected to logistics. Many of these activities are not the core competence of the nurses. As such, these tasks should be transferred or assigned to the transportation department, for instance, or another in-ward service position that can carry out non-patient-related tasks. This measure, combined with the use of automated solutions, would free nursing time for patient-related activities, a more efficient way of using the resources.

Overall strategic view
There is a lack of overall strategic responsibility of the healthcare process, including the technology management of internal logistics. Each ward is individually responsible for its own budget, but is left with basically only one way to control the expenses: the level of staff. The visionary views of the future hospital articulated in Case c1 interviews were quite modest, with only small details differing from the current situation. It is important to complement the ideas and suggestions from the staff that works in the processes, as found in Case c3, with the strategic overview of the whole hospital, as seen in Case c2.

Setting the target
Studies have shown that small hospitals in particular are less often involved in quality improvement (Chow-Chua and Goh, 2000). However, there are well-documented methods for development work, often originating from the manufacturing industry, that have proven to be useful also in the healthcare sector (Swedish Association of Local Authorities and Regions 2009). One success factor found in both Case c2 and c3 is that the hospitals, when planning a new hospital, evaluated the current way of working and used it to set targets for what they desired to change. Case hospitals c2 and c3 also had different kinds of goals for the new system, whether it related to the degree and types of automation or the ownership of it and the logistics function.

Transfer of knowledge
There are a number of automated solutions and aids available for hospital activities today. Case hospital c3 spent a great deal of time benchmarking others to find available solutions and systems for their new hospital. Other lines of business can also be an inspiration, since the internal logistics supply chain is fundamentally the same as that in the trade sector or industry, for example (Jarrett, 2006; Arvidsson, 2007). In many aspects, the state in healthcare similar is to the state in the manufacturing industry a decade ago regarding organisation and technical adaption. The main issue is not the
lack of available technology and role models. Instead, it is how the knowledge is transferred and how to adopt the knowledge and technology to best suit demands and needs.

Ownership
During the study, the aspects of ownership and the lack of clear responsibility for new, especially long term, automation investments were revealed. As internal logistics is often an outsourced function, no one takes strategic responsibility for developing it. However, it is clear that hospitals need to focus on the management of the internal supply chain to maximise service levels, as Pan and Pokharel (2007) point out.

Physical limitations
Comparing Case hospital c1 with Case hospitals c2 and c3, it is evident that available automation technology and ways of working exist that Case hospital c1 would benefit from. Apart from the improvements suggested above, an AGV system would yield a much more flexible transportation plan. It would not be limited to available human work power and would allow more frequent deliveries both night and day time (Özkil et al., 2009). However, the physical structure of the hospital is a limitation when trying to adapt new technologies (such as AGVs) in old buildings that have steep inclines/declines in culverts and narrow elevators, for example. This is one reason why, despite mature technology, it is still a costly investment.

4.4 Study D
Study D was an exploratory case study aimed at increasing the awareness of automation and how it can be a means to develop and improve operations at new users and be used in activities and environments not traditionally associated with automation. Thus, the objective of the study was to develop an automated solution for the case company’s specific needs and demonstrate it at an open event.

4.4.1 Results
Study D was conducted at a small manufacturer of quality food products, mainly different types of marmalade. The case company production is dominated by craftsmanship, with small production series and a yearly production of about 50,000 jars of marmalade. The company has two full-time employees. However, since the production volumes are seasonal, with production peaks, for example, before Christmas, the workforce is often reinforced with extra staff. The motivation for this study is an anticipated and large increase in production volumes their current production method and system could not handle.

Study D was realised through three phases: a two-step feasibility study, a solution development phase and an implementation phase. The results from the different phases are described below.

The first step of the feasibility study aimed at investigating how a future expansion could be achieved at the case company in reaction to increased production volumes. The main recommendation from this study consisted of implementing automation to ensure
the company’s ability to meet future customer demands. The second step of the feasibility study, therefore, started in order to examine how parts of the production process at the company could be automated.

The case company’s needs were analysed, and factors important to consider were listed. The most important features were that the future solutions should:

- Preserve the craftsmanship by keeping the actual making of the marmalade manual, since it was part of the trademark
- Be appropriate for the fast changing and seasonal demands, with temporary peaks
- Focus on simplicity and usability, since the solution was to be handled by staff without previous experience and knowledge of automation

A mapping of the production process was made, and the results showed that the three steps identified as having most potential for automation were: sealing of filled jars, cooling of filled jars, and the labelling of the filled and cooled jars. With automation, the long cooling time could be eliminated, as well as the high precision, time-consuming manual labelling. Further, and perhaps most important for the employees, the repetitive and ergonomically unsound activity of sealing the jars could be removed.

