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FACILITATING AUTOMATION DEVELOPMENT IN INTERNAL LOGISTICS SYSTEMS

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som för avläggande av teknologie doktorsexamen i innovation och design vid Akademin för innovation, design och teknik kommer att offentligen försvaras torsdagen den 13 februari 2014, 10.00 i Raspen, Smedjegatan 37, Eskilstuna.

Fakultetsopponent: Professor Mats Johansson, Chalmers Tekniska Högskola

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Abstract

The internal logistics system includes all activities connected with managing the flow of materials within the physical limits of a facility. This system is an important part of operations in need of increased focus and continuous improvements. Automation is one possible tool with a previously confirmed great potential to improve internal logistics. Despite this great potential and a growing trend of using automation in the area, internal logistics activities are still not automated to the same extent as other parts of operations. The overall aim of this research is therefore to develop knowledge that supports the successful use of automation in internal logistics systems.

The automation development process has been identified as critical for the success of the use of automation. With the overall aim of the research in mind, the objective of this thesis is to develop a framework facilitating the automation development process in internal logistics systems. To help fulfil the objective, empirical data have been collected through five case studies and a survey study. During the empirical studies, the process of improving the internal logistics system and the automation development process have been analysed and the focus has been on identifying challenges and facilitators for the successful use and development of automation in internal logistics systems.

The findings indicate a poor awareness of both current and desired performance of the internal logistics system at the companies studied. In addition, automation development is often conducted in an unstructured and poorly supported manner and there is often insecurity regarding what steps and actions to take. Foremost, the findings indicate a poor base for proper evaluation and decisions during automation development in internal logistics systems. This is analysed and concluded as a cause of unclear goals and requirements and the lack of a strategic view with regard to both internal logistics operations and the use and development of automation.

A framework, including proposed guidelines to overcome the observed challenges by including identified factors facilitating successful automation development in internal logistics systems has been developed. The core of the framework is a proposed process model for automation development in an internal logistics context. Due to the identified importance and the lack of a strategy linked to and supporting the automation development process, the framework also includes a proposed model for an internal logistics strategy as well as a proposed model for an automation strategy.

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ABSTRACT

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SAMMANFATTNING

Det internlogistiska systemet omfattar alla aktiviteter som relaterar till hanteringen av materialflödet inom en anläggnings fysiska gränser. Detta system, som är en viktig del av en operativ verksamhet i en mängd olika branscher, är i behov av ökat fokus och ständiga förbättringar. Automation är ett möjligt verktyg med en tidigare bekräftad stor potential att förbättra internlogistiken. Trots denna potential och en växande trend att använda automation inom området är internlogistiska aktiviteter fortfarande inte automatiserade i samma utsträckning som många övriga delar av verksamheten. Det övergripande syftet med forskningen presenterad i denna avhandling är därför att utveckla kunskap som stödjer lyckad användning av automation i internlogistiksystem.

Processen att ta fram och utveckla automationslösningar har identifierats som avgörande för lyckad användning av automation. Med forskningens övergripande syfte i åtanke är målet med denna avhandling att utveckla ett ramverk som underlättar processen att ta fram och utveckla automation i internlogistiksystem. För att bidra till måluppfyllelsen har empiriska data samlats in genom fem fallstudier och en enkätstudie. Under de genomförda empiriska studierna har processen för att förbättra internlogistiksystemet och processen att ta fram och utveckla automationslösningar analyserats. Fokus har varit på att identifiera utmaningar och möjliggörare för en lyckad användning och utveckling av automation i internlogistiksystem.

Resultaten indikerar en låg medvetenhet hos de studerade företagen kring både nuvarande och önskat prestationsläge för internlogistiksystemet. Dessutom bedrivs automationsutveckling ostrukturerat och det finns ofta en osäkerhet kring vilka steg som skall tas i processen. Främst tyder resultaten på en bristfällig grund för korrekt utvärdering och beslut vid framtagning och utveckling av automation inom internlogistik vilket analyseras och konkluderas som en följd av otydliga mål och krav samt avsaknaden av en strategisk syn både gällande den internlogistiska verksamheten och gällande användning och utveckling av automation.

Ett ramverk har utvecklats vilket innehåller föreslagna riktlinjer för hur de utmaningar som observerats kan överkommas. Ramverket inkluderar faktorer vilka identifierats underlätta lyckad framtagning och utveckling av automation. Kärnan i ramverket är en föreslagen processmodell för att ta fram och utveckla automation i en internlogistisk kontext. Baserat på den identifierade betydelsen men avsaknaden av strategi kopplat till denna process inkluderar ramverket även en förslagen modell för en internlogistikstrategi samt en förslagen modell för en automationsstrategi.

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The last five years of work leading up to this thesis has, to say the least, been a journey. Many people have supported me on this journey and helped me reach the destination, and I would therefore like to acknowledge them.

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Anna

Eskilstuna, December 2013

APPENDED PAPERS

This thesis is based on the six papers listed below. The papers are appended in full and are in the text referred to by their Roman numbers. For the papers with multiple authors, the contribution of the authors is described.

Paper I Granlund, A. and Jackson, M. (2008) Logistics Automation – an Enabler for Competing. In *Management in Logistics Networks and Nodes: Concepts, Technology and Applications, Proceedings of Hamburg International Conference of Logistics,* 4-5 September 2008, Hamburg, Germany, pp. 129-146.

Paper II Granlund, A. (2011) Resource Efficiency in Internal Logistics: a Survey on Objectives and Performance. *Proceedings of the 4th International Swedish Production Symposium*, 3-5 May 2011, Lund, Sweden, pp. 303-311.

Paper III Granlund, A. and Wiktorsson, M. (2013) Automation in Healthcare Internal Logistics: A Case Study on Practice and Potential. *International Journal of Innovation and Technology Management*, Vol. 10, No. 3, pp. 1340012-1 – 1340012-20.

Paper IV Granlund, A. and Wiktorsson, M. (In press) Automation in Internal Logistics: Strategic and Operational Challenges. Accepted for publication in *International Journal of Logistics Systems and Management*.

Paper V Granlund, A. (2013) Designing Internal Logistics Systems Fit for the Future. *Proceedings of the 20th EurOMA Conference*, 7-12 June 2013, Dublin, Ireland.

Paper VI Granlund, A. and Friedler, N. (2012) A Model for the Formulation of an Automation Strategy. *Proceedings of the 4th Production and Operations Management World Conference/19th EurOMA Conference*, 1-5 July 2012, Amsterdam, the Netherlands.

Contributions to the appended papers:

Paper I: Granlund was the main author and presented the paper. Granlund performed the literature review, data collection and analysis. Jackson reviewed and quality assured the paper.

Paper II: Granlund single author.

Paper III: Granlund initiated the paper and performed the data collection and analysis. Granlund was the main author but the planning and writing procedure was shared.

Paper IV: Granlund initiated the paper and performed the data collection and analysis. Granlund was the main author, Wiktorsson participated in the writing process, reviewed and quality assured the paper.

Paper V: Granlund single author.

Paper VI: Granlund was the main author and presented the paper. Granlund and Friedler collected data, performed the analysis and planned the paper. Friedler supported the writing process.

Additional publications by the author, but not included in the thesis

Granlund, A., Hedelind, M., Wiktorsson, M., Hällkvist, A. and Jackson, M. (2009) Realizing a Factory-in-a-Box Solution in a Local Manufacturing Environment. *Proceedings of the 42nd CIRP Conference on Manufacturing Systems*, 3-5 June 2009, Grenoble, France.

Wiktorsson, M., Granlund, A. and Bellgran, M. (2009) Reducing Environmental Impact from Manufacturing: Three Industrial Cases for the Manufacturing of 'Green' Products. *Proceedings of 42nd CIRP Conference on Manufacturing Systems*, 3-5 June 2009, Grenoble, France.

Granlund, A. (2011) *Competitive Internal Logistics Systems through Automation*. Licentiate Thesis No. 137, School of Innovation, Design and Engineering, Mälardalen University, Västerås, Sweden.

Wiktorsson, M., Granlund, A. and Bellgran, M. (2011) Reducing Environmental Impact from Manufacturing – An Industrial Case Study, *Journal of Production Research & Management*, Vol. 1 No. 3, pp. 17-32.

Jackson, M., Hedelind, M., Hellström, E., Granlund, A. and Friedler, N. (2011) Lean Automation: Requirements and Solutions for Efficient use of Robot Automation in the Swedish Manufacturing Industry, *International Journal of Engineering Research & Innovation*, Vol. 3 No. 2, pp. 36-43.

Granlund, A., Friedler, N., Jackson, M., Hellström, E. and Carnbo, L. (2012) The concept of Lean Automation – a pilot installation. *Proceedings of the 5th Swedish Production Symposium*, 6-8 November 2012, Linköping, Sweden, pp. 11-20.

Friedler, N. and Granlund, A. (2012) Defining the automation equipment acquisition process – from a system supplier's perspective. *Proceedings of the 22nd International Conference on Flexible Automation and Intelligent Manufacturing*, 10-13 June 2012, Helsinki, Finland.

Granlund, A. and Jackson, M. (2013) Managing automation development projects – a comparison of industrial needs and existing theoretical support. *Proceedings of the 23rd International Conference on Flexible Automation and Intelligent Manufacturing*, 26-28 June 2013, Porto, Portugal, pp. 761-774.

TABLE OF CONTENTS

PART 1

SUMMARISING CHAPTERS

1. INTRODUCTION

This chapter introduces the research that is presented in this thesis. The background and motivation of the research is described and based on that, the research aim, the objective of the thesis and the formulated research questions are presented. Further, the scope and delimitations of the research are described and the chapter concludes with an outline of the thesis.

1.1 THE IMPORTANCE AND POTENTIAL OF THE INTERNAL LOGISTICS SYSTEM

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 operational performance in the form of, for example, just-in-time supply of materials, efficient materials handling solutions and on-time delivery of finished goods. Thus, today's market puts a high pressure on logistics operations (Kartnig et al., 2012). This is from the aspect of improving the logistics system in the given situation, but also to keep it fit and adjusted for future needs and requirements.

The role that logistics plays in a company's overall performance, profitability and competitiveness is large. In fact it plays a major role in creating value and determining the overall corporate response to market opportunities (Gattorna and Walters, 1996; Rutner and Langley Jr., 2000; Stank et al., 2003). Christopher (1997) even concludes that it is supply chains that compete, not companies. Logistics, being an important part of the supply chain, should thus be accorded a high strategic priority (Stock et al., 1998; Stock et al., 2000) since it represents a source of sustainable competitive advantages (Mentzer and Williams, 2001; Porter, 2004a; Stalk et al., 1992; Stock and Lambert, 2001; Yazdanparast et al., 2010). Building on the resource-based theory of the firm (Wernerfelt, 1984), logistics capabilities can also be regarded as key strategic resources (Cheng and Grimm, 2006; Olavarrieta and Ellinger, 1997; Stank et al., 2005), which emphasises the importance and potential of this area.

The area of logistics can be described as a framework including several different academic and industrial disciplines since the term is used for, and includes, several aspects, components, subparts and activities. The core of logistics is, however, focused on managing the flow of materials and the information related to it into, through and out of the corporate system (Gattorna et al., 1991). Further, logistics can be divided into internal and external logistics (Groover, 2008; Gupta and Dutta, 1994). This research focuses on the internal flow of materials and thus belongs to internal logistics, which includes all logistics activities within the physical walls of an isolated facility, for example internal transports, materials handling, storing, warehousing and packaging. The internal logistics system (further elaborated in Section 2.1.3) includes and enables the internal logistics flows and activities within a facility and is hence a part of the overall logistics system. But it is also an integrated subsystem or part of an overall system, such as a production system, a hospital system or a warehouse system in the organisation of which it is a part. For example, in the manufacturing industry the role of the material flow system can be likened to that of the cardiovascular system in living organisms (Rembold and Tanchoco, 1994), because the main task of the internal logistics system is to provide necessary supplies to the company's value-adding operations and core processes. In other lines of business, such as the healthcare sector, the need to have the right material, in the right place, in the right time is even more critical since it can influence the possibilities to provide proper care. Although internal logistics activities in general is considered non-value adding, the internal logistics system constitutes an necessary and vital part of the overall function of organisations in a wide spectrum of lines of business.

While internal logistics can be both necessary and critical, it is also often a time-consuming part of the overall operations. In manufacturing industry, more than 80 % of the lead time for the material in the facility is related to internal logistics activities (Aized, 2010; Monden, 1998), and in the healthcare industry, previous research has shown that larger parts of nurses' time are spent on logistics-related activities than on direct care (Elmfeldt and Kardbom, 2009; Hendrich et al., 2008; Johnreden, 2002). Internal logistics activities also in general constitute a large part of the overall cost for businesses (Rouwenhorst et al., 2000). In producing industry, the cost of internal logistics constitutes around 30-40 % of the processing costs (Monden, 1998), and Poulin (2003) states that 30-46 % of hospital expenses are invested in various logistics activities. The main reason for these large costs is that logistics activities in general are very resource-intensive, since they are often characterised by a high degree of manual handling and hence have a high degree of labour usage, which in turn also strongly affects the cost of these operations.

In today's highly competitive climate, companies are forced to look into every part of their organisation for possible improvements. Due to the large impact of the internal logistics system on both resource usage and cost, there are large potential benefits of improving this system. Also, as discussed above, the performance of the internal logistics system directly affects the whole organisation. A well-designed and correctly used internal logistics system increases the efficiency of the organisation in which it is embedded (Aized, 2010; Hassan, 2010; Mattsson and Jonsson, 2003; Rembold and Tanchoco, 1994; Öjmertz, 1998), which also signifies the importance of focusing on and continuously improving this system.

Still, despite the importance of internal logistics, it has previously mostly been viewed only from a cost perspective (Gattorna, 2012; Mentzer and Konrad, 1991; Michalos et al., 2010; Olavarrieta and Ellinger, 1997), and its influence on the overall business performance and its potential to create value and increase competitiveness are not fully recognised (Rutner and Langley Jr., 2000). Instead, it is traditionally seen as only a support function, or a function among others in the firm (Kihlén, 2007). Further, the connection of internal logistics to other functions in the firm has not been realised (Olavarrieta and Ellinger, 1997), and its activities have often been divided along functional boundaries (Stock et al., 2000). The internal logistics system is not fully given the strategic priority required, which is unfortunate since logistics involves strategic aspects that need to be considered to properly develop it (Harrison and van Hoek, 2008; Jonsson, 2008; Storhagen, 2011).

1.2 AUTOMATION AS A POSSIBLE MEANS TO IMPROVE INTERNAL LOGISTICS

One possible way to improve competitiveness in operations is with the help of automation technology. In, for example, the manufacturing industry, automation is a well-known means of improving productivity, efficiency, quality and safety as well as lowering cost (Cruz Di Palma and Basaldúa, 2009; Frohm et al., 2006; Groover, 2008; Michalos et al., 2010). While the manufacturing industry is one of the sectors most closely connected with using automated equipment, automation has a wide scope and can be found in many fields (Spath et al., 2009). The range of applications is also constantly increasing.

The potential benefits of using automation in internal logistics activities (such as in internal transports or materials handling) are vast since, as explained in the previous section, they are often characterised by a large amount of manual work, which is both time-consuming and often physically strenuous. These tasks are therefore suitable to automate, and the potential benefits of the investments are often both obvious and large. The logistics costs, for example, vary depending on the degree of automation in the logistics processes (Groover, 2008). Besides reduced cost, the use of automation in internal logistics has also many other advantages such as, in different aspects, increasing performance and improving work environment (Chung and Tanchoco, 2009; Cruz Di Palma and Basaldúa, 2009). Frazelle (2001b) even points out automation in internal logistics as one of the common denominators for a successful warehouse project. The view in industry also points in the same direction. In a survey by the Material Handling Industry of America (2011) more than 90 % of the respondents using automation in their internal logistics system said that it is an asset to their operations and creates a competitive advantage.

Schulze and Wüllner (2006) conclude that it is most likely that automation is a key point in the future development of internal logistics. Looking back, automation has also, since the 1960s, played a key role in the development of the internal logistics area (Kartnig et al., 2012), and the sales of automated equipment for use in internal logistics have been growing steadily during the last decades (Baker and Halim, 2007; Cruz Di Palma and Basaldúa, 2009; Echelmeyer et al., 2008). The outlook for the coming years is continued growth in automated materials handling equipment orders (Material Handling Industry of America, 2010). In a large-scale survey on investment plans for materials handling operations, 74 % of the respondents indicated that they are planning or considering automation (Material Handling Industry of America, 2012).

It is clear that automation in internal logistics is reasonably commonplace, but it is to some degree only implemented in certain logistics activities and mostly in large-scale operations (Baker, 2004a). 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 can be one reason for a slower adoption of automation in internal logistics than in other areas. Parallel to the growing trend of automation in internal logistics, the degree of automation in, for example, production processes has 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 in the manufacturing industry. The results showed that internal logistics activities such as materials handling and packaging were all automated to a lower extent than production-related activities such as machining, changeover and maintenance.

It is clear that automation of internal logistics activities can provide great potential benefits and, as stated by Richey Jr. et al. (2010), firms cannot afford to lag behind in implementing appropriate automation technologies in their logistics system. But, as confirmed by Baker and Halim (2007), there has, despite its large potential benefits, been a relatively small amount of research into the area of automation in internal logistics, and evidence from live cases is rarely documented in scientific contexts. There is hence a need for empirical research in the area of automation in internal logistics systems.

1.3 THE CRITICAL ROLE OF THE AUTOMATION DEVELOPMENT PROCESS

The need for research in the area of using and developing automation in internal logistics systems is supported by Richey Jr. et al. (2010), who conclude that there is little guidance on how to utilise automation in the supply chain to create opportunities and value. The question of how to use automation for successful outcomes is crucial because it is important to understand that the use of automation does not per se guarantee advantageous results. The use of technology such as automation can worsen as well as improve a firm's competitive position (Porter, 2004a). In spite of the numerous benefits and advantages that automation offers, it is not always the best solution and in some cases it is not even a feasible one (Cruz Di Palma and Basaldúa, 2009; Groover, 2008; Spath et al., 2009). Paradoxically, the wrong technology, or even the right technology poorly implemented, can be disastrous (Baines, 2004). Further, previous research shows that the main problems with automation are not associated with the actual automation level or the lack of technology, but rather with its implementation and difficulties in choosing and incorporating it (Durrani et al., 1998; Sambasivarao and Deshmukh, 1995).

The key to a successful use of automation therefore lies in finding, selecting, acquiring and properly implementing the right type and level of automation in relation to the company's needs, goals and prerequisites (Baines, 2004; Ceroni, 2009; Daim and Kocaoglu, 2008; Spath et al., 2009; Säfsten et al., 2007). The process of developing automation, which includes all these steps, is thus a crucial part in determining the success of automation investments and thus the use of automation (Baines, 2004; Spath et al., 2009). This in turn puts great demands on a company's way of working since the process not only requires that the actual automation development and its adherent processes are well structured and supported, it also puts large demands on the structure, control and understanding of the operations to be automated.

Before investing in automation it is first important to structure the system in which the automation should be included and make sure that it is well integrated with other systems and adjusted to current needs (Groover, 2008; Hammer, 1990; Tu et al., 2011). It is also important to be well aware of the parameters affecting your system as well as what requirements there are on the system and the future automated solution (Fasth et al., 2007; Frohm et al., 2003; Groover, 2008). However, as addressed in the previous section, the connection of internal logistics to other functions in the firm has not been realised and the fact that its activities are often divided across functional boundaries may provide poor prerequisites for a proper automation development process in internal logistics systems.

Further, the selection of equipment is an important strategic part of designing and developing internal logistics systems (Chung and Tanchoco, 2009; Gu et al., 2010; Hassan, 2010), on which Gu et al. (2010) also conclude there has been little academic research. When considering automated equipment in internal logistics systems it is thus important to recognise that it is a strategic decision that will have a long-term impact on the system (Baker and Halim, 2007; Ceroni, 2009). It is also important to view automation in a targeted way and not only in terms of cost or headcount (Trebilcock, 2011). In the previous section it was concluded that internal logistics has traditionally only been viewed from a cost perspective and its strategic impact is not fully recognised. Therefore, this might also have a negative impact on the automation development process and the important selection of equipment, which thus needs to be further studied.

1.4 RESEARCH AIM, THESIS OBJECTIVE AND RESEARCH QUESTIONS

From the introduction so far it can be concluded that the internal logistics system is an important part of operations with a need for increased focus and continuous improvements. Automation is one possible tool with, also previously confirmed, great potential to improve the internal logistics system. Despite this great potential and the growing trend of the use of automation, internal logistics activities are still not automated to the same extent as many other parts of operations. There has also, as supported by Baker and Halim (2007) and Richey Jr. et al. (2010), been little previous research contributing to the understanding and knowledge of using and developing automation particularly in an internal logistics context. Based on this, the overall aim of the research presented in this thesis is specified as follows:

The overall aim of this research is to develop knowledge that supports the successful use of automation in internal logistics systems.

Further, as a guideline for the direction of this research, the automation development process was identified above as a crucial part in determining the success of automation investments and thus the use of automation. In order to support the successful use of automation in internal logistics systems, this research focuses on the critical aspect of developing automation within such systems. The complete automation development process has also, according to Baines (2004), received limited attention in previous research. This motivates the research focusing on the automation development process and highlights the need for a holistic perspective on the process.

In the previous section it was also addressed that while the potential benefits of using automation in internal logistics systems are large, the prerequisites for properly conducting automation development within such systems need to be improved. There is thus a need to investigate how the automation development process can be facilitated. Addressing both a theoretical gap and practical needs, the objective of this thesis is formulated as follows:

The objective of this thesis is to develop a framework facilitating the automation development process in internal logistics systems.