Further, the Factory-in-a-Box concept was chosen as an appropriate approach. The Factory-in-a-Box concept was developed as part of a three year research project started in 2005. The overall vision of the project was to realise the concept of mobile production capacity on demand (Hedelind et al., 2007). There are several potential applications of mobility within manufacturing systems. For example, (Ask and Stillström, 2006), it can be applied to:

- cover occasional production volume peaks
- reach new markets
- share investments in equipment between plants or companies
- demonstrate equipment
- cover temporary disturbances in supply chains
- lease equipment to 3rd parties

Based on the results from the feasibility study, the project’s development phase of the solutions started. The final solution was an industrial robot automation cell developed to perform the above selected steps in the production process. Figure 7 shows a 3D overview of the final robot cell.
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- Cover temporary disturbances in supply chains
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Figure 7 Overview of the solution (created by Erik Hellström)

Some of the most important features of the cell were the following:

- Mostly standardised equipment was used in the cell to enable reuse for other purposes. The use of an industrial robot keeps the cell flexible since its range of possible applications is vast and new tasks can easily be added.
- The user interface, on a PC-screen, was made as simple as possible to enable the easy handling of the cell even for people unfamiliar with industrial robot systems. For example, a touch screen was used to manage start/stop and the choice of labels.
- Parameterised programming was used to make it easy to change the programming and the cell behaviour (for example, to change the type of jar or the batch size).
- The cell's small size and light weight made it possible to be portable. The robot was placed on a platform that, because of its weight, does not need to be secured to the floor. The small size of the cell (2.8 m × 1.9 m × 2.0 m) also enables it to fit in many environments, a requirement if the cell were to be leased to different customers.
- Wireless sensors were used to provide as few cables as possible and to allow the easy installation and reconfiguration of the cell.

In the implementation phase, the resulting solution was demonstrated at an event in a lab environment at Mälardalen University in Eskilstuna, Sweden.
The solution implications for the case company

The main benefits of the suggested solution for the case company are that it:

- Allows them to concentrate on their core competence, making marmalade, while keeping the trademark of craftsmanship
- Shortens their lead times by performing the tasks faster and eliminating the long cooling time
- Increases production capacity
- Improves the work environment for the employees

Since the suggested solution follows the Factory-in-a-Box concept, the idea is that the case company can lease the robot cell when needed. With the Factory-in-a-Box solution, the case company will benefit from the desired extra production capacity during the peaks in production volume without the extensive cost of a fixed automation solution or investing in an industrial robot of its own. The focus on simplicity in the suggested solution also enables the fast ramp up of production volumes when new orders are being placed, one of the case company’s main requests.

4.4.2 Conclusions

The main object of this study was to show one possible way of using automation as a means for improvement. This study in the same time targeted several of the problems discovered in Study A (one example concerned how to decide on the most appropriate solution). In this study, much time was spent on the careful mapping of the current situation and the needs and requirements to have a base of aspects to evaluate different solutions on and hence to find an appropriate solution for the given circumstances.

The given solution also focuses on simplicity to avoid overly complicated solutions and facilitate ease of use. Many companies in Study A expressed concerns regarding the ability of the staff to handle automated equipment. Standard components and an industrial robot with a wide spectrum of possible applications were used to overcome the fear of automated equipment not being flexible.

Finally, the Factory-in-a-Box concept also addresses the economical aspects of high investment costs and the desire for fast implementation and ramp up. It also functions as a complement to hiring an integrator to develop a company-specific solution. Such hiring is often a long and expensive process involving many potential difficulties, as found in Study A. One example of a difficulty is ending up with overly complicated or poorly suited solutions.
5. A FRAMEWORK FOR DEVELOPING COMPETITIVE INTERNAL LOGISTICS SYSTEMS USING AUTOMATION

This chapter discusses the findings and the results of this research and their implications connected to the research objective and questions. Critical factors for obtaining competitive internal logistics systems are proposed, as well as a way to assess the logistics performance. A structure for the development of an internal logistics strategy and a framework for an improvement process of internal logistics activities using automation are also proposed.

The main objective of this thesis has been to contribute to an increased understanding of how automation can be used to develop competitive internal logistics systems. In order to reach the conclusions necessary to build this knowledge, several aspects need to be addressed and discussed. Based on the theoretical review and the empirical results the following areas have been identified as important and relevant to discuss in relation to the stated objective and research questions:

- Critical factors for creating competitive internal logistics systems
- The meaning of competitive internal logistics and ways to evaluate logistics performance
- Ways of identifying improvements in the internal logistics system
- An approach for how to use automation as a means to improve internal logistics systems
- Implications and challenges regarding the use of automation in internal logistics activities

The respective areas are discussed and dealt with in the following five sections.

As mentioned in Section 2.2, this research was related to designing competitive internal logistics systems. A general feature from the results and conclusions from the empirical studies is that many companies experience difficulties in the early phases of systems design. Many of the problems identified are also related to the basis of systems design, strongly affecting the companies’ possibilities to successfully design and improve their internal logistics system. Consequently, the following discussions will mainly concentrate on the conceptual level of designing and improving internal logistics systems, with a focus on basic requirements that need to be fulfilled in each area discussed. The overall aim of the chapter is to propose a framework for the development of competitive internal logistics systems.

5.1 From critical factors to internal logistics strategy

In answering research question one, several critical factors needed to be considered when creating a competitive internal logistics system were identified and analysed. However, during the research the need for an internal logistics strategy that includes all these factors emerged and hence are these factors presented below, in form of being included in a structure for an internal logistics strategy.
In the presented frame of reference, the importance of a logistics strategy clearly emerged. It was concluded that such a strategy was a very important factor for the development of internal logistics systems. The importance of an overall business strategy is understood in industry. However, there is also a need for functional strategies for specific parts of the organisation, such as production, maintenance and logistics. Unfortunately, one of the main results from the survey in Study B (presented in Section 4.2.1, Vision and strategy) was a lack of vision and strategy for internal logistics systems. This presents many difficulties, such as no base for:

- Internal logistics goals in terms of performance
- Strategic goals and plans for development
- Developing performance measurement systems
- Improvement motivations
- Requirement specification for improvements
- Evaluation of improvement suggestions/solutions

Hence, an internal logistics strategy is one of the most critical factors and requirements for achieving competitive internal logistics systems. However, as concluded in the frame of reference, there is weak support for how to develop a logistics strategy. Therefore, a base for an internal logistics strategy is proposed below, and schematics for the hierarchy of the internal logistics strategy can be seen in Figure 8. The formulation of the upper parts of the schematics is based on the findings from the theoretical findings, while the content on the lowest level is created based on the empirical findings.

**Figure 8** Schematics of the internal logistics strategy hierarchy

In Section 3.3.3, the basis of a logistics strategy was discussed. As stated by for example Tan (2007) and Jonsson (2008), it is of utmost importance that the logistics strategy is integrated and aligned with the organisation’s other functions and strategies. As illustrated in Figure 8, an internal logistics vision should therefore be derived from the overall business mission. The vision should reflect not only the overall business strategy
and goals, but also the essence of the internal logistics focus for the company. From the internal logistics vision, an internal logistics strategy should be formulated. The internal logistics vision and strategy are both influenced by, as well as they influence other functional visions and strategies in the company.

According to Harrison and van Hoek (2008), a strategy should include plans (both long and short term) and integrate the company’s goals and policies. Based on this, together with the empirical findings, the author suggests that the internal logistics strategy should be based on three main parts:

- **Success factors** - which are basic functions, features, deliveries and factors affecting the internal logistics operations and, hence, need to be fulfilled and work correctly to ensure desired system performance.
- **Performance goals** - which specify which performance criteria are most important and how important certain aspects and resources are compared to each other.
- **A development plan** - which specifies how the internal logistics system should be developed and systematically improved.

Thus, the internal logistics strategy and its sub-parts form an important basis for all decisions concerning the strategic and operative development of internal logistics operations. The three sub-parts are discussed separately below.

**Success factors**
The first part of the strategy aims at identifying all success factors, in other words, basal functions, aspects and features necessary for the overall function of the logistics system. When identified, guidelines and instructions for how these areas are supposed to work should be developed to ensure a standardised and correct way of working. The results from Study B (Section 4.2.1, Success factors) proposed some generic categories for success factors:

- System performance features, such as on-time deliveries and short lead times are necessary to ensure a continuous flow without hold ups and unnecessary idle time.
- Information is not only one of the main flows constituting logistics, but also an enabler for all logistics activities. Well-functioning, updated, dependable, and supportive information systems is therefore one of the main success factors.
- Well-functioning logistics processes are necessary to enable a balanced flow without disturbances.
- The commitment and responsibility of the humans working in the system was one of the most prominent success features not well-covered in literature.
- Planning, both short and long term, is vital to make sure that the processes are adjusted to the given circumstances and systems and the people working in them are always updated.
- Organisational aspects, such as clear roles, responsibilities and work instruction, guarantee that processes run as intended.
The success factors, together with the performance goals, should work as guidelines when allocating resources in the logistics system to the most important functions.

**Performance goals**
The second part of the strategy, the performance goals, have many similarities with the success factors. However, they aim at finding the most important aspects and criteria for success and competition; hence, they are more company-specific than the success factors.