The framework objective was chosen since it has the possibility to embrace the entire automation development process and include enablers and facilitators for automation development in general and in particular the process by which it is conducted. Further, developing a framework is a way to present new and existing theoretical knowledge in a way that also has practical implications and uses, thus being a suitable goal for this type of applied research.

A framework can however take many forms and shapes. With the overall aim of the research and the specified objective in mind, two research questions have been formulated to help guide the development of a framework facilitating automation development in internal logistics systems as well as understanding how it could be structured and what it should include. The two research questions are presented and described in the following.

RQ 1: *What challenges are there to successfully use automation as a means of improving internal logistics systems?*

The first question is posed to build a better understanding of why automation has not been used to a greater extent in internal logistics systems and to better understand the prerequisites for using and developing automation in the internal logistics system.

Specifically challenges connected with the process of improving the internal logistics system affecting the possibilities of successfully using and developing automation are sought for as well as challenges such as problems and difficulties directly connected with the process of developing automation in internal logistics systems.

RQ 2: *How can the automation development process in internal logistics systems be facilitated?*

The second question is posed to investigate how the challenges identified in the first research question can be handled and overcome and to identify what enables and supports automation development in general. This is in order to understand how the automation development process in internal logistics systems can be facilitated and how a proper automation development process supporting successful use of automation in internal logistics systems can be achieved.

1.5 THE SCOPE AND DELIMITATIONS OF THE RESEARCH

The overall theme of this research is connected with improvement and development work in operations with a focus on two processes, the process of improving the internal logistics system and the automation development process, and the ways of working connected with them.

The context of this research is the internal logistics system, which is the system that includes and enables the internal logistics flows and hence all related activities, processes, resources and organisational structures (further defined and illustrated in Section 2.1.3). Internal logistics in turn refers to all activities and processes connected with managing the flow of materials (and adherent information) within the physical limits of an isolated facility. This research focuses on studying the physical flow of materials, which is also the main feature of the logistics flow. But it is important to remember that the flow of materials cannot be seen as isolated from the related flow of information (Lumsden, 2012).

As mentioned in Section 1.1, internal logistics systems exist in a number of lines of businesses. The internal logistics system and its subparts as well as the context and prerequisites in the aspect of being an integrated subsystem in an overall system are common features regardless of business. This is also described in Jarret (2006), where it is concluded that structure and prerequisites of an internal logistic system in a hospital for example share many similarities with those in the manufacturing industry. During this research, cases in different lines of businesses have been studied but the focus has not been on a specific line of business but on the processes of improving the internal logistics system using automation in different settings (the selection of cases is further elaborated in Section 3.2.2).

Further, this research takes its stance in automation of internal logistics activities as a means of improving operations, thus a user perspective on automation is adopted in the sense that the result aims at aiding users (current and potential) of automation in internal logistics systems by increasing the knowledge in the area.

The attention in this research has not been specifically on the automation technology or solution per se but on the successful use and development of it. The automation development process has been the main focus of study due to its proven strong role in determining the success of the use of automation. The term *automation development process* is in this research used to denote the entire chain of activities concerned with planning for, identifying, selecting, designing, acquiring and implementing automation solutions and systems.

Further, the research is focused on the use of automation in the physical logistics flow and not in the flow of information. However, aspects of information and information handling related to the automation of physical internal logistics activities are included. The type of automation applications studied mainly concerns industrial automation such as industrial robotics, pick-and-place units, automated lifting aids, AGVs and other types of automation integrated as a part of the internal logistics system. Complex standalone automated systems such as automated storage and retrieval systems have hence not been the main focus.

1.6 OUTLINE OF THE THESIS

The thesis is constructed in two main parts: (1) the summarising chapters and (2) the appended papers.

In Part 1, the structure is as follows: Chapter 1 introduces and describes the background of the research area and presents the aim of the research, the objective of the thesis along with the research questions and the scope and delimitations of the research. In Chapter 2 the frame of reference is presented focusing on the internal logistics system and the process of improving it as well as automation in internal logistics systems and its development. Chapter 3 presents the research methodology, where first the research philosophy and the research approach are described. The chosen research method and the applied research process are then presented along with the studies conducted and the data collection and data analysis processes. The chapter concludes with a discussion of the quality of the research. Chapter 4 provides an overview and summary of the findings from the six empirical studies, which are then analysed in Chapter 5. In Chapter 6 the proposed framework facilitating automation development in internal logistics systems is presented. Finally, Chapter 7 concludes the thesis by discussing and summarising the research and its results. This chapter also includes discussions of the contribution along with suggestions for future research.

In Part 2, six papers produced during the course of the PhD studies are appended. Paper I investigates prerequisites for using and developing automation in internal logistics systems. Paper II addresses the perception and development of the internal logistics system. Paper III focuses on the potential use of automation in hospital internal logistics and investigates the management of automation development in internal logistics systems. Paper IV focuses on strategic and operational challenges of using and developing automation in internal logistics. The paper also summarises the conclusions and results from the licentiate thesis and presents a model for an internal logistics strategy. Paper V focuses on the process of improving the internal logistics system and addresses challenges connected with it. Finally, Paper VI focuses on the automation development process and presents a model for an automation strategy.

Figure 1 illustrates the outline of the thesis and how the different chapters and parts are related.

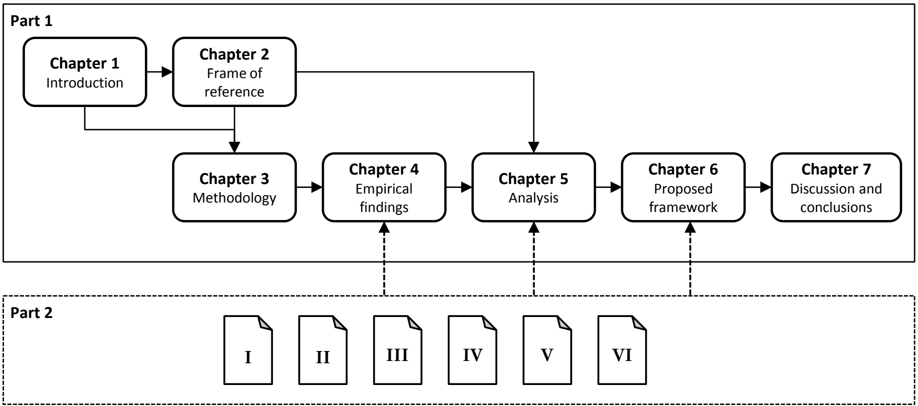

Figure 1 Outline of the thesis.

2. FRAME OF REFERENCE

This chapter presents the frame of reference of this research. The chapter is structured around two main topics: (1) the internal logistics system and the process of improving it and (2) automation in internal logistics systems and its development.

Since this research covers the areas of both internal logistics and automation, this chapter includes a theoretical overview of the relevant fields and topics as well as results and conclusions from previous research related to these two areas. The frame of reference is intended to provide input and a base for answering the research questions and fulfilling the objective of the thesis. It has also helped to structure the studies and it provided a base for the empirical research and the analysis.

The chapter is divided into two main parts: the first is connected with the internal logistics system and the process of improving it and the second is connected with automation in internal logistics systems and its development. The chapter concludes with a short reflection from the theoretical review.

2.1 THE INTERNAL LOGISTICS SYSTEM AND THE PROCESS OF IMPROVING IT

This section begins with an introduction to the area of logistics leading on to a definition of internal logistics and the internal logistics system. Since the research is related to improving this system, the aspect of performance and ways to measure and assess it are presented and discussed specifically related to logistics. Thereafter, design and improvements of internal logistics systems are addressed and a number of both logistics-related and general design and improvement process models presented. Finally, due to its important role in improvement work, strategy is addressed by first a short introduction to the area and the applied view of it and then a presentation of theory and previous research connected with strategy in internal logistics.

2.1.1 Logistics

Logistics is commonly described from a practical perspective, as about satisfying a demand (Gattorna et al., 1991). Popularly this is described using seven Rs, namely those activities that ensure the availability of the *right* product or service, in the *right* quantity and in the *right* condition, at the *right* place, at the *right* time for the *right* customer, at the *right* cost (Shapiro and Heskett, 1985). It is thus a generic term for all the activities that together create time and place utility (Jonsson, 2008; Stock and Lambert, 2001).

The creator of the demand that logistics aims at satisfying and the receiver of the created value is the only player mentioned in the seven Rs, namely the customer. Logistics aims at satisfying all interested parties' needs and wishes but the emphasis is always on the customer (Lumsden, 2012), who is the point of reference

(Storhagen, 2011) and who should be the focus point of any logistics activity (Gattorna and Walters, 1996).

Logistics can also be described from the perspective of the flow of materials, where it covers the total flow of all types of materials such as raw materials, components, manufactured parts and packaging materials (Gattorna and Walters, 1996) as well as the information related to it into, through and out of the corporate system (Gattorna et al., 1991). This research mainly focuses on studying the physical flow of materials, which is also the main feature of the logistics flow. But it is important to remember that the flow of materials cannot be seen as isolated from the related flow of information (Lumsden, 2012).

The essence of the logistics task is to manage these two distinct flows: the material flow (of physical goods) and the information flow that enables the material flow to be planned, performed and controlled (Harrison and van Hoek, 2008). Therefore, the concept of logistics management is quite similar to the concept of supply chain management, which can be described as managing the flow of material and information through the entire supply network and all its processes (Harrison and van Hoek, 2008). This is not surprising, since logistics can be seen as part of the overall supply chain or a subset of supply chain management (Harrison and van Hoek, 2008; Rushton et al., 2006) that is primarily concerned with optimising flows within the organisation (Christopher, 2005). The goal of supply chain management is improving performance and increasing efficiency through the elimination of waste and a better use of capabilities and technology (Tan, 2001). This notion both can and should be filtered down the structural hierarchy to internal logistics.

Logistics is considered a wide concept since it covers both strategic, tactic and operative aspects connected with the flow of materials (Jonsson and Mattsson, 2011; Lumsden, 2012; Rushton et al., 2006; Storhagen, 2011). In addition, it can also be interpreted in a number of ways since the same word is used for the organisational department, the operational function and the activities. 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 a an approach in which the term is used for a number of activities and processes (Jonsson, 2008). An appropriate way to view and describe logistics to incorporate all these aspects is thus as a system, which is the view applied in this research and which will be further addressed in the next section.

With support from the above-presented descriptions of logistics, the term *logistics* is in this research used to describe the framework of all activities and processes connected with managing the flow of materials (and adherent information) into, through and out of an organisation.

2.1.2 Logistics systems

The logistics field does not only have its theoretical base in systems thinking (Storhagen, 2011). The emphasis behind the logistics concept is also on systems (Gattorna et al., 1991), and logistics is commonly described as a system (Jonsson, 2008).

A system can be defined as *"a finite set of elements collected to form a whole under certain well defined rules, whereby certain definite relationships exist between the elements, and to its environment"* (Hubka and Eder, 1988 p. 244).

Hubka and Eder (1988) however emphasise that the two terms elements and systems are relative and that systems are hierarchical. Each element can thus be regarded as a system on its own and each system is part of a wider system at the same time as it can be divided into subsystems.

A system is enclosed within a system boundary and everything outside of the boundary is considered the external environment (Wu, 1994). Further, there are two main types of systems: open and closed systems. The environment is especially important to open systems since it includes factors that are important for the system to consider but beyond its control (Arbnor and Bjerke, 2009). The logistics system is always open and in exchange with its surroundings (Jonsson, 2008).

According to Rouwenhorst et al. (2000), there are three different aspects 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 refers to all means, equipment and personnel needed to perform the processes. Finally, organisation includes all structures, planning and control procedures needed to run and manage the system.

In this research, the term *logistics system* is thus used to denote the system that includes and enables the logistics flows and hence all related activities, processes, resources and organisational structures.

2.1.3 Internal logistics and the internal logistics system

In the definition of logistics by the Council of Supply Chain Management Professionals it is stated that it includes internal and external movements. The logistics operations can thus be separated into internal and external logistics, where internal logistics refers to the logistics flows within a facility (Groover, 2008; Gupta and Dutta, 1994). Internal logistics thus includes parts of materials management and materials supply such as receiving, materials feeding, materials handling, storing of all types including buffering and inventory, internal transports and packaging. It also includes parts of distribution such as warehousing and internal shipping activities.

Internal logistics is thus, in this research, defined as follows:

All activities and processes connected with managing the flow of materials (and adherent information) within the physical limits of an isolated facility.

Figure 2 gives a survey of the applied view of internal logistics in relation to other logistics-related terms. There is however a certain degree of confusion and disorder of the different terms used in the logistics area since they often do not have a single clear definition in the literature. The physical handling of materials in the internal logistics concept could be said to be equivalent to the term materials handling since it includes movements within facilities (Öjmertz, 1998) and is usually considered to include storage, handling, packaging and internal transportation (Johansson and Johansson, 2006). However, the term internal logistics was preferred since it entails a systems perspective.

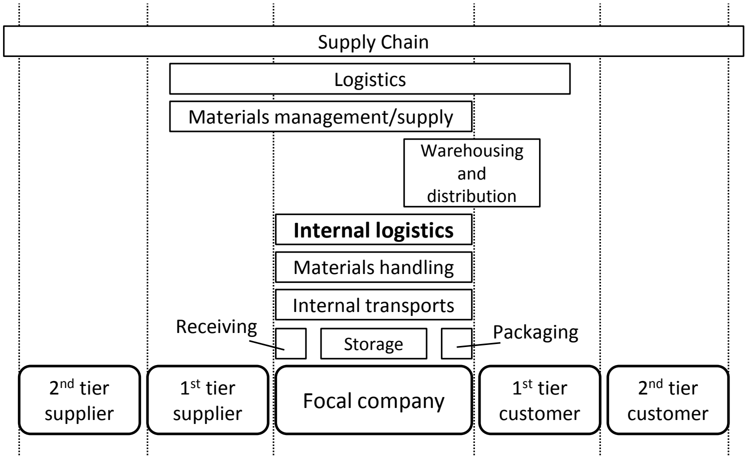

Figure 2 Internal logistics in relation to other logistics terms (inspired by Jonson (2008) and Harrison and van Hoek (2008)).

Building on the description of logistics, the core of the internal logistics concept is the flow of materials (and adherent information). However, it also importantly includes all the activities that enable the flow and the processes by which these flows and activities are managed, controlled and planned. The internal logistics system thus includes all these flows, activities and processes but also the resources that help perform them such as the humans (and their skills and competences), the physical equipment and IT systems as well as materials and energy. It also includes all organisational structures, routines and processes that enable but also manage, control and affect the flows, activities, processes and resources.

In this research the term *internal logistics system* is thus used to denote the system that includes and enables the internal logistics flows and hence all related activities, processes, resources and organisational structures.

The system boundaries of the internal logistics system in one aspect correspond to the physical limits, i.e. the walls of a facility. However, referring to Hubka and Eder's (1988) hierarchy of systems, the internal logistics system is a system on its own but often part of, for example, a production system, an assembly system, a warehouse system or a hospital system. These systems therefore make up the external environment of the internal logistics system, and since the system is open, it is an environment that interacts with it, provides it with input and affects it (Hassan, 2010).

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 external customers influence the internal logistics system with their external demand and requests. However, the focus of internal logistics is rather on the "company-internal customer" for whom value in the first hand should be created. This internal customer can, for example, be a production or health care department or part of such a department.

An overview of the internal logistics system, its constituent parts and relation to other systems is given in Figure 3.

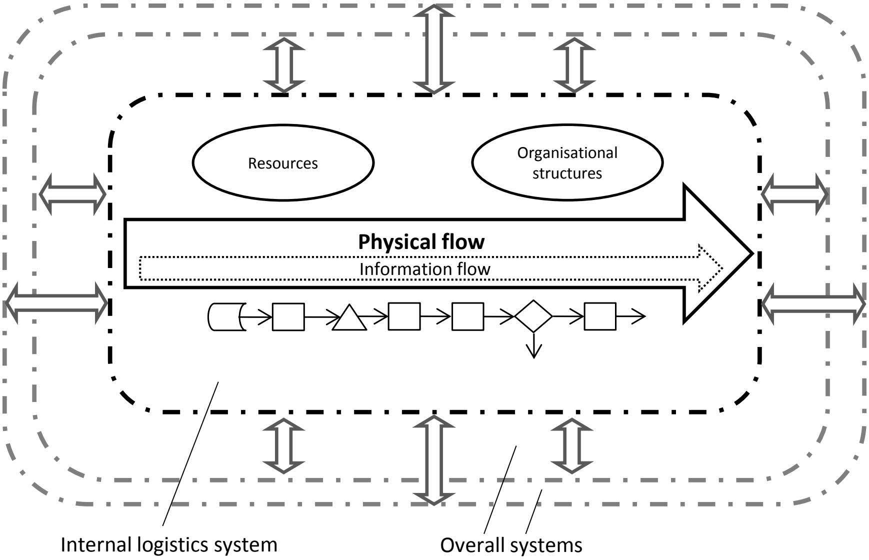

Figure 3 Illustration of the internal logistics system.

2.1.4 Logistics performance

The aim of this research is connected with improving the internal logistics system using automation. When discussing improvements, performance is a key concept. This section thus discusses performance from a logistics perspective.

Performance

Performance is 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. Therefore, performance is the function of resources utilised and results achieved compared to standards and goals (Mentzer and Konrad, 1991).

A central part of performance is cost, but the performance concept also involves almost any other non-cost objectives of competition such as dependability, flexibility, quality and speed. Still, when discussing performance, the terms productivity, efficiency and effectiveness are perhaps the ones most often used.

In the field of industrial engineering, *productivity* is defined as the relation of input to output (Tangen, 2004). In manufacturing terms, productivity can be explained as how much and how well one produces from the resources used (Bernolak, 1997).

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 is therefore a measurement that reflects the internal performance of the unit studied (Öjmertz, 1998), i.e. how well the expended resources are utilised (Mentzer and Konrad, 1991). *Effectiveness*, on the other hand, is an output-oriented measurement, related to offering the customers what they demand (Johansson and Mathisson-Öjmertz, 1996). It is thus linked to the external performance (Tangen, 2004), i.e. how well the desired output is achieved. 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.

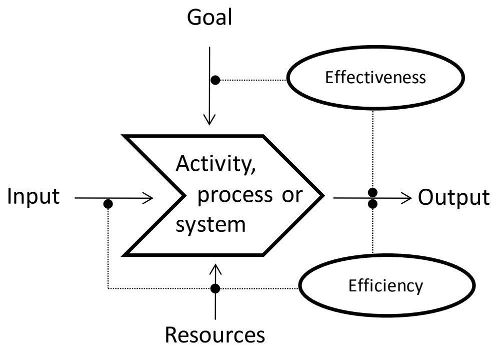

Figure 4 Efficiency and effectiveness model modified from O´Donnell and Duffy (2002).

It is important to observe that there is no point in having a high degree of efficiency if the resources are used to achieve something not connected with the goal. It is the combination of high efficiency and effectiveness that leads to high performance.

Performance measurements

One way to analyse or assess the efficiency and effectiveness of actions taken and tasks performed 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 the system. Performance measurement is thus a critical instrument of control that creates an understanding of the organisation and can thereby steer a company's direction (Fawcett and Cooper, 1998; Maskell, 1991).

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, and it is important that the measurements used actually measure what the company needs to know. It is also important that the measurements are followed up and evaluated in relation to the goals (Mentzer and Konrad, 1991). Finally, possible actions need to be taken to improve the organisation and should be taken based on the results of the evaluation.

Aspects of logistics performance

As concluded above, it is the combination of high efficiency and high effectiveness that leads to high performance. Thus, the concepts of efficiency and effectiveness need to be considered simultaneously, also in logistics (Fugate et al., 2010; Kihlén, 2007). As mentioned previously, the concept of logistics covers both strategic and operative aspects connected with the flow of materials (Jonsson and Mattsson, 2011; Lumsden, 2012). The strategic aspects can be translated into doing the right things, especially towards the customer, i.e. attaining effectiveness. In this aspect the management of the flows is the most important feature. The operative aspects on the other hand involve doing things right, i.e. attaining efficiency. The efficiency of the logistics operation is on the other hand dependent on how well the logistics system "produces", which is turn depends on how it is designed (Lumsden, 2012), something that will be addressed later in this chapter.

When reviewing literature in the logistics area, the importance of attaining high performance seems indisputable. But there is, besides the efficiency/effectiveness discussion, no consensus about what constitutes logistics performance since there are many different ways to compete in logistics (Harrison and van Hoek, 2008) as well as the fact that performance is a subjective matter (Fawcett and Cooper, 1998).

However, logistics is, as explained above, about satisfying a demand and it is agreed that the key to both survival and logistics success is linked to the seven Rs. 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 appropriate documentation (Fawcett and Cooper, 1998). From this, several aspects of important performance features can be singled out, and these are discussed below.

As explained above, *economic aspects,* specifically different aspects of *cost,* are a central part of performance, and in logistics this is very much the case since it has traditionally been viewed only from a cost perspective (Gattorna, 2012; Mentzer and Konrad, 1991; Michalos et al., 2010; Olavarrieta and Ellinger, 1997).

Another of the most obvious features of logistics performance is *delivery performance*. This aspect has generally two dimensions: speed and reliability (Stock et al., 1998). Speed, both in the sense of *time*, having short lead, response and delivery times, and in the sense of *flexibility/agility* in operations to rapidly respond to changes in demand. *Delivery reliability/dependability* (Harrison and van Hoek, 2008) relates to the capability to deliver on time while *delivery precision* is related to capability to assess appropriate delivery dates and always deliver when promised.

Another and 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 by the number of incorrect orders or damaged goods. However, there are also many non-quantitative aspects 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 (Harrison and van Hoek, 2008).

An additional performance aspect critical to logistics management is the *quality of information* (Gattorna et al., 1991). A*vailability* and *quality of data* are both pre-requisites to running operations but also critical in the management functions of planning and control (Langley Jr. et al., 1995).

According to Christopher and Towill (2001), the consumer ultimately determines the success or failure of supply chains. Accordingly, an important part of logistics performance is *customer service* and being able to respond to demands and needs.

Other performance variables can be *environment* (Jonsson, 2008) or soft objectives such as *confidence* and *security* (Harrison and van Hoek, 2008).

Performance measurements in logistics

Numerous logistics performance measures exist. Wen and Wang (2007) have created a performance measurement system for the quality evaluation of the logistics system of a manufacturing enterprise. Many others such as Gattorna et al. (1991), Mentzer and Konrad (1991), Fawcett and Cooper (1998) and Shepherd and Günter (2006) list or present taxonomies of measures of supply chain and/or logistics performance. Far from all of these measurements are directly connected with internal logistics. However, Lambert and Pohlen (2001) argue that most supply chain metrics are in fact for measuring internal logistics performance. Further, Swinehart and Smith (2005), who studied internal supply chain performance in the healthcare sector, concluded that many traditionally external logistics measures are potentially 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-Öjmertz, 1998). Generally, good measurement systems should cover all aspects of the process measured and be appropriate for the situation. The measurements should also reflect the goals of the firm and be linked to corporate strategy (Gunasekaran et al., 2004; Lambert and Pohlen, 2001; Zacharia and Mentzer, 2004). But this is not always the case. Hackman et al. (2001), for example, present frequently used performance measures in warehousing activities and discuss their flaws. However, the main problem is not the lack of appropriate measurements but the fact that few companies actually measure their logistics performance. A study by Fawcett and Cooper (1998) investigated the use of performance measures in a vast number of companies. The results showed that the area with the least improvement over the years involved traditional logistics productivity measurements. The same study also showed that nine of the ten most used measures still focus on cost measurement and control.

2.1.5 Design and improvements of internal logistics systems

The design of the internal logistics system affects both the performance of the logistics operations and the competitiveness of the overall organisation of which the system is part (eg. Gupta and Dutta, 1994; Johansson, 2007; Lumsden, 2012; Mattsson and Jonsson, 2003; Rembold and Tanchoco, 1994; Öjmertz, 1998). Even though the main design of an internal logistics system is made and decided during the construction and planning of a new facility or during larger reconfigurations in an overall system, improvements in the existing system design are (or, at least, should be) a continuous process in order to maintain or improve competitiveness.

The design of logistics systems is highly complex (Baker and Canessa, 2009) and it is generally accepted that the concept of "one-size-fits-all" does not apply (Baker, 2004b; Christopher and Towill, 2002). This is because logistics systems must meet 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 further addressed and discussed in Section 2.1.6 in relation to logistics strategy.

The selection of equipment is also an important part of the design of internal logistics systems (Baker, 2006; Chung and Tanchoco, 2009; Gu et al., 2010; Hassan, 2010); the selection of specifically automated equipment, being the focus of this research, is further elaborated in Section 2.2.

When designing systems, the use of sound models and methods is essential (Bennett and Forrester, 1993) since they provide guidance and structure, thus allowing more time to be devoted to the design and less to the design process (Bellgran and Säfsten, 2010; Wu, 1994). Conclusions from 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 (Baker and Canessa, 2009; Rouwenhorst et al., 2000). But there is some support to be found both specifically related to internal logistics and in systems design literature in general. This is presented and discussed in the following sections.

Logistics-related design and improvement process models

Frazelle (2001a) presents a methodology for redesigning logistics systems. The methodology is divided into three phases: investigate, innovate and implement. During the first phase, investigate, it is important to profile current logistics activity, measure current logistics performance and benchmark performance and practices. When it comes to benchmarking, a study by Fawcett and Cooper (1998) investigated the relationship between companies' degrees of benchmarking and their own logistics performance assessment. From the study it was concluded that companies that actively benchmark have a more realistic view of their own performance (Fawcett and Cooper, 1998).

In the area of materials handling systems, Tompkins et al. (2010) present a six-step engineering design process for systems design. These steps are as follows:

1. Define the objectives and scope for the material handling system.
2. Analyse the requirements for moving, storing, protecting and controlling material.
3. Generate alternative designs for meeting system requirements.
4. Evaluate alternative material handling system designs.
5. Select the preferred design
6. Implement the preferred design, including the selection of suppliers; training of personnel; installation, debugging, and start-up of equipment; and periodic audits of system performance.

Johansson and Johansson (2006) present a materials supply system design model containing different design areas and levels for describing and analysing materials supply systems design in product development projects. This model is further elaborated in Johansson (2007), where a materials supply system design process is presented.

Hassan (2010) presents a framework for materials handling equipment selection with ten main steps distributed across the three phases conceptual design, preliminary design and detailed design.

Literature on production systems design such as Bennett and Forrester (1993), Wu (1994), Bellgran (1998) and Bellgran and Säfsten (2010) also discusses some aspects of internal logistics system design but to a limited extent. Bellgran (1998) presents a checklist of system aspects to consider during production system development in which materials handling is one category. Of Bennett and Forrester's (1993) ten components, several are related to and can give support during improvements of internal logistics systems as well as automation development.

General and related design and improvement process models

According to Roozenburg and Eekels (1995), the design process is a form of problem solving where the means to reach the ends are sought intentionally. Many design processes and models originate from the field of product development. Figure 5 gives an overview of the main steps in (A) Roozenburg and Eekels' (1995) problem-solving model for systems design as well as the main phases in the design processes by (B) Pahl et al. (2007) and (C) Ulrich and Eppinger (2012).

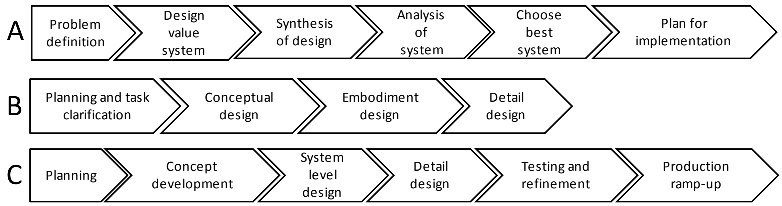

Figure 5 Overview of main steps in the design processes adapted from A, Roozenburg and Eekels (1995), B, Pahl et al. (2007) and C, Ulrich and Eppinger (2012).

The process by Pahl et al. (2007) focuses on the actual design of the product while the model by Roozenburg and Eekels (1995) and the process by Ulrich and Eppinger (2012) are somewhat more generic and also cover implementation.

Wu (1994) presents both a general systems approach to problem solving (D) and a general design framework (E) illustrated in Figure 6.

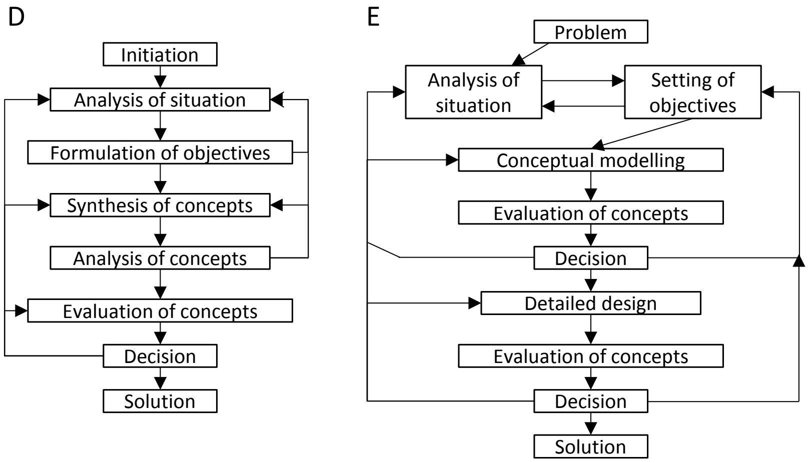

Figure 6 A general systems approach to problem solving (D) and a general design framework (E) adopted from Wu (1994).

Several of the models and processes presented above have many similarities and share phases/main steps. Some models such as those by Wu (1994) do however not have an intermediate phase between concept design/development and detailed design. But, according to Johansson (2007), this phase has an important function when designing logistics-related systems. One of the main characteristics of Wu's design framework compared to other models is however the explicit setting of objectives, which is closely connected to and dependent on strategy; this will be addressed in the next section.

Expanding on Wu's design process, Säfsten (2002) presents different approaches from the perspective of a manufacturing company, (a) concept-generating approach, where all steps are taken, (b) concept-driven approach, where concept modelling and evaluation of concepts are left out, and (c) supplier-driven approach, where with (b) as a base also the first decision and the detailed design is left out.

Further, according to Wu (1994) there are two approaches when designing a system, setting the objectives without considering the existing system or considering the existing system and modifying it to fulfil the requirements. The framework suggested by Wu (1994) is a combination where the current situation is considered before setting the objectives. Also Bennett and Forrester (1993) and Bellgran (1998) note the design of the existing system as something to consider when designing a new system. This is also addressed by Wiktorsson (2013), who elaborates on the link between production system design and production system operations and the need to feed experience, knowledge and data from operations into design, and feed decisions, plans and guidelines from design into operations. In general, evaluation is emphasised as an essential part of a design process (Bellgran and Säfsten, 2010; Bennett and Forrester, 1993; Säfsten, 2002; Wu, 1994) and is often a recurring step in the models presented.

In the different process models presented above, each phase or step is in turn broken down into smaller steps with their own activities. Although the processes are presented or illustrated in a sequential flow it is rather an iterative process, often with overlapping activities. The degree of structure varies and is, as noted by Bellgran and Säfsten (2010), dependent on aspects such as the awareness of the complexity of problems, time and priority, availability of methods and information. The information aspect is well covered in Bruch (2012), in which the importance of continuously acquiring, sharing and using design information during the design process is stressed. Specifically in connection with logistics and the design of materials supply systems in manufacturing, Johansson (2007) points out that information that affects the flow, for example the type of production, needs to be obtained from the production department.

2.1.6 Strategy connected with improving internal logistics systems

As noted above by Wu (1994), improvement work should be closely connected to strategy. This section, dealing with strategy connected with improving internal logistics systems, starts with a short introduction to the strategy area and a description of the definition and view of the term strategy used in this research. Strategy connected with and having an internal logistics perspective is then discussed with a special focus on what it should include and how it can be formulated.

Strategy

There are many different and often conflicting views and perspectives of what strategy is (De Wit and Meyer, 2010). Mintzberg et al. (2009) summarise some of these views and perspectives using the five Ps for strategy, which entails that strategy can be a plan (intended), a pattern (realised), a position, a perspective or a ploy.

Further, according to De Wit and Meyer (2010), there are three dimensions of strategy:

- *strategy process* – refers to the manner in which strategies come about
- *strategy content* – refers to the product of the strategy process
- *strategy context* – refers to the circumstances under which both the process and the content are determined

When it comes to the process, strategic initiatives or formulation can be created either in a top-down or a bottom-up manner (Burgelman, 1983; Nonaka, 1988).

By dividing and combining four of the Ps across the two dimensions strategy process and content, Mintzberg et al. (2009) suggest four basic approaches to strategy formation as illustrated in the matrix in Figure 7.

		Strategic Process to:	
		Deliberate Plans	Emergent Patterns
Strategy Content as:	Tangible Positions	Strategic Planning	Strategic Venturing
	Broad Perspective	Strategic Visioning	Strategic Learning

Figure 7 The four basic approaches to strategy formation (Mintzberg et al., 2009).

The approach supported in this research is the strategic planning approach. The reasoning and motives for this are linked to both the theme of this research, which is connected with development work (where deliberate plans are sought to reach a tangible position), and the field in which the research is situated (where strategy is most often described as a plan or position). A definition of strategy that well corresponds to this view is adopted from Porter (2004b p.xxiv), who describes competitive strategy as *"a combination of the ends (goals) for which the firm is striving and the means (policies) by which it is seeking to get there".* This definition thus includes two views of strategy, both as a position (ends) and as a plan (means).

Skinner (1969) points out the importance of strategy and that companies must make active choices of approach and between different deliveries. Hayes and Wheelwright (1984) further conclude that a strategy must be convincing so that all levels of an organisation act in a supportive manner to the strategy.

Strategies are formulated and implemented at many levels in an organisation (Miltenburg, 1995). Hill (2000) defines four levels of strategy present within a firm's context and its environment:

- *Industrial level strategy* – concerns issues of an industrial sector or reflects the level and nature of government intervention.

- *Corporate level strategy* – concerns the market sectors in which a company competes and to what degree the company allocates its resources to each sector.
- *Business level strategy* – concerns the identification of the markets in which all the businesses compete and the dimensions of competition involved.
- *Functional level strategy* – concerns investment and the development of the necessary capabilities in order to fulfil the business level strategy.

These levels can be seen as hierarchical (Hayes and Wheelwright, 1984), where the corporate strategy is a long-term general statement of goals, and how competitive advantages will be achieved (Miltenburg, 1995). This should be broken down into the business strategy, which is more short-term and detailed than the corporate strategy (Bellgran and Säfsten, 2010). Functional strategies such as manufacturing strategy or research and development strategy are at the lowest level and should describe how the functional area in question will help achieve the business strategy (Miltenburg, 1995). When it comes to strategy connected with internal logistics and automation, they can be placed on the functional level (Jonsson, 2008; Säfsten et al., 2007) and could also be part of another, superior functional strategy or at least well connected to it since all functional strategies need to complement each other and be consistent with the business strategy (Miltenburg, 1995).

Strategy-related literature and research from the manufacturing field, which is closely connected to both internal logistics and automation, can thus be relevant to this research. Several frameworks for formulating manufacturing strategies exist (eg. Baines et al., 2005; Hayes and Wheelwright, 1984; Hill, 2000; Miltenburg, 1995; Platts et al., 1998; Skinner, 1969) which can provide input on the process of formulating a strategy as well as on the content of the strategy. Minarro-Viseras et al. (2005) also identified 36 key success factors, linked to the categories people, organisation and system, for implementing strategic manufacturing initiatives.

Strategy connected with internal logistics

On the supply chain level, strategy is an often recurring term being part of the supply chain management concept. Broken down specifically into internal logistics, strategy discussions are not commonly occurring in literature but support can be found in the overall logistics area, since it involves strategic aspects that need to be considered (Harrison and van Hoek, 2008; Jonsson, 2008; Storhagen, 2011).

La Londe and Masters (1994) point out the importance of having a logistics strategy, and McGinnis et al. (2010) conclude that the importance of logistics in overall organisational strategy has increased during the last two decades. Going back a few decades, during the 1970s-1980s a strategic view of logistics emerged in which logistics rather *was* the strategy. In the following decade, the strategic decision instead consisted of determining where the firm should operate on the cost/service trade-off curve (La Londe and Masters, 1994). This view has to some extent been retained, but while cost reduction is what traditionally has been in focus, future challenges are more connected with internal efficiency or service enhancements such as shortening lead times (Baker, 2004b; Christopher, 2005; McGinnis et al., 2010; Rouwenhorst et al., 2000).

Depending on how deliberate the strategy process is and what the goals of the strategy setting are, Whittington (2000) proposes four approaches to setting strategy: evolutionary, classical, processual and systematic. Harrison and van Hoek (2008) point out that logistics strategy usually demands a systematic strategy setting where the goals should be linked to the means by which they will be achieved in practice. One of the central parts of the logistics strategy is hence the goals, often related to the different aspects of (internal) logistics performance discussed in Section 2.1.4. As noted by Jonsson (2008), it is necessary to be aware of the conflicting nature of these aspects and the fact that they may be assigned different levels of importance by different people in a company. In internal logistics it is therefore not a question of optimising one individual performance variable, but rather creating efficiency and minimising suboptimisation within the company as a whole (Jonsson, 2008; Noble and Tanchoco, 1994; Rembold and Tanchoco, 1994). The internal logistic strategy formulation thus includes choosing from and making a trade-off between performance aspects in an attempt to achieve the best overall performance supporting the company's overall goals and strategy (Harrison and van Hoek, 2008; Jonsson, 2008; Miltenburg, 1995; Porter, 1996).

However, there is a lack of standardised ways of dealing with requirements in internal logistics (Finnsgård, 2009), which negatively affects the possibility of prioritising performance aspects forming the goals and hence the internal logistics strategy. For example, there are performance aspects such as environmental and ergonomic conditions that might be neglected due to the difficulty of quantifying them in terms of goals. Rouwenhorst et al. (2000) also state that there is a need for further research in the area of trade-offs between costs and operational performance in logistics.

Also, one improvement in a materials flow system might have a negative impact on other components of the performance of the system (Öjmertz, 1998). Or, as the water bed analogy by Zylstra (2006) illustrates, cost reductions in one area may actually "resurface" as increased costs in another area. Therefore, it is very important that the internal logistics strategy not only covers the goals of the internal logistics system but also involves the important task of measuring and following up the system, in order to actually know how it performs and be able to see how improvements or changes affect it. Besides the goals, the strategy should therefore consist of those plans or patterns of actions that relate to the flow of materials (Jonsson, 2008). It is also of utmost importance that the logistics strategy and its adherent plans are integrated and aligned with the company's other functions and strategies (Jonsson, 2008; La Londe and Masters, 1994; McGinnis et al., 2010; Tan, 2001).

2.2 AUTOMATION IN INTERNAL LOGISTICS AND ITS DEVELOPMENT

This section introduces automation and its driving forces in general and specifically in connection with internal logistics. Commonly occurring areas of application in internal logistics are described as well as common concerns associated with automation in internal logistics. Thereafter automation development is addressed, specifically support connected with the development process. Finally there is a survey of theory and previous research on strategy related to automation and its development.

2.2.1 Definitions 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 and Amber, 1962). This means that the automated technology can also be used together with or supported by human assistance.

Automation can be divided into mechanisation and computerisation (Frazelle, 2001b). Mechanisation mainly relates to the automation of and in the physical flow of materials, while computerisation refers to the automation of and in the flow of information. It can also be said that computerised technology deals with the control and support of mechanised technologies (Frohm et al., 2005). Since this research is focused on the flow of materials, the automation focus is mainly on the mechanised area of automation, but the information handling connected with managing and controlling both the physical flow and automation technology is of course an important part of the context.

Further there are different types of mechanised automation, ranging from fixed and programmable to flexible automation (Groover, 2008). Automation can also be used to several different degrees, which refers to the fraction of automated functions out of the overall functions in a system (Nof, 2009). The degree of automation is thus related to what is automated and what is performed manually. Fitts's famous MABA–MABA list (Men-Are-Better-At – Machines-Are-Better-At) from 1951 was created to give guidance in the allocation of functions between humans and machines. This analysis however inherited the view that automation is an all-or-nothing concept, something today often criticised by, among others, Parasuraman et al. (2008). The *level of automation* has therefore emerged as a concept often used when discussing automation and in particular to assess the degree of automation in terms of the extent to which a certain task is automated or performed manually. In contrast to the view of automation as an all-or-nothing decision, the level of automation can be described as a continuum, ranging between totally manual and totally automatic operations (Frohm, 2008; Parasuraman et al., 2000). Further, levels of automation scales have been proposed by, among others, Parasuraman et al. (2000), Sheridan et al. (1978) and Frohm (2008) and Lindström (2008) presents a methodology for analysing and choosing levels of automation.

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
- reduce labour cost
- mitigate the effects of labour shortages
- reduce or eliminate routine manual and clerical tasks
- improve worker safety
- improve product quality
- reduce lead time
- accomplish processes that cannot be done manually
- 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 line of business or type of activity being automated.

A large-scale survey among automation users in warehousing and distribution found that the following performance metrics in fact had been enhanced by automation (in parentheses, by the share of the respondents): order accuracy (61 %), throughput (58 %), cost per order (30 %), order fill rate (29 %), on-time delivery (22 %) and cycle time (17 %) (Material Handling Industry of America, 2011).

In another survey by the Material Handling Industry of America (2012), cost savings, improved efficiencies and accuracy/speed were found to be the most important operational factors driving automation investments in internal logistics systems. This is in line with a previous study by Baker and Halim (2007), who found the main factors that brought about the need for automation in warehouses to be to accommodate growth, reduce operating cost and improve customer service. Other factors mentioned were to reduce staffing level, consolidate inventories, improve accuracy, increase stock rotation and improve image. Other potential benefits of automation in logistics not mentioned in the previous studies are, based on Naish and Baker (2004), better use of floor space and buildings and less reliance on staff.

Improved work environment/ergonomics was surprisingly not cited as a main reason or driving force for automation in the studies above. 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 internal logistics often involves a large amount of manual, repetitive handling, heavy lifting and long transportation routes, a better work environment with improved ergonomics is one of the main advantages of using automation in internal logistics (Chung and Tanchoco, 2009; Cruz Di Palma and Basaldúa, 2009).

2.2.2 Automated applications in internal logistics

Since the 1960s automation has played a key role in the development of internal logistics (Kartnig et al., 2012), and today automation of certain logistics activities is reasonably commonplace, especially in large-scale operations (Baker, 2004a). The sales of automated materials handling equipment have also been growing steadily during the last decades (Baker and Halim, 2007; Cruz Di Palma and Basaldúa, 2009; Echelmeyer et al., 2008) and this trend is expected to continue (Material Handling Industry of America, 2010; 2012).