As presented and discussed in Section 3.2.4, a vast number of performance criteria exist that can be considered when deciding upon the performance goals for the logistics. The emphasis of this part of the logistics strategy is that the performance goals should state what aspects are of most importance to the company and how important different aspects are in relation to each other. Therefore, all companies need to develop their own unique set of performance goals that reflect the logistics vision. As concluded and practiced in Study D, the performance goals are also influenced by and should reflect the organisation's:

- Line of business
- Overall mission and strategy
- Long and short term goals
- Core competence
- Core values
- Competitive climate and strengths
- Customers' requests and needs

Even though the performance goals are unique to each organisation, the results from Studies B and C show some general trends:

- Different aspects of delivery performance are of the highest importance, especially in the manufacturing industry.
- The service degree towards the customer is more and more recognised as a base for finding a competitive edge.
- The robustness of the logistics system and balanced flows is very important, and is often one of the main concerns during improvements (i.e., fear of obstruction) both in the healthcare sector and in the manufacturing industry.
- There is a strong trend that the logistics focus is shifting from cost driven to other performance aspects.
- Ergonomics, staff safety and work environment is the one of the performance aspects that is starting to come more and more in focus as a step in achieving sustainable processes.

As concluded in Section 3.2.2, the performance goals should form the basis for developing a performance measurement system since the criteria and aspects of importance need to be followed up on as well. The performance goals should also help identify areas for improvement, since they help direct attention to the most important
aspects to consider. Thus, they also work as guidelines when evaluating and deciding on the most appropriate improvement solution.

**Development plan**

As discussed above, a strategy should not only include goals but also a plan for how to reach them. The third part of the proposed strategy structure, the development plan, should cover development approaches and development goals for the internal logistics system.

In Section 3.3, several important aspects to consider when designing and improving internal logistics systems were presented. The results and conclusions from Studies A and C, also highlighted several potential problems that can occur when conducting improvement work due to the lack of a development plan. Based on these findings, it was concluded that areas the development plan should include are:

- An approach regarding the use of technology, for example, an automation strategy for logistics connected to the overall automation strategy for the company. The automation strategy should cover what level of automation is desired in terms of higher or lower than the current state, whether certain types of automation are preferred, other requirements regarding technology, or the implementation and maintenance of automated equipment.
- An approach regarding the desired way of working with improvements, such as continuous improvements or radical changes. This affects how improvements are initiated and on what grounds.
- Responsibility, in terms of who is responsible for the strategic versus operative development of the logistics system or its sub-parts. This should include decisions regarding who should be involved during the improvement work (e.g., conducting the improvement work internally or consulting/hiring system suppliers, consultants) for certain steps in the process.
- Ownership, connected to the responsibility for especially long term improvement measures. It should be clear who the owner of potential new equipment is and who is responsible for operating, managing, and maintaining it.
- Benchmarking, information gathering or other approaches regarding how to find potential improvement areas or solutions.
- Economic aspects, such as a budget for developing and maintaining the logistics systems.
- Plans for how the logistics operations are controlled in terms of how often measurements are performed, how the measurements are followed up, evaluated, and so on.

**5.2 Competitive internal logistics**

An important part in answering the first research question is to explain what characterises competitive internal logistics and how the performance of internal logistics systems can be evaluated.
The view that emerged during this research is that competitive internal logistics systems are mainly characterised and can be defined as high performing internal logistics systems. Based on the conclusions in Section 3.2.1, logistics performance is in turn defined by and evaluated based on not only what the system delivers from its input in relation to the organisations goals of the system but also the context the organisation is active in. This is illustrated in Figure 9, which is inspired by O’Donnell and Duffy’s (2002) illustrations of efficiency and effectiveness. One of the main differences in Figure 9 compared to O’Donnell and Duffy’s (2002) illustrations is the view of resources. Since the applied view of the internal logistics system (presented in Section 3.5) includes the resources as a part of the internal logistics system there is no separate arrow for resources into the system.

Hence, high logistics performance is reached through a combination of:

- High effectiveness (in other words, doing the right things in relation to the performance goals dealt with in Section 5.1).
- High efficiency (i.e., things are performed in the right way in relation to the goals).
- High performance in relation to the rest of the company, competitors, customer expectations, and other external demands and pre-requisites.

The last point above is important since the level of competitiveness is a factor that is both affected by internal actions and highly dependent on what others do and perform.

The goal is to achieve a sort of internal supply chain where the key success factor is to view internal logistics as a system in itself that is also connected to the rest of the organisation and its surroundings.