There are numerous possible automated applications and pieces of equipment that can be used for improving internal logistics activities. Below is a compilation of the most commonly occurring applications and types of mechanised automation used in internal logistics presented in a selection of publications (Aized, 2010; Baker, 2004ab; Baker and Halim, 2007; Dadzie and Johnston, 1991; Echelmeyer et al., 2008; Frazelle, 2001b; Jonsson, 2008; Lumsden, 2012; Rushton et al., 2006; Tompkins et al., 2010; Öjmertz, 1998):

- Automated loading and unloading systems
- Automated guided vehicles (AGVs)
- Automated storage and retrieval systems (AS/RS)
- Automatic fork-lift trucks for mechanised handling

- Carousels (various types)
- Conveyor belts and conveyorised sorting systems
- Industrial robots/robotics (for numerous applications)
- Item-picking devices
- Lift and turn tables/aids
- Linear actuators
- Mechanised palletising
- Moving decks
- Screening and/or sorting systems

In addition to these mechanised automation applications, various forms of information automation for communication, data handling, monitoring and control, etc., are also mentioned including automatic identification and recognition applications such as barcode and RFID systems, vision systems as well as various IT systems for planning, managing operations and systems, etc.

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, benchmarking of automated applications in other business areas could be very valuable in developing the area of automation in logistics.

2.2.3 Concerns regarding automation in internal logistics

As with any other technology, there are difficulties and potential challenges of using automation. Several studies (eg. Material Handling Industry of America, 2011; Baker and Halim, 2007; Dadzie and Johnston, 1991; Naish and Baker, 2004) have investigated the most common concerns or problems associated with automated equipment in logistics operations. The most commonly mentioned concerns were:

- 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 it
- 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 with the automation technology were related to the following:

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

A study by Hofmann and Orr (2005) on the adoption of advanced manufacturing equipment showed that middle management more than other business levels was worried about the workers' acceptance of the new technology while the process workers were more worried about interruptions during the installation.

Implementing automation in logistics activities often enables a redistribution of resources in the organisation (Echelmeyer et al., 2008). Since the use of automation can improve efficiency, it often leads to a reduced number of 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 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 improvements, there is a risk of disruption and service level failings during the implementation and start-up of an automated system before the 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 experiences of dealing with similar projects and technology and perhaps foremost the degree of preparations and planning.

Further, prerequisites that affect the automation decision in internal logistics could be the number and diversity of goods to be handled (de Gea Fernandez et al., 2007; Frohm et al., 2006). One of the most common arguments against automated equipment is that it is generally considered inflexible. However, this depends on the type of automation. Based on the prerequisites and intended area of use, the suitability of the different types varies. Hackman et al. (2001) conclude that inefficiencies in highly automated logistics systems, in addition to the lack of adequate maintenance and the difficulty of reconfiguring the systems, often depend on inappropriate selection of system types.

2.2.4 Automation development

It is important to remember that the use of automation does not per se guarantee advantageous results. The wrong technology, or even the right technology poorly implemented, can instead have negative effects (Baines, 2004). The key to a successful use of automation thus lies in finding, selecting, acquiring and properly implementing the right type and level of automation in relation to the company's needs, goals and prerequisites (Baines, 2004; Ceroni, 2009; Daim and Kocaoglu, 2008; Spath et al., 2009). The process of developing automation, which includes all those steps, is thus a crucial part in determining the success of automation investments and the use of automation (Baines, 2004; Spath et al., 2009). This in turn puts great demands on the company's way of working since it requires that the automation development process is well structured and supported.

Before automating, it is important to understand the operations of which the automation should be part. 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 before automating (Frohm et al., 2003).

Further, from a survey study Tu et al. (2011) conclude that automation can increase performance in a system but first it is important to make sure that there is proper system integration, i.e. physical connections and information flows among the system components. Also Hammer (1990) and Groover (2008) address this and point out the importance of structuring the processes for current needs before automating.

As with development processes in general, it is important to have a process model for automation development. Baker and Halim (2007) have created a model of the generic steps in a typical warehouse automation project divided into three main phases: pre-project phase, implementation phase and post-project phase, each with its substeps. Unfortunately, since this model was not intentionally created as a guideline, it does not thoroughly describe the steps in the process. Also, this process is mostly based on and adjusted for large-scale automation implementations of complex and extensive automated systems, which thus only covers parts of the possible uses of automation in internal logistics. Thus, there is a need for a more detailed process description that also suits small-scale automation projects.

Also outside the logistics area, previous research into current technology acquisition practices has highlighted the lack of formal structure for acquisition activities as well as a lack of mechanisms to support decision making and plans for implementation and concluded the need for a structured approach (Durrani et al., 1998; Sambasivarao and Deshmukh, 1995). But there are in the literature a number of frameworks, processes and other types of support models connected with and relevant for managing the process of automation development. Table 1 presents a selection of identified literature and its main content and characteristics.

A large part of the support presented in Table 1 comes from the area of advanced manufacturing technology (AMT), which includes automation but is not limited to it. Most literature also primarily covers the acquisition process and not the entire development process. There is thus still need for process support particularly addressing mechanised automation and covering the entire automation development process. The support should also be suitable for the context of internal logistics systems in which also small scale automation investments are of interest.

Hammer (1990) emphasises that automation technology should be used to help the customer of the automation equipment to “help themselves” and become less dependent on experts. As noted in the study by Baker and Halim (2007), most companies during warehouse automation projects take help from consultancy firms, equipment suppliers and/or a system integrator to complete many of the steps in the development process. Hax and Majluf (1991) address the extent to which the firm will rely on third parties as one of the strategic decisions that is linked to technology management and hence needs to be actively addressed. On the same note Baines (2004) emphasises a rigorous supplier selection due to its large impact on the automation development process and its outcome.

Table 1 Identified theoretical support connected with automation development

Source	Type of support	Description
Baines (2004)	Technology acquisition process	Nine steps and five gates. The steps: technology profiling, establish requirements of technology, find technological solution, form outline business case, choose technology source, demonstrate technology, confirm business case, implement technology, post-investment audit.
Durrani et al. (1998)	Technology acquisition process	Five stages: establish market-place requirements, identify technology solutions, classify the technology solutions, assess sources of technology acquisition, make the technology acquisition decision.
Trudel and Goodwin (1990)	Automation project process	Five key decisions points: development strategy, establishing system architecture, system design and specification, communications and start-up support. Focuses computer-integrated manufacturing.
Archibald (2003)	Approach to handling technology projects	Specific focus on project management issues during large-scale technology projects.
Meredith (1987b)	Framework for managing automation projects	Four primary phases: initiation, planning, implementation and control. Focus on useful project management concepts and techniques.
Langley and Truax (1994)	Technology adoption process	Three subprocesses: strategic commitment process, technology choice process and financial justification process.
Sambasivarao and Deshmukh (1995)	Approach for implementation of AMT	Lists 14 issues involved in technology implementation procedures.
Hax and Majluf (1991)	Strategic decisions linked to technology management	Categories of decisions linked to technology selection, acquisition, strategy, planning, etc.

2.2.5 Strategy connected with automation development

The use of technology such as automation affects competitive advantage and can worsen as well as improve a firm's competitive position (Porter, 2004a). Before considering automation, it should therefore 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 prerequisites, not the other way around. Säfsten et al. (2007) for example address the concept of rightomation, and Meredith (1987b) stresses that an automation project ideally is the logical outcome of a business strategy that can best be achieved through automation.

Of the literature on the automation development process presented in Table 1, many sources in different aspects point out the need for strategy connected to and supporting the automation development process. For example Trudel and Goodwin (1990) list development strategy as the first key phase/decision point, Langley and Truax (1994) list the strategic commitment process as one of the three subprocesses and Hax and Majluf (1991) present categories of strategic decisions linked to technology that need to be made. The value and importance of strategy connected to the automation development process (as well as vice versa) is also mentioned in other sources (e.g. Arvanitis and Hollenstein, 2001; Greenfield, 2003; Kotha and Swamidass, 2000; Sambasivarao and Deshmukh, 1995). Hax and No (1992) point out that a technology strategy cannot be created in isolation from the corporate objectives and the businesses it is intended to support. Successful automation decisions are rather made in line with what the company aims for in the long term and are synchronised with the company's strategies and capabilities (Winroth et al., 2007). According to Sambasivarao and Deshmukh (1995), a company must, before investing in advanced manufacturing technology such as automation, first reassess its direction, strengths and weaknesses and develop a strategy for successful implementation accordingly. This however rarely seems to be the case (Granlund, 2011). Automation-related decisions are often made ad hoc and based on other issues than solid facts and a well-defined strategy (Winroth et al., 2007). It is, as also noted by Hill (2008), surprising that many companies still do not appreciate or recognise the impact an automation strategy has on the company's overall operating objectives. Winroth et al. (2007) have also acknowledged the need to improve the development of automation strategies.

In the manufacturing area, Skinner (1969), Hayes and Wheelwright (1984) and Miltenburg (1995) only deal with automation very briefly and as an issue that is involved in the process technology decision. Chiesa and Manzini (1998) and Hax and No (1992) suggest different models for developing a generic technology strategy, while Ford (1988) suggests an eight-step audit for its formulation. Hax and Majluf (1991) present major categories of strategic decisions linked to technology selection, acquisition, projects, organisation, etc.

Further, in Lindström and Winroth (2010) a five-phase method for formulating an automation strategy is presented, but it does not address the content of the strategy. Winroth et al. (2007) and Säfsten et al. (2007) suggest two different approaches to automation strategy, automation either being the manufacturing strategy or being one of several decisions within the manufacturing strategy. The latter view, where automation is a functional strategy strongly related to the business strategy and other functional strategies, is the view supported in this work. Lindström (2008), for example, describes automation strategy as the fit and alignment of choices on automation and the higher system related to manufacturing and business strategy.

To conclude, while the importance and need of strategy connected with automation development and decisions and some support for the formulation of an automation strategy can be found, there is less support and descriptions of the actual content of the automation strategy (Säfsten et al., 2007; Winroth et al., 2007).

2.3 REFLECTIONS FROM THE THEORETICAL REVIEW

Since it can be difficult, and not always relevant, to clearly single out internal logistics activities from other parts of operations, relevant literature and previous research in the area might have been overlooked due to difficulties in identifying it or properly interpreting its context. Also, as noted by Gu et al. (2010), there have been few publications in the internal logistics area and specifically regarding design decisions during the last 10-15 years.

When it comes to automation in internal logistics, large parts of previous research focus on warehousing and often large-scale and complex automated solutions, the latter trend being evident in automation-related research in general. Also, a large part of previous research on automation both in general and specifically in internal logistics focuses on optimisation, simulation and/or task allocation, and little research was found on the process of developing automation. Related research that was found suitable and that investigates the process of developing automation instead often originated from the area of advanced manufacturing technology.

Further, the literature addressing the design and improvements of and in internal logistics systems strongly focuses on attaining high efficiency and not as much on the effectiveness aspect. This might be related to the small amount of research on how to link internal logistics operations to strategy and vice versa despite the need often pointed out in related design and improvement work literature. Also connected with developing automation was the need for connection to business goals and strategy often pointed out, but only a small amount of literature addresses the content and structure of an automation strategy.

3. RESEARCH METHODOLOGY

This chapter presents the research methodology applied. The chapter begins with a presentation of the author's research philosophy and the research approach. The chosen research method is then explained and the research process is presented. The studies conducted are described along with the data collection and data analysis process. The chapter concludes with a discussion about the quality of the research.

3.1 RESEARCH PHILOSOPHY AND APPROACH

One of the critical aspects that influence the design of research studies is the paradigm (or paradigms) within which the work is situated (Maxwell, 2005), this because in every paradigm there are certain general philosophical assumptions about the nature of the world (ontology) and how we can understand it (epistemology). One component of the paradigm is thus the research philosophy, which strongly affects the way of conducting research since the research process in every step involves making assumptions. These assumptions tend to be shared by researchers working in the same field (Maxwell, 2005). But it is nonetheless important to reflect on your research philosophy since it typically underpins your research strategy and the methods you choose as part of that strategy (Saunders et al., 2012).

The author's research philosophy is connected with positivism and realism or rather somewhere in between them. Both philosophies entail an objective view of the world that will affect the way the object of study is viewed. In both philosophies, credible data and facts are collected on an observable reality or phenomenon. For positivists, the research focus is causalities and law-like generalisations while for realists the focus is on explaining within a context (Saunders et al., 2012). While causalities are of interest in this research, it is understood that the research results are connected to, and valid in a specific context (rather than law-like), a context that is also of utmost interest for the research. In this research it is also understood that as a researcher you are biased by your views, experiences and culture (realism) but the goal, when conducting research, is to be as value-free as possible (positivism). However, it is understood that the latter can never fully be achieved since in order to be able to understand the phenomena and make a conceptual contribution, interpretations of qualitative data must be made.

The area of study in this research is the process of improving internal logistics, specifically using automation. This process takes place in a context that, as noted above, is important to consider. The context is the internal logistics system, which is a complex system involving a number of elements, subparts and interrelated activities. The system is in constant exchange with, affected by and dependent on its surroundings and has a large impact on the processes in the system. Due to this, the systems view has been adopted during this research. Situations characterised by rapid change, multiple interests, limited resources and high complexity are good candidates for the systems perspective (Leonard and Beer, 1994), and this is to a great extent the case when it comes to logistics in any industrial or organisational setting.

The adoption of this particular view has some consequences for the research process and results worth noting. In line with the research philosophy described above, the systems view allows an objective conception of the reality, but since the knowledge created is dependent on the context (the system), it cannot be regarded as general but valid only for specific classes of systems (Arbnor and Bjerke, 2009). Further, since one of the essentials of systems theory is that the system is a whole that cannot be taken apart without loss of its essential characteristics and hence must be studied as a whole (Ackoff, 1972), a holistic point of view has been adopted during the research. In the frame of reference (Section 2.1.3) an effort has also been made to describe the system studied. It is important to note that the description of the system is always an interpretation and simplification of the reality studied but it has to be based on studies of the real system (Arbnor and Bjerke, 2009). Systems theory has in fact been described as a framework for thinking about, making sense of and finding ways of improving real-world situations that are perceived as problematic (Checkland and Haynes, 1994). This is in line with categorising this research as applied. This implies that the knowledge developed as a result of this research should not only be of scientific value but also of practical use. To achieve this, an abductive research approach has been applied, where the empirical data collection and theory building phases overlap in a learning loop (Dubois and Gadde, 2002; Lundberg, 2000). To some extent also existing theories and frameworks from other areas (such as design of production systems) have been applied to a new phenomenon (improving internal logistics systems), which also corresponds to an abductive approach. Thus, during the studies conducted, there have been elements of theory testing but the research in general is of an exploratory character aiming at theory building.

To ensure both academic and practical relevance, the research undertaken has also in some stages (further explained in the different studies below) been inspired by an interactive approach, which is characterised by a joint learning process together with the participants (Larsson, 2006). These interactive elements have, however, not always been the focus of the research and the main responsibility for the research process and especially the theoretical development rests with the author.

3.2 RESEARCH METHOD

The choice of research method and design should be guided by the research objective and the research question(s) (Saunders et al., 2012). Since this research has scientific goals that are related to understanding processes and the particular context these processes take place in and to some extent also develop causal explanations, the research has had a qualitative design (Maxwell, 2005). This implies that methods for collecting mainly qualitative data were needed and that the data collected should be analysed in a qualitative way to be able to achieve those goals.

To be able to fulfil the objective of this thesis and answer the research questions, a multiple research method was chosen. The main method used in this research is the case study method. The reasons for choosing the case study method are several. One of the main reasons is that it is a suitable method for studying a phenomenon within its real-life context (Yin, 2009) and especially appropriate for situations where the experiences of individuals and the contexts of actions are critical (Darke and Shanks, 2002). As discussed above it has been highly important to be able to actually study the real phenomena and connected experiences and the importance of the context has also been lifted. The case study method is also suitable for *exploratory "what" questions* (RQ1) and *explanatory "how" questions* (RQ2) (Yin, 2009) as is the case in this research. The case study approach is also suitable when, as in this research, aiming at theory building due to the likelihood of generating novel theory from cases (Eisenhardt, 1989). Through multiple sources of evidence the case study method can also be used to study both current phenomena through longitudinal real-time cases and past phenomena through retrospective cases (Leonard-Barton, 1990), which has been useful in this research since it made it possible to study several cases in different depths.

The case study method was supplemented by a survey method. The survey method was chosen since it gathers information faster and with fewer means from a larger sample than for example case study or interview methods (Bell, 1999) and it is also possible to generate findings that are representative of the whole population (Tanner, 2002). The combination of case and survey methods can expand the scope of the research, giving a more detailed understanding and leading to more precise and generalised results (Miles and Huberman, 1994). The survey method thus complemented the case study method and made it possible to study a larger population than if only case studies had been used. In addition, data collected by a survey method can be used to suggest possible reasons for particular relationships (Tanner, 2002), which was sought for to understand how the process of improving the internal logistics system could be facilitated.

3.2.1 Case study design

This section covers some of the generic features of and rationales for the case study design. The actual designs of the case studies conducted are, however, described in detail in relation to each study in Section 3.3.

With reference to the time aspect there are two main types of cases: real-time cases and retrospective cases. In retrospective cases, collection of data on historical events is possible but it can be difficult to determine cause-and-effect relations and participants may not recall important events (Voss et al., 2002). Real-time cases on the other hand overcome these problems but may be difficult to conduct due to time requirements (Voss et al., 2002). Both types are possible and suitable to use when studying the process of improving the internal logistics system and the process of automation development. In this research a combination has therefore been used to strengthen the validity of the research (Leonard-Barton, 1990).

When designing case study research there are also other choices to be made, such as between single and multiple case design (Voss et al., 2002; Yin, 2009). Single cases have the advantage of greater depth but limited generalisability and increased risk of bias, while for multiple cases the situation is reversed (Voss et al., 2002). In this research, depending on the purpose of each study, a combination of single and multiple case designs has been used. Multiple case design was preferred in Studies A, C and F due to the increased external validity (Voss et al., 2002), while the rationale for the single case design in Studies D and E was a longitudinal case to enable in-depth studies (Yin, 2009).

The case studies in this research have had both a holistic and an embedded design (Yin, 2009), and the unit of analysis has, as described in Table 1, been the process of improving the internal logistics system and/or the automation development process, either in the context of the internal logistics system or the case company. The unit of analysis represents the major entity that has been analysed in the studies.

3.2.2 Case selection

As previously explained, internal logistics systems exist in a number of lines of business. The structure and prerequisites of the system are common features regardless of the business (Jarrett, 2006). In this research, cases in three lines of business have been studied: the manufacturing industry, the healthcare sector and the warehousing and distribution sector. But in the studies, the focus has not been on the line of business. The reason for choosing cases in different settings was to study the same system and adherent development processes in different settings, this in term of differing experiences of automation but also different ways of working with improvements and development specifically connected with the internal logistics systems and automation. Studying several lines of business thus provides a wider view of the specific challenges and prerequisites connected with developing automation in internal logistics systems.

Further, cases in different sizes of companies have been studied. This is also to cover different settings and thus different prerequisites, approaches, problems and challenges and to aid transfer of knowledge between them. The size of the companies in the studies has also varied as an effect of the different phases of the research and which research question was in focus. In the early phases of the research and when the focus was on the first research question, the studies were in general directed towards smaller companies and/or lines of business traditionally not associated with automation development, since they often have inferior conditions and prerequisites in the form of little experience (and confidence) of automation (Caldwell et al., 2009) and thus have the most challenges to overcome. In the later phases of the research and when the focus was on the second research question, the studies were instead mainly directed towards larger companies and/or lines of business traditionally associated with structured improvement work and automation development, since they can be assumed to have superior conditions and prerequisites for the types of development work studied and thus provide useful experience and knowledge. But there has also been an overlap in the sense that challenges and problems have been studied also in larger or more experienced businesses and enablers and facilitators have been studied also in smaller and less experienced businesses. Studying companies of different sizes thus provided a more nuanced picture of the research area.

Further, all cases were selected for theoretical rather than statistical reasons (Eisenhardt, 1989) due to the theory building aim of the research.

3.3 THE RESEARCH PROCESS

The research has been undertaken through a literature study and six empirical studies (Studies A-F), of which five were case studies and one a survey (Study B). Table 2 gives an overview of the empirical studies conducted but since they differed in topic and had different objectives and hence structure, they are each from the point of view of research design, data collection and data analysis described separately in Sections 3.3.2 – 3.3.7. The overall process for data analysis is described in Section 3.4.

The research process is schematically illustrated in Figure 8 showing when the different studies in terms of data collection were performed and roughly when the appended papers were written in relation to the three large milestones in the research, i.e. the start of the studies and the presentations of the licentiate and doctoral theses. How the appended papers relate and contribute to the two research questions is illustrated in Table 3, where a large X indicates a strong contribution and a small x indicates a contribution.