![Figure 9 Internal logistics performance, inspired by O’Donnell and Duffy (2002)](image-url)
5.3 Improvements in internal logistics systems

The main objective of this research was connected to improving internal logistics systems using automation. Hence, internal logistics improvement work in general was one important aspect to cover during this research.

Based on Frazelle’s (2001a) methodology for improvement work (presented in Section 3.2), an improvement potential or improvement area in general can be seen as the gap between the current and desired states, as illustrated in Figure 10. The view of the current state can become known by mapping the activities and measuring performance. However, what emerged during Study B was that many have insufficient insight into the current state of their logistics operations. This is mainly because many do not measure or follow up on the system and its performance in a satisfying way (Section 4.2.1, Performance measurements). Further, the desired state is influenced by the logistics strategy and experiences from studying competitors or role models. Since it was evident from the empirical results (from Study B) that most do not have a logistics strategy, many also have a poor view of the desired state of their internal logistics system. These two factors are both challenges when it comes to improving internal logistics systems since they present difficulties in properly identifying and motivating improvements.

5.4 Improvements using automation

The empirical findings from Study A (presented in Section 4.1.1) and Study C (presented in Section 4.3.1) showed that there is existing automation technology available, suitable and today used in internal logistics. The main key to successful implementation, however, lies in finding the most appropriate type and level of automation to suit the needs, requirements and pre-requisites of the organisation, as practiced in Study D. As support for this, a framework for an improvement process of logistics activities using automation was, based on both the theoretical and empirical findings, developed.

The framework is inspired by Baker and Halim’s (2007) schematics of a typical warehouse automation project, combined with Frazelle’s (2001a) methodology for logistics improvement work. The development method used for creating the automated solution in Study D has also provided experiences and hence a base for the framework. The framework further aims to address the difficulties and challenges in using automation that emerged during the empirical studies. The aim of the framework

![Figure 10 Internal logistics improvement potential](image-url)
is to support companies considering automation as a means for improvement of their internal logistics system. The framework is illustrated in Figure 11 and the different steps in the process are further described and discussed below.

**Figure 11 Framework for improvement process using automation**

**Initiation/current state**
There are several ways an improvement project can be initiated, and many are related to each other. Some of the most common ways are through:
- Evident problem(s) in operations
- Identifying a possible improvement area
- Striving for continuous improvements
- Not fulfilling performance goals

Irrespective of the cause of initiation, in this step it is important to carefully assess the current state of the identified improvement area (i.e., the left side of Figure 10). This means to, through mapping, measurements and analysis identify the following:
- How activities/actions in the improvement area are carried out today
- Diagnosing the operations, in order to identify the root causes of the problem (if appropriate)
- The current performance related to the improvement area

Requirements/desired state
During the second step, the right side of Figure 10 is in focus (i.e., identifying the desired state for the identified improvement area). The requirements should be based on the internal logistics strategy to ensure that the improvement measures help develop the organisation in the desired direction. Thus, the requirements can be related to specific performance goals that should be reached after improvement measures. They can also be related to the development plan in terms of the preferred use of technology or a desired way of working with improvements and aspects, such as a budget for the improvement work.

Improvement options
Different approaches for how to reach the desired state and how to undertake the improvement work should be analysed. Further, various types of solution options should be identified and evaluated based on the requirements made clear in the previous step. One possible approach is the use of automation technology. Alternatives can include other types of technology, work methods for organisational changes, systematisations/improvement tools etc. The focus in this step is not on identifying specific solutions; instead, it is on distinguishing different types of solution/improvement means and evaluating them in relation to the requirements.

Decision Gate 1 (DG 1)
The first decision gate involves choosing the improvement approach expected to provide the best result. The following steps in the described process are based on the decision that automation is chosen as the improvement means.

Requirement specification
When automation has been chosen as the means for improvement, it is necessary to develop the requirement specification for the future solution. This specification should be more detailed and specific than the requirements specified in the second step of the process. However, it should still be based on the internal logistics strategy. Examples of areas the specification should cover are the following:
- What activities/functions/goods the solution need to and/or is desired to handle/perform
- Performance requirements
Development of solutions
During this step, potential solution suggestions should be developed and potential system/equipment suppliers should be investigated. Connected to each solution should be an investment calculation and an action plan for how the solution is to be implemented. Whether all necessary competence exists within the organisation or if there is a need for hiring or using consultants for specific tasks should be assessed.

Solution evaluation
All solutions developed during the previous step should be evaluated on the basis of the requirements and pre-requisites specified in previous steps. Potential risks should be assessed and taken into consideration.

If none of the solutions are considered to fulfil the requirement, there is a need to go back to step 2 or 4 to make sure that they are correctly assessed and then continue with the process once more.

Decision Gate 2 (DG 2)
The solution that best fulfils the requirements, provides the highest payback and potential benefits, and matches well with both the logistics strategy and the overall business mission and goals should be selected.

Implementation
If the selected solution involves extensive changes in the organisation and its way of working, a thorough implementation plan should be developed. The selected solution should be installed according to the plan and tested to ensure satisfactory function before put into full use. Necessary training for the staff handling the equipment should be take place, and a maintenance plan should, if necessary, be developed.

Follow-up evaluation
The implemented solution, as well as the improvement project, should be evaluated, not only to provide knowledge and experience for future projects, but also to be able to make necessary corrections.

5.5 Challenges for using automation in internal logistics activities
During Study A (Section 4.1.1, Way of working with improvements), it emerged that the tasks corresponding to steps 4 and 5 in the developed framework in Figure 11 was perceived as difficult. The most probable explanation for this is the lack of knowledge of and experience with automated equipment and, hence, a lack of understanding of:

- what is possible to solve with automation
- what expectations/requirements are realistic
- what alternatives and possible solutions there are
One way to overcome these obstacles is through benchmarking and networking, which increases the knowledge of potential applications and ways to use automation. Another approach is to enlist the help of experts by hiring consultants or turn to system suppliers or integrators for help. There are, however, difficulties associated with relying too heavily on a third party: there is a strong need for a certain degree of competence within automation to be able to properly perform the different steps in the process to ensure a satisfying and suitable outcome.

Difficulties in step 5 regarding indentifying possible solutions are also related to the automation technology and the needs for suitable, flexible and to some extent standardised solutions that are ergonomically justifiable. Study D indentified several potential ways to fulfil those needs by:

- using technology and lessons from other lines of business
- developing solutions that are flexible but still easy to use
- exploring new ways of supplying automated technology

During the Study A and C, several typical and reoccurring application areas for automation in logistics came to light. It should therefore be possible to develop some form of standardised but scalable solution for generic tasks where the adaption of the solution only involves adjusting it depending on the needs of the company.

The automated equipment in itself was also experienced as complicated and difficult to handle (Section 4.1.1 Automation of logistics activities – extent and difficulties). For logistics in general, the competence of the workers was considered both a large success factor and the most critical resource (Section 4.3.1). In addition, the lack of competence in handling automated equipment was one of the most common reasons for not automating (Section 4.1.1 Automation of logistics activities – extent and difficulties). There are two ways of examining this problem and finding ways to overcome it: either the worker competence and knowledge of automation must increase or the automated equipment must be made more available and easier to handle.

Overall, there are many potential areas of application for automation in logistics activities. Further, in both Study A (Section 4.1.1 Improvement areas and their causes) and Study C (Section 4.3.1 Case hospital c2: Current state and future hospital logistics and Case hospital c3: Development, solutions and initial problems) there were good examples of how automation had improved the competitiveness for the company/hospital. One of the main reasons for and driving forces behind implementing automation in logistics was identified as being connected to ergonomics and staff safety. This is not fully reflected in the literature, where primarily efficiency and cost cutting are brought out as the key motivations. The reason for the focus on ergonomics can be assumed to be related to two realities. First, the fact that logistics activities often involve a large amount of repetitive manual handling. Second, a shift in focus from only cost to other performance criteria and aspects is beginning to take place.
Finally, as emerged Study A (Section 4.1.1, Way of working with improvements), step 6 and decision gate 2 in Figure 11 (evaluating and deciding on the most appropriate solution) was also considered difficult which to a large extent is caused by problems and difficulties in performing the previous steps in the improvement process. It also depended on the lack of strategy and, hence, not having anything to evaluate and base decisions on. One condition for a successful outcome when using the suggested improvement process, therefore, is that a developed internal logistics strategy exists that can function as a base for, and provide input to the improvement process, as illustrated in Figure 11.
6. CONCLUSIONS, CONTRIBUTION AND FUTURE WORK

This chapter presents the overall conclusions and contribution from the research presented in this thesis. Further, the fulfilment of the objective and research questions is discussed, as well as the quality of research. The chapter concludes with a discussion of possible future research topics.

6.1 Conclusions

The main objective of this thesis has been to contribute to an increased understanding of how automation can be used to develop competitive internal logistics systems. A theoretical frame of reference has been presented in order to provide a theoretical foundation for the research. Further, four empirical studies have been performed to investigate how companies perceive and work with their internal logistics systems, specifically in terms of improvements using automation. The empirical studies also aimed at identifying and describing how they could benefit from automation. The main conclusions from these theoretical and empirical studies are summarised below.