Table 2 Overview of the empirical studies conducted

Study	**Study A**	**Study B**	**Study C**	**Study D**	**Study E**	**Study F**
Type of study	Exploratory embedded multiple case study	Descriptive survey	Exploratory and descriptive embedded multiple case study	Exploratory and explanatory holistic single case study	Explanatory holistic single case study	Exploratory and explanatory holistic multiple case study
No. of case companies (cases)	8 (8)	47 (of 300) survey responses	3 (4)	1 (1)	1 (1)	1 (3)
Type of case(s)	Retrospective	-	Retrospective	Real-time	Real-time	Real-time and retrospective
Study topic	Prerequisites for using and developing automation in internal logistics systems at SMEs	The internal logistics system	The use and management of automation in healthcare internal logistics	Development of an automated solution	The process of improving the internal logistics system and adherent challenges	Facilitating the automation development process
Contribution to RQs*	RQ1, rq2	RQ1, rq 2	RQ1, RQ 2	rq1, RQ2	RQ1, rq2	rq1, RQ2
Main unit of analysis	The process of improving the internal logistics system	Perception and development of the internal logistics system	The process of improving the internal logistics system	The automation development process	The process of improving the internal logistics system	The automation development process
Embedded unit of analysis	The automation development process	-	The automation development process	-	-	-
Main data collection techniques	Interviews, observations and questionnaire	Questionnaire	Interviews, documents and observations	Interviews, observations, process measurements	Interviews, documentation, participant observations.	Interviews, documents, participant observations
Main data analysis techniques	Coding, clustering, categorisation, pattern matching	Descriptive statistics, tabulation, coding, clustering, categorisation	Explanation building	Design process tools	Coding, clustering, categorisation, pattern matching, explanation building	Coding, clustering, categorisation, pattern matching, explanation building
Study outcome	Initial mapping of industrial problems and challenges	Mapping of how the internal logistics systems is viewed and developed	Identification of challenges and success factors for automation development in internal logistics	Automation support for new users	Identified prerequisites for the process of improving the internal logistics system	Model for automation strategy
Presented in Paper(s)	I, IV	II, IV	III, IV	IV	V	VI

* RQX = strong contribution to research question X, rqX = contribution to research question X.

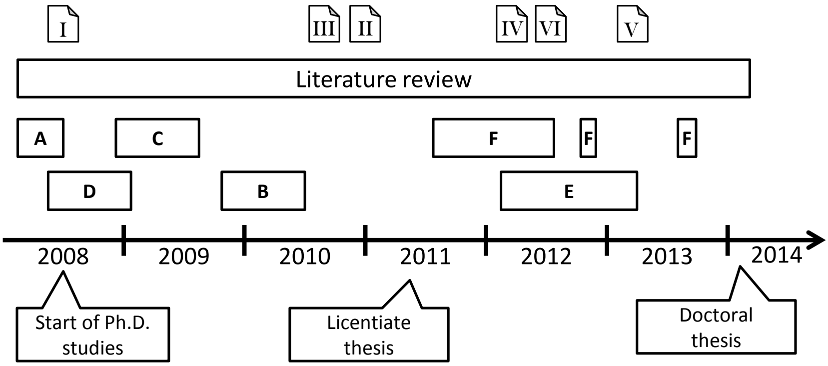

Figure 8 Overview of the research process.

The rationale for naming the studies is related to the way in which they contributed to the progress of the research and the logical construction of the research results rather than the chronological order in which they were conducted. For example, Study D was in reality conducted before Study C, but based on the findings and conclusions from Study C the data from Study D were reanalysed and the experiences were examined from a new perspective made evident by the later findings. In the same way the results from Study B contributed to better understanding of the findings in Study C.

As illustrated in Figure 8, a review of literature has been ongoing throughout the research process. The review was conducted to give an understanding of the research area and previous research connected with it. It has contributed directly by giving an input to answer the research questions and indirectly by providing a base for designing the empirical studies, analysing the data and developing the research results.

The first empirical study conducted, Study A, filled the purpose of research clarification (Blessing and Chakrabarti, 2009) and involved an initial mapping of the industrial problem areas, needs and challenges connected with improving internal logistics using automation. The aim was to structure an initial model of the research area and, based on the empirical findings, pinpoint industrial problems and theoretical gaps that would set the goal and help plan for the coming research.

Studies B and C helped identify additional challenges for a successful use of automation as a means of improving the internal logistics system and develop a deeper understanding of the challenges identified in Study A, their causes and effects. The first study of a prescriptive character was Study D, in which methods for automation development were explored. The experiences from Study D together with the findings from Studies A-C were used to develop a first version of a supporting framework for automation development in internal logistics presented in the licentiate thesis (Granlund, 2011).

Two extensive and longitudinal case studies (Studies E and F) were conducted after the presentation of the licentiate thesis and gave the possibility to further develop and evaluate its results. Study E was a deeper investigation of the process of improving the internal logistics systems to understand how it works and can be facilitated, while Study F focused specifically on how the process of developing automation can be facilitated. The main data collection in Study F was made between August 2011 and June 2012 but there were two follow-up and evaluation occasions in connection with this study (further described in Section 3.3.7).

Table 3 The relation of the appended papers to the research questions

	Paper I	Paper II	Paper III	Paper IV	Paper V	Paper VI
RQ1	X	X	X	X	X	x
RQ2		x	X	X	x	X

3.3.1 Literature review

An extensive literature review related to the process of improving the internal logistics system and automation development in internal logistics has been performed throughout the research. The literature review was conducted by searching for academic literature using online search engines that cover several databases and also by searching directly in specific databases. The search engines used were Google Scholar, ELIN@mälardalen (no longer available), SewPub and Discovery. The databases directly searched were Scopus and ScienceDirect. The following main keywords were used during the searches, sometimes separately but most often in combination with each other (two or more):

- Logistics
- Internal logistics/Intra logistics
- Materials handling
- System
- Development
- Improvement
- Process
- Automation
- Strategy
- Acquisition
- Technology

Besides the database searches there was also a degree of a snowball effect when references and sources used in literature that were found suitable and interesting were further investigated.

3.3.2 Study A

Study A was a multiple case study of eight companies, mainly SMEs (small and medium-sized enterprises). The aim of the study was to gain a deeper understanding of how the case companies work with improvements of their internal logistics systems, especially with regard to automation. The study covered the following topics:

- the interest, knowledge and needs for improving the internal logistics system
- to what extent the case companies apply automation to internal logistics activities
- problem areas and difficulties connected with the processes of improving internal logistics and developing automation
- future industrial needs connected with internal logistics and automation

The design of Study A with its eight cases, context and units of analysis (UoA) is illustrated in Figure 9.

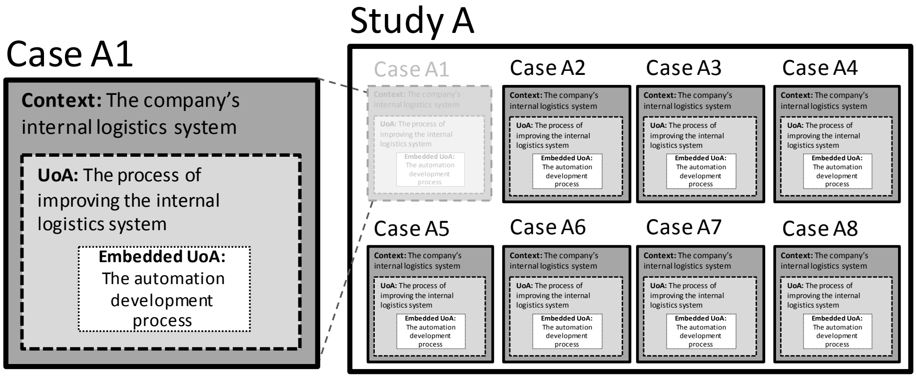

Figure 9 Research design of Study A.

The sample in this study comprised eight companies. The sampling frame consisted of in first hand SMEs (fewer 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. Information about the participating companies and the data collection is compiled in Table 4.

Table 4 Case company information and data collection, Study A

Company information					Data collection		
Case no.	Line of business	Own products	Sub-contractor	Size (est.)	Interview	Observation	Questionnaire
Case A1	Producing industry	X		M	X	X	X
Case A2	Producing industry	X		S	X	X	X
Case A3	Producing industry		X	S	X	X	X
Case A4	Producing industry	X		M	X	X	X
Case A5	Producing industry	X	X	L	X	X	
Case A6	Warehousing and distribution	X		M	X	X	X
Case A7	Distribution		X	M	X	X	X
Case A8	Food industry	X		S	X	X	X

Three 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 once for observation of the internal logistics system. During the observations, a guide highly acquainted with the organisation and its internal logistics system (often the production/logistics manager or plant manager) gave a tour, hence providing a holistic overview of the system. Unstructured interviews without pre-formulated questions (Bryman, 1995) 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 of an unpolished view of the system.

In each case, a semi-structured interview with the person strategically responsible for the internal logistics was conducted. The interviews ranged between 40 and 90 minutes and interview guides were used. A self-administered questionnaire (Bryman, 1995) was distributed to the interviewee after the interview. One case company did not respond to the questionnaire. The questionnaire partly covered the same aspects as the interviews, to enable triangulation of the data. It also allowed for different kinds of questions of a quantifiable nature (Yin, 2009). The questionnaire mainly contained structured questions, where the respondents were asked to choose from a set of alternative answers. However, a few open questions, to which the respondents could freely formulate answers, were included.

To strengthen the quality of the research (further discussed in Section 3.5), two people took notes during the observations and interviews and afterwards documented the collected data individually. The data were then compared to verify concordance before they were compiled, reduced, displayed and coded (Miles and Huberman, 1994). The data were thereafter categorised (Merriam, 1998) according to previous and future improvement measures and their causes, how the company worked with improvement work in internal logistics, and general thoughts and views regarding internal logistics and automation. The data were also searched for recurring patterns (Yin, 2009) and trends among other examples connected with 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 to the structured questions (with answer options) were compiled for each question and then searched for recurring patterns (Yin, 2009).

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, prerequisites and needs for using and developing automation in the internal logistics system at the case companies.

3.3.3 Study B

Study B was a survey study with the aim to understand how manufacturing companies work with, perceive and develop their internal logistics systems. The internal logistics system was hence the object of study. 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 study set out to explore not only what performance criteria were most important, but also what performance measurements were used to monitor the internal logistics. Improvement areas (from both a long- and a short-term perspective) were also covered, along with responsibility aspects.

A self-administered questionnaire (Bryman, 1995) 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 at the company, etc. The second part contained both open questions (where the respondents could freely formulate their responses) 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 (Swedish Standard Industrial Classification (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 thereafter random, performed by the company providing the business information (address and contact name).

Of the 300 questionnaires sent out, 47 usable responses were received. 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. Being a descriptive survey, the aim was not to receive a fully statistically secured result (Tanner, 2002). Instead, this study was intended to give an outlook on the current situation, views and trends from a larger sampling of respondents that the otherwise applied case study method enabled. The resulting response rate of useful answers was 16 %, which can be considered as both common (Williamson, 2002) and adequate given the purpose and intentions of the study.

The size of the responding companies, in terms of number of employees, can be seen in Figure 10.

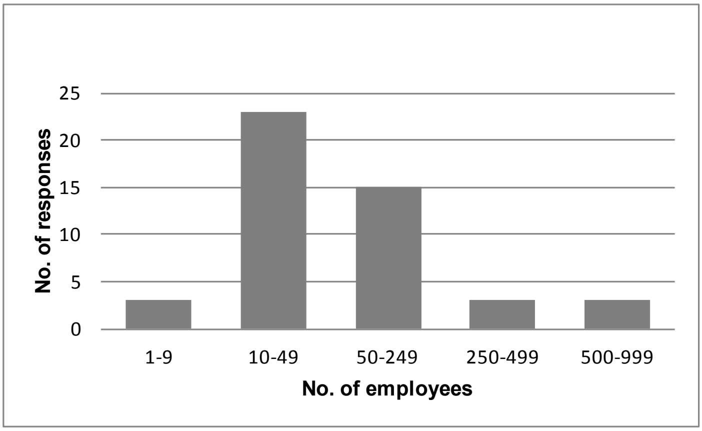

Figure 10 Size of responding companies, Study B.

The answers from the survey were coded to facilitate comparison between similar answers (Maxwell, 2005) and then clustered by sorting the coded answers into groupings that had something in common (Holme and Solvang, 1997; Merriam, 1998), in that way creating data-driven categories (Saunders et al., 2012). The results from the questions with answer options were compiled and presented as number/share of responses and ranking averages for the different options. As a result, the answers were treated as statistical data and analysed and presented using descriptive statistics. The results from this study were not intended to be fully statistically verified, but were still chosen to be analysed and displayed in a descriptive statistical way to enable the results to be analysed for trends, etc.

3.3.4 Study C

Study C was a case study in the healthcare sector. The objective of Study C was to examine and analyse the use and management of automation and its development in internal logistics systems. Success factors for automation development were mapped, as well as challenges to deal with in order to better benefit from automation.

In order to fulfil the objective, Study C was planned and executed as a multiple case study consisting of three substudies (Case C1-C3) with somewhat different purposes, scopes and approaches, individually described below and illustrated in Figure 11. The main logic of conducting a multiple, but not replicated, case study was to build a comprehensive understanding, where the findings from the different substudies together build a complete body of knowledge. Thus, the three cases were selected in order to complement each other and cover a wide range of hospitals with different prerequisites and levels of applied automation.

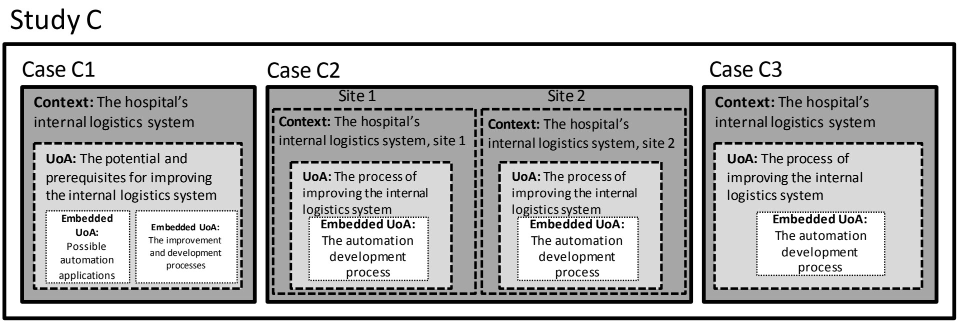

Figure 11 Research design of Study C.

Case hospital C1 is a Swedish hospital with 400 beds, chosen since its physical and organisational conditions represent the majority of Scandinavian hospitals in terms of size, age and organisational structure. Case hospital C2 is one of Europe's largest hospitals with 1,680 beds distributed across its two sites. Case hospital C2 was selected since it actively works with improving its internal logistics system and one of the explicit ways it does so is through automation. The hospital was also in the process of planning and designing a new future site (which will replace one of its current sites), which made it possible to follow that process in real time. The third case, Case C3, aimed at being a role model, describing a possible future in hospital logistics. Case hospital C3, with its 675 beds, 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 regard to the level of technology and the way of working.

Three main methods for data collection were used in Study C: observations, interviews (open and semi-structured) and archival records/documents. Table 5 gives an overview of the data collection conducted in the three cases.

Table 5 Overview of data collected in Study C

	Case C1	Case C2	Case C3
Observations occasions (duration)	3 (1.5-3.5 h)	2 (3-4h)	1 (5 h)
Observation areas	*E.g. nursing wards, storage sections, corridors and culvert systems, transportation department (incl. areas for handling supplies, waste, laundry, food, mail and patient transports), laboratory, etc.*		
Interviews number (duration)	23 (20-90 mins)	6 (15-90 mins)	3 (35-60 mins)
Respondents	*Nurses, heads of nursing wards, director of ward division, hospital coordinator, manager of transportation department, transportation staff.*	*Logistics system project manager, supply manager, persons responisible for automated systems (such as AGVs, phenumatic tube-system, industrial robots, etc.).*	*Hospital coordinator, manager of information, communication and technology department, manager of service and technology department.*
Documents	yes	yes	yes
Types of documents	*E.g. time studies, reports, information and presentation materials, strategy documents, handbooks, work instructions, gudielines, photographs, layouts, plans of action, etc.*		

The direct observations mainly involved being guided through the internal logistics system with a special focus on internal transports (of both patients and goods), storage and materials handling activities and adherent areas. This was to understand how the internal logistics system was structured and together with the data from the interviews the observations also gave an understanding of how the system had been developed and could be/was planned to be improved. During the observations special attention was also paid to automation applications (both current and potential), how they had been developed was covered during the interviews. Observation notes were taken and during the analysis scanned for general themes mentioned and compared with the results from the interviews.

The interviews in general covered current practice and the way of working in the internal logistics system with a special focus on improvement processes and the use of automation. But due to the different roles of the cases, the interview topics also differed. In Case C1, the focus was mainly on potential improvement areas (both in the actual system and in the way of working). Case C2 concentrated on the way of working with improvements, both operatively in the current internal logistics systems and strategically with the development of a new internal logistics system for the future site. The area of interest in Case C3 was the process of developing the hospital internal logistics system (how it had been conducted and why, experiences, etc.) and experiences from current operations with a focus on automation.

Besides the observations and interviews, documents were gathered and studied in order to verify or further investigate areas discussed. The documents were also a good complement to the interviews and observations since they enabled a detailed study of several aspects not otherwise possible. Among other things data from a time study at Case hospital C1 were collected. The time study was performed at 13 of the nursing wards with the nurses mapping activities every ten minutes, day and night, over a period of 14 days, using a form with 30 predefined activities. The material was compiled to describe which activities were most time-consuming.

With its three subcases, Study C was a comprehensive study that included many aspects and resulted in a large amount of collected data. Therefore, special attention during the data analysis was paid to data reduction, i.e. the process of selecting, focusing, simplifying, abstracting and transforming the data collected (Miles and Huberman, 1994). Data reduction is a form of analysis that sharpens, focuses and organises data in such a way that the research questions can be answered and conclusions can be drawn and verified. It is hence a continuous process throughout the life of any qualitatively oriented project (Miles and Huberman, 1994).

The data were mainly analysed by building an explanation about the case by identifying and describing the causal links within and between the subcases, a method referred to as explanation building (Yin, 2009). 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 were 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. Also, in the cases with the same units of analysis the objective of the cross-case analysis was twofold: find what is common across the cases and focus on the differences, a perspective encouraged by Stake (2006).

Since other researchers than the author were involved in this study, there is a need to clarify the roles. In Case C1, the author, together with two other researchers, was responsible for the planning of the study and analysing data collected. However, the other two researchers had the main responsibility for gathering data. The same three researchers performed all data collection in Case C3 to guarantee a broad 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 would help answer the research questions at hand and to fulfil the objective of this research.

3.3.5 Study D

Study D was a case study that aimed at exploring how automation can be developed and applied by new users and 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. The research design of Study D is shown in Figure 12.

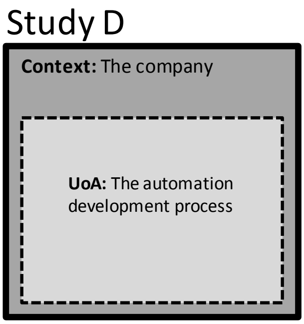

Figure 12 Research design of Study D.

The study was conducted at a small manufacturing company (in total three employees) in the food industry with a profile of craftsmanship and small production volumes. The case company was selected since it represents many SMEs that have inferior conditions in relation to larger companies when it comes to structured ways of working with improvements and therefore often need help and tools in order to improve their business. Many SMEs also 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. Further, the case company 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 aim of the first 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 done. During this stage, the main part of the data collection was made using interviews, direct observations and process mapping/measurements. During the interviews, the employees were asked to describe the way of working, what areas were perceived as difficult, time-consuming, strenuous, and so on, as well as 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. of 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 and the capacity was calculated.

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 were collected through 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 solutions developed was analysed and evaluated based on the information that had emerged during the first stage of the study.

During the third and final stage, the solution selected was implemented and demonstrated. As a result, the study shares many similarities with a design or realisation 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 for two reasons. First, it addresses general problems when improving industrial systems and using automation in particular. Second, it demonstrates possible ways of using and developing automation where internal logistics is one aspect covered.

This study was performed by a group of researchers and staff from Mälardalen University. Therefore, its results are not only a part of the research presented in this thesis. The author was, however, involved throughout the entire course of the study, during the first stage as supervisor for the person performing the work and in the second and third stages as part of the project team when developing the solution and conducting the demonstration.

3.3.6 Study E

Study E was a single longitudinal case study at a large manufacturing company in the automotive industry. Even though a project was studied, the area of interest in the study (and hence the unit of analysis) was the actual process of developing the internal logistics system and specifically challenges and prerequisites connected with it. This was enabled through the longitudinal design by which the project was followed in real time. The longitudinal design made it possible to study if and how automation was considered during the improvement process. Figure 13 presents the design of Study E.

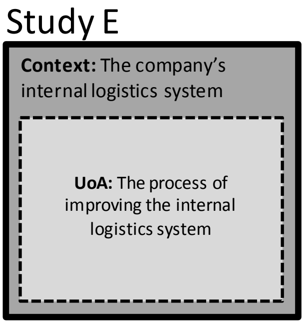

Figure 13 Research design of Study E.

The case study took place at a manufacturing facility that in total employs 700 persons. The logistics department, where the project took place, consists of 72 persons of which four are dedicated to logistics development. The case was selected due to the possibility and access given to follow this project in real time.

Data were gathered through observations, interviews and documentation collected. Table 6 gives an overview of the data collected.

The observations involved participation at project meetings, steering group meetings, workshops, etc. during the project. Notes were taken during the observations in order to, among other things, describe who were involved, what steps and actions were taken and by whom, decisions taken and their base, problems/difficulties encountered and how they were solved, etc. After each observation the notes were typed out and questions, comments, etc. stored in the case study database. The interviews were both of an informal character, in the form of a few questions in connection with a meeting or short discussion about what had happened since the last meeting, and of a semi-structured character with scheduled interviews both during and after the project time frame. For the scheduled interviews, interview guides were used and the interviews were recorded and transcribed. The interviews made it possible to capture opinions and feelings (Ejvegård, 1996) about the project and the process of developing the internal logistics and also to complement information from the observations and documents. The interviewees were the project and steering group members. The documents gathered included strategy documents, routines and specifications as well as meeting notes, company internal data, status reports and presentation materials.