From the theoretical review, a description and definitions of the main characteristics of the internal logistics system were presented. Different aspects of logistics performance were introduced and discussed, and the importance of performance measurements was made evident. Steps and aspects to consider in the process of designing and improving internal logistics systems were also presented. Based on the frame of reference, a need for more knowledge was identified relating to the development of performance goals, what design, improvement and automation decisions should be evaluated and what those decisions should be based on.

Study A investigated the way of working with improvements of internal logistics systems in industry, especially with regards to automation. The study concluded that there is a low degree of automation invested in internal logistics systems in industry. Still, there is a need for, and a great potential of, using automation to improve and solve problems within internal logistics systems. Many companies encounter the same types of problems that could be solved with standardised automated solutions. However, they lack the knowledge to be able to identify possible applications, pinpoint the most appropriate solutions, and, to some extent, use them properly. The case companies very much depend on system suppliers help to improve their operations. Nonetheless, the lack of pre-requisites for and competence in defining requirements and evaluating automation solutions sometimes results in poorly suited solutions.

Study B was a survey study with the aim of showing how industry works with and perceives their internal logistics systems. The study identified important success factors, performance criteria and critical resources. Current improvement areas within internal logistics systems in industry were listed. However, it was found that these often poorly correspond to the factors and criteria experienced as most critical for success and
competition. This was concluded to be related to the fact that few companies measure and follow up logistics performance; as a result, they are unaware of the current situation. It was also made clear that many companies do not have anyone strategically responsible for operating and developing their internal logistics system, and few have a formulated logistics vision or a strategy. In addition, a trend was discovered regarding a shift of focus for internal logistics, from the traditional financial focus to other performance features, such as ergonomics and staff safety. The general conclusion from this study is that a need for more focus and attention to internal logistics systems as strategic tasks exists and a better understanding of the system and its performance will help improve its efficiency and effectiveness.

Study C was a multiple case study that investigated automation within internal logistics as a means of improving efficiency and supporting the value-adding core processes in the healthcare sector. The study showed several potential ways to use automation in order to improve internal logistics operations and increase direct patient care time. The study concluded that the main key to successful automation implementation lies in finding the right type and level of automation to suit the organisation's needs, requirements and pre-requisites. However, organisational issues such as a lack of ownership and a lack of a strategic view present difficulties and need to be dealt with. Another conclusion from the study is that transfer of knowledge and technology used in manufacturing industry would be beneficial.

Finally, Study D was an explorative case study that addressed several of the problems related to improvements made using automation. The study included a careful mapping of the current situation at a specific company. The mapping in turn included specification of the pre-requisites, needs and requirements to establish a base for evaluation and decision regarding most appropriate and economically justifiable solution. The end result demonstrated possible ways of using automation by including technology and lessons from other lines of business, employing easy-to-use yet highly flexible equipment, and a new way of supplying automated technology.

6.2 Fulfilment of objective and research questions

The objective of this research, as stated in Section 1.2, was to “contribute to an increased understanding of how automation can be used to develop competitive internal logistics systems”.

The importance of performance measurements and being aware of the current state of internal logistics performance is highly stressed as one of the basic elements that needs to be fulfilled before conducting improvement work within internal logistics systems. Further, one of the main overall conclusions from this research is the need for an internal logistics strategy that includes goals and plans for the operation and development of the internal logistics system. As a result of the research, a structure for the development of an internal logistics strategy was developed and presented in Section 5.1. An eight-step framework for conducting an improvement process in internal logistics using automation was developed and presented in Section 5.4.
The objective of this thesis can be considered fulfilled by answering the research questions posed in Section 1.3. The two questions and a summary of their respective answers are presented below.

**RQ 1: What critical factors need to be considered when creating a competitive internal logistics system?**

The concept of competitive internal logistics systems was defined in Section 5.2, along with a description of how to assess the internal logistics performance.

Success factors and critical resources were investigated and listed in Study B. Different types of performance features were covered through the literature review, and the importance of the different performance criteria was also ranked in Study B.

During this research, it became apparent that the critical factors that need to be considered are highly individual to each company, due to their context. Based on the results and findings from Studies A, B and C, it was concluded that the main success feature for developing competitive internal logistics systems is an internal logistics strategy that considers and states the needs, goals and plans for each organisation, based on that organisation's business mission, vision, individual pre-requisites and aims. The presented structure for a internal logistics strategy involves several critical factors and aspects to be considered and included to make the strategy comprehensive, and thus improve the chances of achieving competitive internal logistics systems.

**RQ 2: What challenges are there to using automation as a means of improving internal logistics systems?**

During Studies A, B, and C, the lack of insight and awareness of both the current state and the desired future state was identified as a major challenge for conducting successful improvements of internal logistics systems. Further, the lack of knowledge of and experience from working with automation technology presents difficulties for seeing the potential uses of automation, finding alternative solutions, specifying reasonable requirements, and evaluating and choosing the most appropriate solution. The lack of logistics strategy was considered to be strongly related to and also an underlying reason for several of these challenges.