The documentation collected made it possible to go back, complement and trace the development in the project.

Table 6 Overview of data collected in Study E

Technique	No.	Duration (minutes)
Observations	6	60-210
Observation occasions	*Project meetings, workshops and steering group meetings.*	
Semi-structured interviews	7	35-100
Respondents	*Logistics developers, person responsible for internal vehicles, person responsible for the goods reception area, logistics manager, manager of materials control, planning and logistics development, production leader for goods reception and internal transports.*	
Informal interviews/ meetings/discussions	16	10-60
Documents	Full access	
Types of documents	*E.g. logistics strategy, production strategy, project specification, time and activity plan, project model, routines, meeting notes, company internal data, project documentation, intreview notes, status reports and presentation materials, etc.*	

The gathered data were reduced and displayed (Miles and Huberman, 1994) in a way that enabled mapping of the project and the way of working. The mapping covered what was done during the different steps and phases in the project, who/what functions were involved and what input was used and what output was generated. The data analysis the data were also clustered into categories to highlight potential weaknesses, strengths and success factors in the current way of working as well as identified problems and difficulties. The findings were compared with the literature to address similarities and differences.

3.3.7 Study F

Study F was a multiple case study where several cases were studied in the same case company. The case company was a medium-sized manufacturing company in the automotive industry. The company was selected based on its interest in developing their processes and way of working with automation development and due to the possibility to follow one of their automation development projects in real time and with unlimited access. This project constituted the real-time case in the study and was supplemented by two retrospective cases in which previous automation development processes were studied. In addition to the three specific cases, as part of the context, the study also covered the case company's process of automation development in general with previous experiences and current routines for automation development as well as the future/ongoing development process. The design of Study F is illustrated in Figure 14.

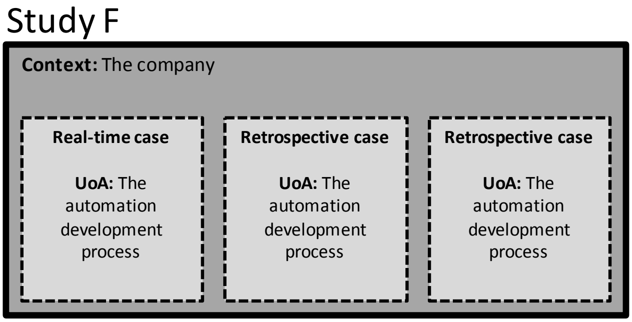

Figure 14 Research design of Study F.

During this study, data were collected using three data collection techniques: interviews, documentation and observations. The three methods, further described below, enabled both data and source triangulation.

Interviews were conducted with the production manager, two production engineering managers, two production engineers and a global production engineering coordinator. An interview guide was used to ensure the same topics and questions throughout the interviews. The interviews were also recorded and transcribed. The interviews covered topics such as structures and routines for improvement work particularly using automation; organisational goals and visions; and past, current and desired ways of working with automation development, for example related to the acquisition process. The documents gathered consisted of routines, plans, specifications and other steering and support documents mentioned during interviews and observations. The collected data in Study E are summarised in Table 7.

Table 7 Overview of data collected in Study F

Technique	No.	Duration (minutes)
Observations		
Project meetings	22	25-160
Workshops	6	120-420
Semi-structured interviews	8	45-70
Respondents	*Production manager, production engineering managers, production engineers, global production engineering coordinator.*	
Documents	yes	
Types of documents	*E.g. routines, plans, project models, checklists, instructions, technical specifications, project specifications, specifications of requirements, status reports, strategy document, project portfolios, etc.*	

According to Yin (2009), 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 and detailed, and able to cover a broad span of time, events and settings. Hence, reviewing documents was a good complement and way to triangulate data that emerged during interviews and observations but it also enabled covering several aspects not otherwise possible. The observations, which were partly of a participating character, involved closely following and participating in a collaboration project between the company and a university research group to which the author belongs. The aim of the project studied was to develop and implement a robot cell for material handling for the company, based on their needs and desired approach towards automation. The project had a nine-month time frame during which project meetings and workshops were attended.

From the data collected, a description of the case company's way of working with automation development was made. During this stage the data were analysed for discrepancies and contradictions but also evaluated with the aim to highlight strengths, weaknesses and potential problems. From the gathered data, elements and aspects that could form an automation strategy were extracted, additions were suggested as well as in what way the company should work with this strategy. During a workshop the resulting automation strategy and adherent plan were presented to the company in order to both validate the results and also further develop them together with the case company. To validate the research results there were also two follow-up and evaluation occasions linked to this study (as indicated in Figure 8). During these the case company was revisited and it was studied if and in what way their process for automation development had changed as a result of this study and also if and in what way they worked with the developed automation strategy. These two occasions are however not included in the collected data described in Table 7.

Study F was planned and executed together with another researcher. Both researchers were involved in the data collection and data analysis and hence the development of the results from the study. The responsibility for summarising the research results connected with and relevant for this thesis as well as the main contributions to writing Paper VI has however rested with the author.

3.4 DATA ANALYSIS

Since an abductive approach was used during this research, the empirical data collection and the theory building phases have overlapped in a learning loop. There has hence throughout the research process been a continuous iteration between theory and data, especially during the data analysis.

Since this research has been of a qualitative character, the analysis of the empirical data has followed the structure suggested by Miles and Huberman (1994 p. 10), who define *"analysis as consisting of three concurrent flows of activity"* which are data reduction, data display and conclusion drawing/verification.

Data reduction is a continuous process part of the data analysis during qualitative research. It refers to the process of selecting, focusing, simplifying, abstracting and transforming the data that appear in written-up field notes or transcriptions (Miles and Huberman, 1994). This has been necessary in order to reduce the vast amount of data collected especially from the case studies (Pettigrew, 1990). The process of improving the internal logistics system and the automation development process has, being the units of analysis during the empirical studies, been the focus of the analysis. Further, the two research questions have formed the data reduction since the data were searched for challenges and facilitators for successful use and development of automation in internal logistics systems. In more detail, the data were analysed through coding, clustering, categorisation and subsuming the data in patterns. The codes and categories used have mostly been data-driven but to some extent of theory-driven character (Saunders et al., 2012). Some codes and categories, such as aspects related to strategic views or base for decision, are theory-driven since the importance of these aspects for successful use of automation were pointed out in literature and the empirical studies thus were designed to cover these aspects and the data hence searched for aspects and patters related to these categories. Most codes and categories, such as challenges concerned with the relationship with the customer, collaboration with third parties and dependency on individuals, however emerged during the analysis thus being data-driven. Also the patterns connected to the different themes and categories were mostly data-driven since, as pointed out by Voss et al. (2002), even prior to formal data analysis it is important that the field researcher is sensitive to the emergence of patterns observed in the field.

Data display refers to the process of organising, compressing and assembling information in a way that permits conclusion drawing and action (Miles and Huberman, 1994). During the data display, the focus has been on finding appropriate ways to extract coded data and display clusters, categories and patterns in a way that enables tracing back to the raw data. With the aim to show transparency, the findings from each study are presented separately in Chapter 4 and are based on the different themes of the study in question. Narrative analysis (Saunders et al., 2012) was used in Studies E and F for describing the case companies' ways of working with the processes studied. Further, the structure in Chapter 5 reflect the analysis process since the subheadings used are based on and grouped from the categories used and/or created during the analysis. In Chapter 5 are also the patterns discovered during the data analysis explained and analysed in connection to the different themes in the empirical studies and the applied units of analysis.

Conclusion drawing/verification starts during the data collection when regularities, patterns, explanations, causal flows and propositions start to take form but final conclusions may not appear until data collection is over (Miles and Huberman, 1994). The continuous analysis and conclusion drawing is partly, as explained in Section 3.3 the rationale behind why the studies have not been named in chronological order. For example, conclusions drawn from Studies B and C put the data from Study D in new light and during the continuous analysis previously not acknowledged conclusions could be drawn from Study D. In each subsection in Chapter 5 the identified patterns from the cross-study analysis are described to explain the overall conclusions drawn. The conclusions drawn from the analysis are also continuously highlighted since they together form the answers to the research questions.

Although the data analysis has been an ongoing process throughout the research project and of an iterative rather than linear character, five main recurring steps can be identified:

1. Literature review
2. Within-study analysis

3. Cross-study analysis
4. Enfolding literature
5. Conclusion drawing

These steps, further described below, were repeated both in each separate study and for the overall research. An illustration of the data analysis process can be found in Figure 15.

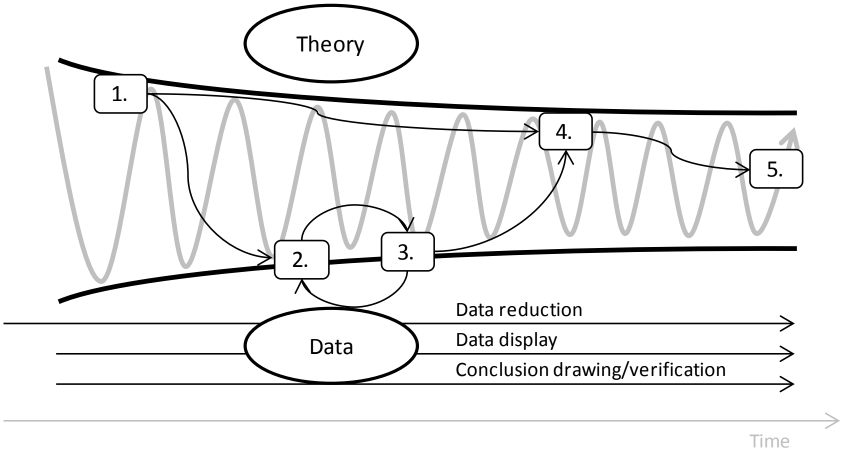

Figure 15 Illustration of the data analysis process (based on Ritchtnér, 2004).

The starting point for the research and each conducted study has been the prior theoretical knowledge gathered through a review of the literature (step 1). The findings from these reviews has contributed to the design of the studies regarding how to conduct them and what to search for but has also provided a base for analysis which is explicitly reflected by the recurrence in step 4.

Each individual study (A-F) has been analysed during step 2. The structure of the within-study analysis has to some extent been described in Sections 3.3.2–3.3.7 during the presentation of each study but also above following the structure of data reduction, data display and conclusion drawing. During step 2, clusters, categories and patterns connected with the two research questions were extracted and summarised in write-ups of each study. Special attention was paid to identifying challenges of using automation as a means for improving the internal logistics system and factors and support facilitating the improvement process of automation development in internal logistics. Since Studies A, C and F were multiple case studies there was also a cross-case analysis step (similar to step 3) performed during the within-study analysis (step 2).

While in step 2 each study was treated as a comprehensive study in and of itself and data were analysed to learn about and describe each study from its context, step 3, the cross-case analysis, on the other hand attempted to build general explanations and theory from the research by building replication and logic across the studies. Especially studies having the same unit of analysis were compared and analysed (Leonard-Barton, 1990), and using the study write-ups as a base there was also an overall cross-study analysis done to compare and search for general clusters, categories and patterns across the studies. The cross-study analysis hence forced the researcher to look beyond initial impressions and see evidence through multiple lenses (Eisenhardt, 1989). As a result there were several loops of conducting step 2 again after step 3 to make use of the new knowledge from the cross-study analysis during the within-study analysis.

In theory development research, it is important to review the emergent theory against the existing literature (Voss et al., 2002). In step 4, enfolding literature, the results from the analysis were compared with both conflicting and similar literature (Eisenhardt, 1989). This was done to further elaborate the results, strengthen the quality of the research as well as to identify and point out the theoretical contributions of the research.

As stated above, conclusion drawing and verification has been an ongoing process but step 5 involved drawing of the final conclusions.

3.5 DISCUSSION ON THE QUALITY OF THE RESEARCH

Determining the quality of the research conducted is an important but difficult task, especially when, as in this research, the results are based on qualitative data (Corbin and Strauss, 2008). The most commonly used aspects or tests for judging the quality of empirical research are construct validity, internal validity, external validity and reliability (Yin, 2009). How each aspect has been addressed and can be judged with regard to this research is discussed separately in the following.

3.5.1 Construct 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"*. Construct validity is therefore about identifying correct operational measures for the concepts being studied, which is especially challenging in case study research (Yin, 2009). But there are tactics and measures to increase the validity of case research. Triangulation by using multiple means of data collection and hence sources of evidence is one (Voss et al., 2002; Yin, 2009). In all the case studies (Studies A, C-F) multiple sources of evidence have been used, see Table 2. For example, in Study A the interviews were supplemented by observations and a questionnaire, which enabled gaining input from not only the interviewees and during one occasion. Real-time observation is an appropriate but very time-consuming and highly selective method (Yin, 2009). The use of observations in Studies E and F was necessary to secure valid results. However, it also limited the possible sample size due to time constraints.

In Studies C, E and F the collected internal documents made it possible to go back, validate and trace data collected during the observations and interviews. The documents also often provided a complementary view of the phenomena studied. In several of the studies such as E, F and to some extent C there were also multiple respondents from the same level/with the same functions in the case company who could provide a diverse view of the phenomena studied.

Another tactic to strengthen construct validity is to develop a chain of evidence during the data collection (Yin, 2009). During the studies efforts were made to maintain the chain of evidence for example by linking observation and interview notes to the case study questions and making sure that results and conclusions summarised in the case write-ups could be traced back to the data collected.

The choice of methods is strongly linked to the aspect of construct 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. To secure the validity of this research, the methods used have continuously been reviewed and their suitability assessed. There has also been an openness to revise the methods used.

The use of multiple case studies such as in Studies A, C and F provided an opportunity to promote construct validity, as the stability of constructs could be validated beyond the immediate case (Leonard-Barton, 1990). In Study A the use of a multiple case study design also permitted studying a larger sample than for example in a single, real-time case, which was preferred in the research clarification step. The applied combination of real-time and retrospective cases also strengthened the validity since it demanded different measures and approaches to study the same phenomena but also provided the opportunity to study the phenomena during different circumstances. The real-time cases for example made it possible to study the entire chain of events in the processes studied. Also, the real-time studies in Studies D, E and F, where data were gathered during a long period, also made it possible to go back to complement or validate gathered data, which also strengthened the validity.

3.5.2 Internal validity

Internal validity is associated with the establishment of causal relationships (Mentzer and Flint, 1997) and the question whether the conducted studies really indicate relationships in the cases where they exist and whether the identified relationships are valid. That is, if the researcher can prove that changes in one variable are dependent on a 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, as in this research, this could be problematic since the systems consist of many parts and relationships that can make the results difficult to judge. To prevent this, there has been a focus on describing the view of the system studied, what parts and relationships it consists of and how they relate to and affect each other.

When studying complex systems such as the internal logistics system, causal relationships could also easily be misinterpreted. However, through the use of the systems approach, a holistic view of the system and all included parts and relationships has been sought. In order to strengthen the internal validity and rigour of the research, the connections and causal relationships discovered have been described and based on the theoretical and empirical findings; it was attempted to eliminate other possible causes of the effects and changes studied. The enfolding of literature during the analysis process thus increased the validity of the findings (Eisenhardt, 1989; Voss et al., 2002).

However, when researchers using the systems view look for explanations, they build models and mental constructions where they subtract (neglect) irrelevant facts and circumstances from the fact-filled reality (Arbnor and Bjerke, 2009). There is hence always a risk of overlooking certain relationships or connections. But the internal validity has been strengthened by using real-time case studies as they enable the researcher to trace cause-and-effect relationships (Leonard-Barton, 1990).

The data collection and data analysis processes in case study research are also subject to the influence of the researcher's character and background and rely heavily on the researcher's interpretation of events, documents and interview material (Williamson, 2002). This may limit the validity of the research findings, although, as Yin (2009) notes, bias may enter into the design and conduct of any type of research. But it has been of importance to continuously be open to revising the results and methods used during the research. And, as pointed out by Maxwell (2005), it is important to acknowledge that the analysis process often starts during the data collection. Reading and thinking about interview transcripts and observation notes, writing study notes, etc. are all-important types of data analyses but may be unintentionally conducted. Therefore, what is first seen as pure data might be a conclusion or an interpretation of the data. It has hence been of importance to be able to separate the two during the research process to strengthen the rigour and avoid unintentionally concluding something the research did not actually reveal (Mentzer and Flint, 1997). Thoughts, remarks, initial conclusions and other comments have been clearly marked in the case study documents to separate them from the data. When writing the study summaries, the aim has been to keep the traceability of the results and conclusions back to the raw data supporting them. The internal validity has also been addressed by building explanations of each case (Yin, 2009).

In several of the studies conducted such as Studies A, C, D and F, the quality aspect of internal validity has also been addressed by involving more than one person during the data collection, especially during interviews conducted. This is to increase the possibility of covering all information available and not miss any important aspects of the phenomena 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 data gathered are lacking.

3.5.3 External validity

External validity 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). It is natural that results from a study using a systems approach include empirical results that to some extent are unique to the study (Arbnor and Bjerke, 2009). However, to a certain level knowledge can be extrapolated, which is often, as in this research, practised.

A common criticism of case studies as a scientific method is an inability to generalise from their results. This is addressed by, among others, Gummesson (2000), who deals with the difficulties of generalising from a limited number of cases. As for many types of empirical research, the results in this research are based on a limited number of empirical studies and cases that will affect the possibilities to generalise from the results. In this research, five case studies have been conducted. The actual number of cases studied is, however, much larger since several multiple case studies were conducted. The cases studied supported by the broader survey study should thus not be seen as too limiting for the validity of the results and the conclusions drawn from the actual contexts studied.

Three multiple case studies were conducted in this research (Studies A, C and F). Multiple cases have higher external validity than single cases (Voss et al., 2002). It is, however, important to note that the use of multiple cases may reduce the depth of study when resources are constrained but can both increase external validity and help guard against observer bias (Voss et al., 2002). The multiple case studies were supplemented by two single case studies (Studies D and E) which, also being real-time studies, allowed in-depth studies of the phenomena.

To somewhat compensate for the low level of external validity that comes from using case studies, a spread has been sought when it comes to the studies conducted, both by selecting several lines of business to study and also in terms of selecting representative samples in the different studies. With a systems view it is usually attempted to use typical cases and to some extent unique cases (Arbnor and Bjerke, 2009). The possibility to select cases was however limited, especially when real-time cases were sought. Often the selection comes down to the companies' openness and the possibility to gain the high level of access required.

3.5.4 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 and methods could achieve 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.

Irrespective of the kind of research at hand, the reliability aspect can be strengthened by careful attention to how data and information are gathered, analysed and interpreted (Merriam, 1994). In this research, the reliability aspect has been addressed by carefully documenting and describing both the data collection process and the data analysis process, making it possible for the reader to follow the process. The detailed descriptions of both the studies and the research process in the thesis together with the detailed description of data in both the thesis and the appended papers should strengthen the reliability.

There is, however, criticism that case studies lack statistical reliability. This is discussed by Yin (2009), who states that the general way of approaching the reliability problem in case studies is to make as many steps as operational as possible and to conduct research as if *"someone were always looking over your shoulder"* (Yin, 2009 p. 45). The application of a systematic way of working during the data collection was aimed at. Field notes from Studies A, C and D were taken during observations and interviews and to some extent written out after the observations and interviews. In Studies E and F all interviews were transcribed and all collected data and adherent notes from the data collections were gathered in a case study database. In Studies A, E and F, research protocols such as interview and observation guides were used to secure the quality of the research and facilitate the research work, especially where several people were involved during the data collection. All case studies also used multiple sources of evidence to study the same phenomena, which, as stated by Voss et al. (2002), increases the reliability of data.

During the data analysis it was also attempted to keep a chain of evidence showing how the results were obtained and how the conclusions were drawn. But despite the measures taken to increase the rigour of the research process, it is understood that the researcher's background, assumptions and interpretations have affected the research process and hence also the results. For example the reliability of Study D can be judged as somewhat weak, since it was an explorative case study whose outcome in terms of the solution developed was to a large extent affected by the specific conditions in the case company and 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 weakness in quality.

3.5.5 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 review 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 research conducted in the area must be thoroughly investigated.

The theoretical review has been ongoing throughout the research process and aimed at giving input on and providing a base for all the studies as well as help in answering 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: either by 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 given in Chapter 2) as a base for the empirical studies. Since this research has an abductive character, there has also been a continuous movement between the theoretical aspects and the empirical data. This was necessary in order to develop the research results but also contributed to the development of theory.

Since the research is of an applied character, other quality aspects of the research include the relevance and applicability that is associated with not only a scientific but also a practical contribution. The contributions of this research are discussed in Section 7.3.

4. EMPIRICAL FINDINGS

In this chapter, the main findings from the empirical studies are presented. For a detailed description of the studies the reader is referred to Section 3.3 in the methodology chapter and for a more detailed description of the findings to the appended paper(s) related to each study.

In the following six subsections, the gathered and compiled findings from the empirical studies are presented. Each subsection is structured in themes related to the topic and aim of the study and then concluded with a short summary of the main findings. The findings will then be analysed in the following chapter.

4.1 STUDY A

Study A was a multiple case study with eight participating companies, mainly SMEs. The study, filling the purpose of giving research clarification, aimed at gaining a deeper understanding of how the case companies work with improvements of their internal logistics systems, especially with regard to automation.

4.1.1 Findings Study A

The findings from Study A, which are more thoroughly described in Paper I, are presented under the following four themes:

- Importance of and responsibility for internal logistics
- Improvement areas and causes for improvement
- Automation of logistics activities – extent and difficulties
- Way of working with improvements and automation development

Importance of and responsibility for internal logistics

The study showed that efficient and effective internal logistics was considered important or very important to their business by all respondents. They also agreed that their company needed to further improve its internal logistics. There was, however, a great difference in the focus on internal logistics, especially when it comes to improvement efforts and budget. When estimating the share of previous years' investments and conducted improvement measures related to internal logistics, the answers were widespread. The desired future share of improvements and investments related to internal logistics was however higher. When asked if costs related to internal logistics activities were followed up on, all respondents answered no.

The organisational responsibility for the internal logistics was in general much more distinct the larger the company was. Also in the warehousing and distribution companies, the responsibilities were clear and well spread across several functions and positions. In the producing companies, the responsibility for internal logistics was not always clearly assigned. Instead, it was often one small part of, for example, the production manager's areas of responsibility, a circumstance more common the smaller the company was.

Improvement areas and causes for improvement

During the interviews, all the respondents agreed that their company needed to further improve their internal logistics system. All respondents could state several identified areas in internal logistics that they desired to improve but, as became evident during the observations, many possible improvement areas were also unknown to the company. Company A6 had initiated benchmarking collaborations in order to get ideas on how to improve their internal logistic system.

The most mentioned (in four cases) desired improvement area related to changing and improving parts of materials handling, especially where a large amount of manual handling was required today. Other commonly mentioned improvement areas related to changes in the layout (three cases) and information handling (three cases). The most recurring reasons these areas needed improvement related to the following:

- Freeing up staff for more value adding tasks/more advanced tasks and assignments
- Improving work environment regarding ergonomics or safety
- Utilising equipment and/or space better
- Reducing cost
- Increasing control over processes
- Reducing lead times

Other reasons mentioned were increasing quality, reducing risks of disturbances, facilitating planning, clarifying areas of responsibility, improving organisational structure and improving reputation/attracting new and younger staff. In general, all respondents expressed a desire to utilise available resources better, by using different terms such as increased productivity and efficiency/effectiveness and/or focusing on specific resources.

Automation of logistics activities – extent and difficulties

There was a positive attitude towards automation in internal logistics; seven of the respondents would, if possible, automate extensive parts of their internal logistics, especially activities that were repetitive and included heavy lifting or other ergonomically unsound activities. One interviewee (case A7) expressed the goal of *"a black factory"* (i.e., fully automated and therefore not needing lights).

There were also recurring trends among the different companies' desired, planned and implemented improvement measures in internal logistics; what some had already implemented, several were planning or desired to do. Further, there were to some extent trends in what areas the case study companies chose to automate and what type of automation they used. For example, case company A1 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 and application of automation suitable for their business.

Despite the positive attitude towards automation and the many possible applications, the respondents assessed that their company generally had a low degree of automation and in internal logistics activities the degree was even lower. This has many reasons. The respondents mentioned high investment costs, the company's priorities (not focusing on internal logistics) and a lack of support from top management. Besides the demand for flexible solutions, which was considered a technical hindrance, six of the respondents however concurred that what had stopped the company from automating to a greater extent was not mainly the result of a lack of existing technology. Rather the respondents referred to a lack of competence and knowledge about how to find it, see the potential benefits of it, economically justify it and properly use it. For example, one respondent argued *"there are probably automated solutions that we would benefit from, we just don't know what they are"*. Further, three respondents had specific concerns about the operators' lack of knowledge about utilising and handling new solutions; this was based on previously experienced problems with automated equipment due to incorrect handling.

Further, several respondents (of which three explicitly) expressed concerns regarding the reliability and robustness of automated systems. One respondent (case company A2) had experience from previous automated equipment that had often failed and caused downtime and other problems, and the respondent pointed out that *"this made a deep mark, creating high resistance to robots for a long time to come".* The resistance towards automation was especially strong among the operators since they were the ones directly affected by previous problems. The resistance were sometimes to the extent that it affected future plans for automating.

Ways of working with improvements and automation development

Concerning improvement work in the internal logistics system both in general and specifically involving automation, the respondents considered particularly the early steps in the improvement process as difficult. During the interviews and the questionnaire, the following steps were identified as difficult:

- Drawing up investment calculations/justifying a solution financially
- Evaluating alternatives and deciding on the most appropriate solution
- Identifying/working out possible solutions
- Identifying problems and/or possible improvements
- Developing the specification of requirements

When conducting improvement work in general and specifically involving automation, all case companies engaged system suppliers or integrators, at least in some steps of automation projects. At one of the companies, the employees performed the greater part of the work themselves but engaged consultants or system suppliers in a few of, as they saw it, the most complicated steps (ones that demanded considerable technological skills, for example). At five of the companies, it was preferred to employ consultants or turn to system suppliers for complete solutions, while the remaining two chose to work in teams with representatives from the company, system suppliers and consultants. Developing (possible) solutions was the step in the automation development process where most companies engaged a third party. The most often recurring steps in improvement work in general that the companies chose to take themselves and not involve a third party, were to identify problems or possible areas of improvements. This was, however, one of the steps considered most difficult in the improvement process.

The case companies were hence, but to a varying extent, dependent on third parties when conducting improvements in general and involving automation in particular. It was, however, considered difficult to find an appropriate level of collaboration with system suppliers. Respondents explained that the third party could take too much control over the project, which I some cases had resulted in a solution that did not fit into the rest of the system or that the company could not handle after the implementation. Two respondents had also experienced problems during collaboration regarding who owed or were responsible for the implemented solution.

However, in the end, the main reasons why identified problems/improvement areas in the internal logistics system had yet not been addressed were considered by all the respondents to be lack of time for improvement work or lack of competence regarding how to do it.

4.1.2 Summary Study A

The main findings from Study A can be summarised as follows:

- The internal logistics was perceived as important, however not focused on.
- An unclear responsibility of the internal logistics function.
- Cost related to internal logistics not followed up on.
- A need and desire to improve the internal logistics for various reasons. Some areas of improvement are well known to the companies, others not.
- A general low level of automation in internal logistics activities, however with specific exceptions and many potential application areas.
- Knowledge gaps in automation possibilities, early steps in the automation development process and economic justification.
- Strong dependency on third parties during development work, specifically involving automation.

4.2 STUDY B

Study B was a survey study with the aim to understand how manufacturing companies work with, perceive and develop their internal logistics systems. The detailed findings from the 47 questionnaire responses are presented in appended Paper II.

4.2.1 Findings Study B

Below is a compilation of the most important empirical findings based on the following themes from the questionnaire:

- Vision, strategy and responsibility
- Success factors in internal logistics
- Performance criteria and follow-up
- Perception and development of the logistics system

Vision, strategy and responsibility

The great majority of the responding companies do not have a clearly stated vision or strategy for the internal logistics system in their organisation. 79 % of the respondents answering the question clearly stated *"no vision"*. Of the few respondents that did provide an answer to the question, none separated their answers into both a vision and a strategy or stated which of these their reply was to be interpreted as.

53 % of the responding companies have a person with strategic responsibility for internal logistics. Further, in 27 of the responding companies the logistics responsibility rests with the production manager and there is no manager solely

assigned to logistics. Even though this is unfortunate, it might not be unexpected since more than half of the responding companies have less than 50 employees.

Success factors in internal logistics

Three data-constructed categories, almost equally referred to, indicating the most important success factors for a well-functioning internal logistics system were: (1) performance factors, such as delivery precision, lead/delivery times and stock levels, (2) information factors, such as dependable/supportive information systems and good communication and (3) flow- and process-related factors, such as a good and balanced flow. But the distinguishing result category is possibly 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.

Performance criteria and follow-up

When ranking the importance of different internal logistics performance aspects, the three criteria that were chosen the most and also had the highest ranking average were the following: (1) delivery precision, (2) service degree towards customer and (3) delivery dependability. Other important performance aspects and criteria were quality, lead time, ergonomics and staff safety and stock level. All cost and financial aspects (such as total logistics cost, operational and administrative cost and return of assets and payback from investments) were however ranked low.

Few respondents followed up on logistics performance; only 60 % listed any performance measurements used. Of those, 46 % only used one or two measures, most often connected with delivery, inventory and/or quality. In total, 15 % of the respondents used four or more measures and they, besides previously mentioned categories, also often followed up on cost.

Perception and development of the logistics system

The resources regarded as most critical, concerning both the organisation in general and logistics in particular, were in decreasing order competence, manpower, equipment and space. While the resulting order of importance for the ranked resources turned out the same, 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.

Despite competence being viewed as the most critical resource, only one respondent specifically listed it as a success factor. Also, in the responses to the questions regarding how the internal logistics system should be structured or how it needed to be improved to better utilise the company's resources, the stated areas in future need of improvement poorly corresponded to the ranking of critical resources. Listed success factors and improvement areas however corresponded better. Further, two respondents answered that their internal logistics system worked well today and that no improvements were necessary. When asking about areas currently being improved or highly prioritised/planned to be developed, 51 % listed at least one specific improvement area and another 11 % answered 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 with logistics, even though they had listed areas in need of improvement.

4.2.2 Summary Study B

The main findings from Study B can be summarised as follows:

- 79 % of the companies in the survey do not have a clearly stated vision of, or strategy for, internal logistics.
- There is a lack of strategic responsibility for internal logistics.
- Performance, information and process factors were considered key success factors for internal logistics.
- 40 % of the companies in the survey used performance measurements and of those 46 % only used one or two measures.
- There is a mismatch between improvement areas and success factors in relation to perceived critical resources.
- Many companies in the survey lack planned or ongoing improvement work connected with logistics, despite a need for improvements.

4.3 STUDY C

Study C was a multiple case study in the healthcare sector with the overall objective to examine and analyse the use and management of automation and its development in healthcare internal logistics systems. Study C with its findings is thoroughly described and presented in appended Paper III. Since the substudies had somewhat different purposes, scopes and approaches, the main empirical findings are presented and summarised below per case.

4.3.1 Findings case C1

Case hospital C1 is a Swedish hospital with 400 beds whose physical and organisational conditions represent the majority of Scandinavian hospitals in terms of size, age and constraints in technology management. In this case the potential and prerequisites for improving the internal logistics system were investigated with a specific focus on possible automation applications. Also the way of working with improvements of the system particularly involving automation was covered.

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 handling and/or transport of patients, waste material, laundry, food, pharmaceuticals and mail). The transportation department owns all the equipment used 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 potential new investments, enabling a long-term view. Also, all wards are individually responsible for their finances. Purchasing and procurement are however managed for the entire hospital. This means that the only way for a ward to control its expenses is basically through the level of staff.

At the case hospital there is a very low degree of automation in the internal logistics activities, which instead involve a vast amount of manual labour for both the transportation staff and the care staff. The time study performed at 13 of the nursing wards showed that indirect care activities occupied as much as 54 % of the nurses' time (followed by direct care 30 %, administrative time 9 % and personal time 7 %). 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. Both care and transportation staff expressed a need for improvements and listed several problem areas but few could specify potential solutions. During the observations and especially in comparison with the other case hospitals, several potential automation applications could be found. The hospital layout and physical properties however involved some challenges and obstacles limiting the automation possibilities.

4.3.2 Summary case C1

The main findings from case C1 can be summarised as follows:

- There is a great improvement need and potential in the internal logistics system.
- There are many possible automation applications that would benefit the case hospital but physical limitations as well as lack of an overall view and split responsibility and ownership offer challenges.

4.3.3 Findings case C2

Case hospital C2 was studied in order to complement case C1 with regard to possible improvement of hospital internal logistics, specifically involving automation and its development, in a larger hospital context. Case hospital C2 has two sites and is one of Europe’s largest hospitals. Its management actively works with improving its internal logistics system, and one of the expressed ways it does so is through automation. At the hospital there is also a process of planning and designing its new, future site. At the current sites in case hospital C2 there is a number of automated applications in the internal logistics system, such as:

- A pneumatic dispatch system for the transportation of small goods, such as samples, blood, medicine, paperwork and money.
- An industrial robot cell that handles 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.

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, resulting in somewhat obsolete solutions today.

In the process of planning the new site a major strategic study of the logistics needs was conducted. The result was presented in a report approved by the hospital management as a guideline for the future internal logistics system. The report concludes that automatic transports will be a fundamental principle for future logistics, due to increasing demands for efficiency, accessibility, shorter lead times and round-the-clock service. In general, a high degree of automation is sought and specific applications are listed as necessary or desired. There is also a general wish to “professionalise and standardise the logistics processes”. The logistics flows, though vital, are too expensive to customise for each ward. A standardised way of working with a focus on an efficient flow is desired. Several lean principles are also mentioned, such 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).

4.3.4 Summary case C2

The main findings from case C2 can be summarised as follows:

- There are several automation applications, although some are obsolete due to lack of flexibility.
- When planning the new hospital, a strategic analysis of the logistics needs and requirements was performed and management-approved guidelines were developed.
- Automation will play a large role in the future internal logistics system but the logistics function will be outsourced.

4.3.5 Findings case C3

Case hospital 3 was studied in order to complement cases C1 and C2 as a role model and a description of what the future of hospital logistics could entail.

At the time of the study, case hospital C3 was a new hospital (it had been in operation for eight months). Prior to planning the new hospital, an analysis of the previous hospital had been 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 hospital staff from different levels and functions. 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 tasks/services internally.

The following are some of the prominent features of the internal logistics system specifically connected with automation at case hospital C3:

- *The layout* – The aim was that wards and units with many transactions and patient transports should be closely situated to one another. All nursing wards also follow the same layout.
- *AGV system* – Extensive and modern AGV system for internal transports integrated with sensor and signal systems.
- *Pneumatic dispatch* – An extensive pneumatic dispatch system for the transport of small goods. Text messages are used to signal the staff when new deliveries arrive.
- *Industrial robot cell* – Robot cell inspired by case hospital C2 for opening and emptying incoming deliveries at the laboratory.
- *Waste material and laundry* – Chutes for waste material and laundry at each ward. Air-pressurised transport system.
- *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. It is 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 skills in technology and IT.

4.3.6 Summary case C3

The main findings from case C3 can be summarised as follows:

- The level of automation in the internal logistics system is high but the degree of entirely new technology is low. Integration between different automated applications/systems is common.
- Automation in internal logistics puts new demands on the competence and skill of the staff.
- During the development process, an analysis of current state and benchmarking was performed. Staff from different parties, functions and levels were involved early in the development process.

4.4 STUDY D

Study D was an explorative case study of how automation can be developed and used as a means to improve internal logistics operations at new users and in activities and environments not traditionally associated with automation. In the study an automated solution for the case company's specific needs was thus developed. The following section describes how the automation development process was performed and why. These findings are also described in appended Paper IV; more detailed information of the outcome of the process and its different steps can be found in Granlund et al. (2009).

4.4.1 Findings Study D

The study was realised in six phases: initiation, feasibility study, current state analysis, solution development, implementation and evaluation, each described below.

The study was *initiated* by an anticipated and large increase in production volumes that the company's current production and internal logistics system could not handle. The *feasibility study* aimed at investigating how a future expansion could be achieved at the case company to meet the new demands. The main recommendation from this phase was to implement automation to ensure the company's ability to meet future customer demands. The *current state analysis* therefore started in order to examine how parts of the production and logistics at the company could be automated.

In this phase, the case company's needs, goals and requirements were analysed and specified along with factors important to consider. This also provided a base to evaluate different options, and hence to find an appropriate solution for given circumstances. Some of the important features were that the future solutions should

- preserve the craftsmanship by keeping the actual production 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 detailed mapping of the company's process was made to understand the prerequisites, help identify the requirements and also provide a base for evaluation of the implemented solution. The activities having the most potential for automation while fulfilling the listed requirements were identified and the benefits of automating these activities were listed.

Based on the results from the current state analysis, the study's *solution development phase* started. This phase aimed at developing possible ways to automate the activities identified. Information and design and solution ideas were collected through benchmarking both in the same line of business and in other business areas. System suppliers were also contacted for design and solution ideas, cost estimates and risk analyses. Several possible concepts were developed and the suitability of the different alternatives was analysed and evaluated based on the information and requirements that emerged in the previous phases. The most promising and suitable design was then selected for further development. During this development it was listed what/how different features in the solutions fulfilled the different needs, goals and requirements in order to help making choices and make sure no important aspects were missed.

During the *implementation phase*, the selected design was constructed, tested, implemented and demonstrated. Necessary introduction and training for the staff was provided. Both the project and the implementation were then *evaluated* in the last phase to identify possible changes needed and lessons learnt.

4.4.2 Summary Study D

The main findings from Study D can be summarised as follows:

- The automation development process had six rough phases: initiation, feasibility study, current state analysis, solution development, implementation and evaluation.
- The current state analysis included process mapping, objective setting and a well-structured requirement specification.
- A broad perspective was applied in the search for potential solutions.
- Staff training and involvement were essential.
- Both the implemented solution and the project were evaluated.

4.5 STUDY E

Study E was a longitudinal case study at a large manufacturing company in the automotive industry in which a redesign project of the case company's internal logistics system was studied. The focus of the study was on the actual process of developing the internal logistics system, specifically challenges and prerequisites connected with it. A more detailed description of Study E and its findings can be found in appended Paper V.

4.5.1 Findings Study E

The main empirical findings from the study are presented below from the following themes:

- Case introduction
- The project process
- Reflections on the process

Case introduction

The project studied was the first large-scale project initiated and performed by the logistics department at the case company. The project had a total timeframe of 14 months, not including the implementation phase, which was not covered in this study.

The project had a somewhat unusual setup with two project managers (both logistics developers) who also carried out most of the actual work. To their help they had a project coach and a project group, which besides the two project managers and the project coach included the persons responsible for internal vehicles and the goods reception area. The steering group consisted of the four logistics managers from different levels and functional areas. The role of the steering group was mainly to be a sounding board and control and influence the progress of the project.

Especially the steering group, in retrospect, pointed out that the setup with two project managers had not worked satisfactorily and it was pointed out that no one took overall responsibility for the project, which became evident during meetings. All parties were however satisfied with the setup of the project group with two persons daily involved in the logistics operations who acted as experts and sounding board rather than executors. During project meetings this however resulted in the project managers, being the actual executors, spending a great deal of time on updating everyone what they had done since the last meeting.

During the first steps of the process the commitment of the steering group was questioned by the project managers since several meetings were cancelled or postponed. Also, the attendance at the meetings was not always satisfactory. This however improved during the project.

The project process

The main phases of the project (not including implementation) and its adherent activities, outputs and gates are summarised in Figure 16. It is however worth pointing out that the activities were not fully sequentially performed. Some of the main features from the different phases are described below with a focus on the project process and not its results.

The main activity during the pre-study was to map the current and future logistics needs from an operations point of view. This was done through interviews with representatives from the different operational areas. The results from the interviews were displayed on information boards to show the progress in the project in the hope of initiating further ideas and discussions. The results and findings from the different mappings were also analysed and the project group tried to build an initial cohesive picture of the needs and requirements to define the feasibility, scope and goals of the project.

INITIATION	Development of project specification Project planning *Output:* Approved project specification and developed project plan
PRE-STUDY	Review of documentation from previous projects Outline mapping of current operations Identification and mapping of the company's strategic needs and demands Mapping of current and future operative needs in the organisation Initial analysis of mapping *Output:* Initial mapping of current state, understanding of the problem, identified feasibility of the project and defined project scope *Gate:* Decision to proceed with concept phase
CONCEPT PHASE	**Information gathering** Detailed current state mapping and analysis Mapping and analysis of current and expected future volumes SWOT analysis Benchmarking *Output:* Detailed description and analysis of current operations, identification of potential techniques, methods and principles
	Concept design – "What could be done and why" Analysis of all information gathered Supplementary mapping of current/future operative needs/demands Development of evaluation criteria for concepts Concept analysis of possible techniques, methods and principles *Output:* Mapping of possible concept designs, listed evaluation criteria
	Concept development – "What can we actually do" Development of rough, possible concepts Development of guidelines for materials supply *Output:* Understanding of suitable concepts, guidelines
	Detailed concept development – "How can this be done" Development of concepts Evaluation of concepts *Output:* Two concepts for receiving with a number of principles, four main concepts for warehouse *Gate:* Decision of concepts to develop further
DEVELOPMENT PHASE	Detailed development of chosen concepts *(Gate to proceed)* Detailed development of solutions Development of business case *Output:* Decision support document *Gate:* Approved funds

Figure 16 Overview of the project process.

Information gathering during both the pre-study and the concept study took much more time than expected and also much time in relation to the total time frame. One of the project managers to acquire correct information from the company's enterprise resource planning (ERP) system regarding volumes, packaging sizes, storage places, etc., to understand the flow of goods and hence the needs and prerequisites for the future internal logistics setup. The information in the ERP system was however sometimes missing or was inaccurate, which made the assessments both resource-demanding (requiring *"detective work"*) and difficult to make and trust. Also, the project managers pointed out that although the importance was well understood, the value resulting from all the time spent on information gathering could to some extent be questioned. Particularly the interviews, during which the demands, needs and prerequisites were to be mapped, took considerable time. They were rewarding in the sense that they involved and engaged staff from different parts of the organisation but, as one of the project managers put it, *"all that time and effort resulted in practically the same thing that we brainstormed in our first meeting".*

One activity considered extremely worthwhile by everyone involved was the benchmarking of six other companies to map possible techniques and principles. Creating this knowledge bank of possible applications was useful not only to this particular project but to development activities in general. But, as one of the logistics managers expressed it, *"you rarely take the time to do this unless it is directly connected with a specific project"*.