During Studies B and C, the lack of strategic responsibility for the internal logistics system and unclear views of ownership for new investments emerged as challenges for improvements. The internal logistics system's possibility to create a competitive advantage is not fully recognised. In order to achieve this, the internal logistics system needs to be viewed and developed as a strategic task.

Several specific challenges with automation technology and the use of it were identified and listed during both the literature study and Studies A and C. Ways to solve several of these challenges were identified and demonstrated during Study D.
6.3 Research contribution
The research presented in this thesis is of applied character expected to generate both a scientific contribution to the research community and a practical contribution to solving the industrial problems targeted. The main contributions made by the author are presented below.

6.3.1 Scientific contribution
This research has focused on the area of internal logistics systems. It contributes to logistics research by defining the internal logistics system and its parts and relationships. The research also offers new insight into the area of systems design by identifying critical factors and challenges for the conceptual design of internal logistics systems.

The use of automation within logistics is not well-explored, and what has been written on the topic is mostly connected to extensive automation projects in large warehouses. Therefore, this research contributes new perspectives by focusing on the challenges and pre-requisites of SMEs and the healthcare sector. The application areas studied in lines of business not traditionally connected with automation (but which both are in need of and are starting to work with automated solutions), also offer new insights into automation research.

The research includes a demonstration where new ways and concepts for making automation available for new applications and new users were tested. The demonstrated solution, which was developed in close collaboration with industry and tested results from the research, provides not only valuable practical insight but also input to available theory and literature.

6.3.2 Practical contribution
This research has been focused on providing a practical contribution that facilitates the development of internal logistics systems using automation. The research has pinpointed several features necessary for successful improvement work that aim at helping logistics developers in their work. The research has generated a structure for developing a logistics strategy that seeks to provide guidelines for how a strategy can be developed and what it should include.

An eight-step framework for how to conduct an improvement process in internal logistics using automation was also developed. This was done to support development work and increase understanding of how organisations should work with automation to ensure suitable, successful solutions. The demonstration conducted within this research also aims to inspire and spread knowledge regarding possible applications of automation in non-traditional environments and tasks.

6.4 Quality of research
There are many possible ways to assess and evaluate the quality of a performed task, in this case the research undertaken. The aim of this research was to create increased knowledge in an area that had previously been explored only to a limited extent. Further, as described in Chapter 2, the research was primarily of a descriptive nature
and mainly based on qualitative data. It is therefore difficult to measure or compare the outcome of the research with any pre-formatted goals. Therefore, the best way to evaluate the research might be not to focus on the results, but instead on the research process.

In Section 2.4, the ways in which the author has sought to assure the quality of the research are presented, related to:

- Choice of methods and approaches
- Sampling and selection of study objects
- Ways to collect, document and treat data
- The author's role

Possible critique of this research might be related to:

- The number of empirical studies, which might limit the ability to generalise the results
- The author’s interpretations of the studied phenomena and collected data, which influence the conclusions drawn and hence the results
- The choice of studies and methods for data collection

The ways of dealing with these potential weaknesses are also discussed and presented in Section 2.4.

6.5 Future work

During the research process, several potential areas for future research work were identified. Some of these are described below.

**Formulation of internal logistics strategies**

The importance of an internal logistics strategy was made evident during this research, and a structure and procedure for developing such a strategy was proposed. There is a need to develop this structure further and to verify/test it for further adjustments. This could be done through a prescriptive study, which is the next step in the DRM framework.

A possible study in this area could include two parts. The first part would include analysing current logistics strategies, what they include and how they were developed and evaluate how well they work and how they are used, etc. The second part would include any necessary revisions of the developed structure and then testing the structure by creating (and possibly implementing) an internal logistics strategy for a case company.

**Framework for automation selection**

During the research, it was made clear that many companies have difficulties identifying and selecting an appropriate automated solution for their internal logistics. Therefore, a framework for how to conduct an improvement process in internal logistics using automation was developed. In similarity with the previous area, there is a need to test and further develop this framework in a prescriptive study.
This potential direction of research could with benefit be combined with the previous described areas of formulation of internal logistics strategy since a strategy is needed for a well functioning framework for automation selection.

**Best practice of automation in internal logistics**
Finally, since the knowledge regarding the use of automation in internal logistics is limited, it would be useful to find an organisation that could be a role model regarding both actual implementations and the way of working with automation. The study would be used for two reasons: to spread knowledge about potential uses of automation and to further identify enablers for the successful use of automation in internal logistics.
REFERENCES


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