During the concept design step in the concept phase the goal was to identify possible concepts. During this step the project group ran into difficulties since the internal customers' demands, needs and requirements were still considered very unclear. Therefore, the project group tried to build a better picture of the prerequisites in terms of future plans and needs by further discussions with the manager of production development regarding possible assumptions to be made. As one project manager pointed out, *"the alternative would have been to design a system that could handle everything, but that is not reasonable".*

At the request of the project managers during the concept design step, criteria for evaluation of the concepts were developed during a workshop with the steering group. The criteria decided on were feasibility, robustness, flexibility, capacity, cost, safety, automation and environment. These criteria were weighted and ranked according to their importance in the different functional areas addressed in the project but was when put together ranked in the order listen above.

The project scope was initially very wide and extensive due to the nature and cause of the project. But it also remained wide during the project due to the unclear demands and prerequisites. It was not until the concept development step in the concept phase that the project scope started to be narrowed down when it was realised that under the assumptions made, parts of the initial scope would not be affected.

Not until the detailed concept development did a number of clear concepts start to take form and their feasibility was assessed and evaluated towards; the interpreted needs and demands (operative and strategic), the goals listed in the project specification and the evaluation criteria developed.

Reflections on the process

During the follow up interviews, the steering group members mentioned that the project took longer time than expected. Indeed, some delays from the timeframes set occurred, but the comments mainly referred to the fact that the steering group members thought that the project group would have come further in each phase. This can be traced back to the inexperience of this type of processes, which resulted in not clearly stating the desired outcome of each phase and the project as a whole.

Also, there were few clear gates during the project, something that the steering group members mentioned would be changed in future projects. The company has a six-phase development process adjusted for product development, which was tried to be applied to this project but which was not fully appropriate.

All parties involved were in general satisfied with the project and its outcome and felt that it was feasible and would solve the initial problem. Some expressed a certain disappointment that the result, in terms of the concepts and solutions developed, was not of any revolutionary character but rather involved small changes. Another thing mentioned was the fear that the solution, or rather the prerequisites that formed the solution, already were on the verge of being outdated. The planning horizon covered in the project was four years, but since the project took more than one year to carry out and the actual implementation of the project is planned to be executed in two phases during the two coming summers, the long-term perspective is no longer valid.

The steering group members estimated that the decisions they made during the process were mostly based on their beliefs and experience of what works and protecting interests connected with their role and area of responsibility. One steering group member clearly referred to making fact-based decisions while two others rather referred to “gut feeling”. Consensus was always reached, often due to the fact that in the end it most often came down to cost (in relation to benefit and value created) as the determining factor for decisions.

The first project specification included aspects and goals that should be specified and quantified for each concept. Some of the steering group members found the goals natural and derived from the business and production strategies. However, as pointed out by the members in the project group, some of these aspects and goals would not at all be affected by the project. The project group members hence to some extent questioned the steering group’s understanding of the logistics operations. The project group found no support or guidance in these goals and felt that they were not related to or drawn from any form of logistics vision or strategy, something strongly asked for. The case company has a logistics strategy that is expressed in an extensive document including overall goals, KPIs, golden rules as well as principles and challenges. Everyone involved however agreed that this strategy was not up to date or filling its purpose but was instead a desk product with some clichés that rather described the current way of working than being an actual strategy. The developed evaluation criteria were however considered more useful and instructive, especially during the development of concepts but not necessarily as a base for decision, at least according to the steering group. Also the business strategy provided some directions according to the project managers.

4.5.2 Summary Study E

The main findings from Study E can be summarised as follows:

- The information gathering was considered important but proved difficult, took longer time than expected and, despite efforts, did not fully provide the information needed.
- The internal customer inability to fully specify plans, needs, goals and requirements as well as inaccurate or missing data in the ERP system strongly affected the process.
- There was a strong bottom-up need for up-to-date and appropriate strategic and visionary guidance. The evaluation criteria developed during the project were considered a helpful substitute.
- Automation was listed as one of the evaluation criteria for concepts and suggested solutions.
- Lack of a process model and unclear prerequisites, requirements and overall project goal resulted in a vast scope, an overly complex and time-consuming process and partly unclear/unfulfilled expectations.
- Benchmarking was considered valuable and rewarding.
- The cross-functional project team was appreciated but the appointment of two project managers was in retrospect considered not successful.
- The management's commitment and overall understanding was considered necessary.

4.6 STUDY F

Study F was a multiple case study within the same case company, a medium-sized manufacturing company in the automotive industry. In the study the company's past, current and desired future way of working with automation development was studied to investigate ways to improve and facilitate the process. A more detailed description of Study F and its findings can be found in appended Paper VI.

4.6.1 Findings Study F

The main empirical findings from the study are presented based on the following data-developed categories:

- Base for improvement work
- The automation development process
- Responsibilities
- Experience of automation
- Desired way of working with automation

Base for improvement work

The case company has several steering documents that provide a clear picture of the desired future stage for the company in terms of strategic market goals and targets for key performance indicators. Further, the company has a three-year improvement project with the aim to increase profitability by improved productivity as well as reduced lead time, manufacturing cost and space usage. This project has been the underlying trigger for most of the recent and current improvement and investment projects. What specific improvement/investment projects to run is, however, determined in the yearly budget for each department, to which the production engineering departments apply for funds.

Most past improvement projects (including automation investments) have been initiated by the production engineers based on what they refer to as *"gut feeling"* for potential improvements or an instinct of self-preservation for their position/department.

The automation development process

At the case company, automation development projects are performed in the production development department with one production engineer as responsible and being the main executor.

The case company has no established project model for process development projects. There is a very basic project management model originating from product development but since it is not detailed or adjusted for process development projects, it is not considered useful.

During interviews with production engineers previously responsible for or involved in automation projects, it became clear that everyone, more or less, had their own view of how to run these projects. A tendency was that the more experienced the person, the more they had developed their own structure of working. Many expressed an experience of *"what usually works"* and had developed close contacts with suppliers and others. Staff more inexperienced with automation projects, for natural reasons, took more support in the various existing routines and support documents. The company has, for example, a general technical specification for new equipment and a checklist for handover of new production equipment. Despite the latter document being for handover (i.e. late in the process), many used it early or from the start as a checklist to remember all necessary steps. However, these two documents are not primarily intended for automation equipment and although providing a good base, they are in need of several adjustments and supplements to better fit the purpose.

When reviewing all documents gathered it became clear that there were support documents that had not been used. Some seemed more or less forgotten due to lack of ownership while others were not useful or suitable for their purpose. Most documents that were used were mainly connected with economic aspects such as investment requests and profit calculations and these were often quite extensive and complex.

With the exception of the approved budget few or no clear decision points existed during the automation development processes studied. The documentation during the automation projects was also often very poor, leaving no possibility to trace the progression of the project. The follow-up on performed projects and their improvement measures was also insufficient since a project was often considered finished once the equipment was installed. The production manager expressed a desire to improve the company's ability to evaluate finished projects and to document lessons learnt. As discovered by reviewing past automation projects, the same problems recurred again and again.

The company often enlisted third parties such as system suppliers or integrators for large-scale and/or technically advanced automation projects. But smaller or less complicated automation projects were often performed internally by the case company employees with little or no involvement of third parties. These internal projects did however often not follow the structures and guidelines that did exist.

For example, specifications of requirements were not always established for internal development projects. Internal projects also often did not keep within planned deadlines.

Responsibilities

During the interviews it emerged that the maintenance department had often been reluctant to take over responsibility for the maintenance of automated equipment due to lack of automation competence. Besides other benefits such as more appropriate solutions, this is one of the reasons why the project teams were desired to and should be cross-functional from the start: to make different functions feel involved and have a more positive attitude towards the new installation.

Only a few people have been responsible for several automation projects. These persons have extensive experience in the field and possess a large amount of knowledge, know-how and contacts, which to a large extent has contributed to the success of previous automation projects.

Experience of automation

The case company employees have experience from a few large-scale automation system investments and several smaller-scale investments, of which most included industrial robot cells. One of the previous automation installations, a turnkey solution provided by a third party including relatively new and untested automation technology, did not turn out well and caused many and large problems. This resulted in scepticism towards automation, among the operators as well as on a managerial level. The reasons for this unsuccessful implementation were partly the technology in itself not functioning properly but also the fact that the solution was insufficiently adapted to the company's prerequisites and needs, which in turn were poorly formulated. One of the respondents responsible for one of the cases studied had identified the importance of a correct and appropriate specification of requirements for the success of the project, especially when third parties were involved.

Desired way of working with automation

During the interviews a cohesive picture of the desired way of working with automation emerged. The main aspects are described in the following but it is worth noting that they were not explicitly formulated or documented in the case company.

Foremost there is a desire to increase the competence in automation in the company to be able to better specify requirements, identify, develop and evaluate options and thus get more suitable solutions for their needs and also to be able to carry out more automation projects without or with less dependence on system suppliers. There is also a wish to increase the competence in handling automation equipment in order to be less dependent on a third party and hence reduce equipment downtime and save time and money in both development and operation of automated equipment.

There is a strong ambition to increase the level of automation in the company, especially of simple, monotonous tasks that are ergonomically not suitable for manual handling. But, as four of the respondents also pointed out during the interviews, what gets automated is in the end a question of what is financially justifiable. Further, the request is for future automated equipment to be mature, simple and flexible. Linear actuators and industrial robots are however considered to fulfil these requirements. The respondents also wanted to keep the possibility to perform all automated tasks manually.

4.6.2 Summary Study F

The main findings from Study F can be summarised as follows:

- A process/project model suitable for automation development is missing. Most staff have developed their own way of working.
- Especially internal automation projects were performed ad hoc.
- With the exception of finance-related documents, support documents are often not existing, not fully suitable or outdated and therefore not used.
- There is a strong dependency on individuals with extensive knowledge and experience in automation development.
- The specification of requirements was listed as one of the most important steps in the automation development process.
- There is a cohesive, but not formulated, desired way of working with automation.
- Cross-functional teams and early involvement are desired in order to increase acceptance and achieve better solutions.

5. ANALYSIS

In this chapter, the empirical findings are analysed. The two research questions provide the basis for the analysis and the findings are compared to and elaborated on in relation to the frame of reference.

The structure of the chapter is as follows. First, the findings primarily connected with general prerequisites for conducting improvement work in internal logistics systems and specifically connected with the process of improving the internal logistics system are analysed. Thereafter the findings more explicitly linked to automation in internal logistics and specifically the automation development process are analysed. The subheadings used are either related to the themes investigated in the studies and the units of analysis to explain the patterns associated with each theme/process studied, or based on and group from the categories that were used or emerged during the data analysis, such as aspects related to responsibility, understanding, strategic view, base for decisions, relationships or commitment. The data analysis process and the forming of the categories are in more detail described in Section 3.4.

The two research questions provided the basis for the analysis and thus are both challenges (RQ1) and facilitators (RQ2) connected with successfully using and developing automation to improve the internal logistics system addressed and continuously highlighted in the chapter (i.e. also in the first section even though it is not exclusively dealing with automation development). Conclusions that will form the basis for the results presented in the following chapter are formulated and highlighted in italics. The chapter concludes with a short summary of the analysis.

5.1 PREREQUISITES FOR SUCCESSFULLY IMPROVING INTERNAL LOGISTICS SYSTEMS

Responsibility for the internal logistics system

As found in both Study A and Study B, the organisational position and thus the responsibility for the internal logistics system is often integrated in the overall system of which it is part, such as in the production system. This fact can be interpreted in two ways. Based on Stock et al. (2000), who conclude that the logistics activities need to be more integrated internally in a company, it is on the one hand positive that internal logistics is not, as previously, seen as a separate entity whose activities are distinct from other functions in the firm (Olavarrieta and Ellinger, 1997). On the other hand, it is unfortunate since it can indicate that not enough attention is paid to the internal logistics system for it to be properly dealt with. The former interpretation is contradicted by two of the cases in Study C, where the operation of the internal logistics function was outsourced. The latter interpretation is supported by the findings from Studies A and B, which indicate that while the importance of the internal logistics was strongly recognised, the efforts and focus on improving it was still poor. One of the reasons for this can be the lack of clear responsibility for the internal logistics system.

In Study B it was found that in most of the cases, and especially at the smaller case companies, strategic responsibility for internal logistics was lacking. Systems design and development literature such as Wu (1994) and Bellgran and Säfsten (2010) address the importance of clear organisational structure and responsibilities during development work. The lack of someone with clear 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, following up and planning for improvements, and so on. Even in Study E, where the logistics organisation, much owing to the size of the company, was well developed, the responsibility during the project studied became unclear and strategic guidance was lacking.

From the analysis it can thus be concluded:

There is a need for an increased focus on the internal logistic system and clarification of (especially strategic) responsibilities connected with it.

Conducting improvement work in the internal logistics system

The empirical findings from Studies A and B revealed an absence of especially ongoing but also continuous improvement work in internal logistics. This was in Study A partly explained by a lack of time for improvement work but can also be traced to the insufficient focus on the internal logistics addressed above. However, it was also explained by a lack of competence in how to do it.

In Studies A, B, C and D inexperience of conducting improvement work, such as automation development, in internal logistics emerged in a majority of the cases. This can to some extent be explained by the size of the companies (smaller companies may have inferior conditions), but also the large case company in Study E was inexperienced in performing extensive improvement processes, which affected the progress in the case studied. Further, in Studies A, E and F the findings revealed a lack of suitable process models for design and process-oriented improvement work. As presented in the frame of reference, the use of sound models and methods is essential during development work (Bennett and Forrester, 1993) as they provide guidance and structure (Bellgran and Säfsten, 2010; Wu, 1994).

The findings regarding inexperience, lack of competence and lack of structured processes can be seen as related. While inexperience can contribute to and be one reason for the perceived lack of competence, the use of appropriate process models could support and facilitate the improvement work, especially for inexperienced companies. The inexperience can also add complexity in improvement work and in turn cause unstructured processes (Bellgran and Säfsten, 2010).

From the analysis it can thus be concluded:

There is inexperience and lack of competence in conducting improvement work in internal logistics.

Appropriate process models are needed but lacking.

The process of improving the internal logistics system

According to Rouwenhorst et al. (2000) and Baker and Canessa (2009), no comprehensive, systematic method or model for designing logistics operations currently exists but, as presented in the frame of reference, there are related models to be found, also from systems design literature in general. The process applied in Study E was similar to the design process phases suggested by Pahl et al. (2007) and Ulrich and Eppinger (2012), especially when considering the main phases. This is not surprising since those are generic processes and the project managers were also inspired by the company's generic development process mainly intended for product development. One difference is however that the applied process involved several information-gathering steps, the early phases of the project hence rather resembled those of Wu's (1994) general systems approach (but with an important exception that will be addressed under the next heading) or Frazelle's (2001a) logistics redesign methodology.

The thorough current state analysis and information gathering in the improvement and development processes in Studies C (cases C2 and C3), D and E are regarded as a strength and valuable since it is important to consider the existing system when designing a new system (Bellgran, 1998; Bennett and Forrester, 1993; Wu, 1994). However, there is a risk of being absorbed in the information gathering if the scope or goal is extensive or unclear or if it is difficult to obtain data, as case company E experienced.

Further, in the literature, the importance of evaluation and follow up is highlighted as an important part of a systems design process (eg. Bellgran and Säfsten, 2010; Bennett and Forrester, 1993; Säfsten, 2002; Wu, 1994). In Study E, an evaluation had not yet been made but was desired by many. Since this was the first large improvement project conducted by the department, there are large potential benefits from evaluating not only the outcome in terms of the implementation, but also the actual project, to capture lessons learnt and build knowledge for future projects. This is a general notion but can be particularly important and helpful in inexperienced organisations.

In Study E, the improvement process benefited from the review of documentation from previous projects since it helped build an understanding of what had previously been done, why and whether it was successful. This however requires that evaluations of previous improvement projects and processes are made and that they are well documented.

Further, the findings from Studies A and D indicated a lack of understanding of what can be improved and how. In Studies C and E benchmarking proved valuable for this purpose and it is also emphasised as an important step in Frazelle's (2001a) methodology and noted by, among others, Bellgran and Säfsten (2010). According to Gu et al. (2010), benchmarking is also a good way to understand and evaluate performance, which will be addressed in the next subsection.

From the analysis it can thus be concluded:

There is a lack of understanding of what can be improved and how.

Thorough information gathering/current state analysis, benchmarking, documentation and evaluation are all important and valuable steps in the process of improving the internal logistics system.

Understanding and objectives of the internal logistics system

As stated above, the findings from Study A indicated a lack of understanding of what *can* be improved. Study A also, together with the identified mismatch between improvement areas and perceived critical resources in Study B, revealed a lack of insight into what *should* be improved in the internal logistics system. One potential cause of this is the finding from Studies A and B that, in contrast to the importance of measuring logistics performance pointed out in literature (see e.g. Fawcett and Cooper, 1998; Griffis et al., 2007), revealed an underdevelopment of performance measurements in internal logistics since few measured and followed up on logistics performance and therefore are unaware of the current situation. The consequence of not measuring and following up on the logistics operations is often a poor general view of the system and its performance, which in turn increases the risk of suboptimisation (Gunasekaran et al., 2004; Mentzer and Konrad, 1991). Being aware of your system, its performance and what affects it is also particularly important for successful use of automation (Fasth et al., 2007). Further, not measuring and following up on the logistics operations can also cause poor availability of data (as experienced in Study E).

From the analysis so far it is thus concluded:

There is a poor insight into the internal logistics operations and its performance. It is important to measure and follow up on logistics performance.

The lack of insight into the performance of the internal logistics system can, as stated above, lead to a weak base of knowledge about what is important and why. This in turn has negative impacts on the prerequisites of conducting improvement work.

For example, the project scope in the case in Study E was initially very extensive, partly due to the nature and cause of the project, but it also remained wide during the project due to the unclear demands and prerequisites. Wu (1994) emphasises that each phase in the design process is dependent on the successful completion of the previous phase. In this project the step corresponding to "setting the objectives", where a vision of the future situation is formed, was somewhat missing and this strongly affected the progress of the project but also the outcome in terms of identifying an appropriate solution. Also other design models (eg. Bellgran, 1998; Pahl et al., 2007) include the formulation of a requirements list for the new system, which was missing in the process in Study E but which most likely could have aided the progress of the improvement work, especially by reducing the wide scope and unclear goal of the project. In Study D the listed requirements filled an important role during the improvement work since they formed the basis for designing concepts and the solution as well as for the evaluation and hence the decisions.

It is thus concluded:

Having a clear objective and list of requirements strongly facilitates the improvement process and increases the chances of a successful outcome.

Relationship with the customer

In Study E, the lack of a clear objective and requirements was in various aspects connected with obtaining information. Bellgran and Säfsten (2010) mention that the difficulty of obtaining relevant information influences the possibility of following a predetermined and structured way of working when developing production systems. Bruch (2012) stresses the need to continuously acquire, share and use design information during the design process. Besides the previously addressed difficulty of obtaining data, the problems in Study E were caused by the internal customer's inability to specify needs, demands and future plans, i.e. the prerequisites for the internal logistics system. Johansson (2007) lists this type of information (e.g. type of production and flows) as one category that must be known when designing materials supply systems and points out that it should be provided by the production department. This was however not the case in Study E. Yazdanparast et al. (2010) conclude that what you focus on in the logistics system should be based on an accurate assessment of what the customer truly values, but logistics managers often struggle with how to identify the services that are desired by the customers. This was the case in Study E, where instead several assumptions had to be made. The alternative might have been to design an extremely flexible system, which would have been associated with a large cost. More formal and active involvement of the internal customer during the improvement work, for example as part of the project team or steering group, could have increased their understanding of the development process. It could also have improved the chances of a better adjusted solution by giving better possibilities to accurately assess the needs and requirements. Both as suggested in the literature (e.g. Ulrich and Eppinger, 2012; Wu, 1994) and as practised in Study C, cross-functional teams are considered to enable and support successful improvement work.

From the analysis it is thus concluded:

The progress and success of the improvement process is strongly affected by the possibility to acquire accurate information and the ability to accurately assess the customer's needs, requirements and prerequisites.

The internal customer and other related functions/areas should, with advantage, be involved during the improvement process.

Strategic view and guidance

Besides obtaining data from the information systems and information from the customer, there is a third category of information, namely that connected with the strategic aspects of logistics (Jonsson and Mattsson, 2011; Lumsden, 2012). As argued in the frame of reference, the strategic information can help answer what should be improved and why (e.g. Porter, 2004b). In Study E, a strategic view and guidelines were strongly asked for to help guide the improvement process and make key decisions during it. Also from Study A it was indicated that not knowing what is important and in what direction and in what way it is desired to develop, not only complicated but often hindered improvement work.

Case company E had a logistics strategy but it was considered non-suitable and outdated. The results from Study B showed a clear lack of both strategy and vision for the internal logistics as opposed to the strong need of them pointed out in the frame of reference. This lack of strategy can be traced back to the lack of responsibility for, ownership of and focus on internal logistics. In two of the cases in Study C, a great deal of effort had been put on developing a vision for a future desired state and a strategy on how to work to reach it, and this proved helpful during the improvement work. This strategic view was in turn enabled by a good overall view of the internal logistics operation and its connection with surrounding systems and actors, something lacking in Study E.

It can thus be concluded:

There is a lack of but strong need for an appropriate and well-founded strategic view and guidance related to the internal logistics system.

Internal logistics performance and goals

As discussed in the frame of reference, some of the main things an internal logistics strategy should include are the goals of the internal logistics system, indicating what performance aspects are most important and how important they are in relation to one another for that specific company (Jonsson, 2008). While it is important to recognise that logistics performance goals are, and should be, highly company-specific (Fawcett and Cooper, 1998; Gunasekaran et al., 2004; Tangen, 2004), it is still of interest to analyse the findings for trends and patterns.

Many of the aspects of logistics performance presented in Section 2.1.4 have been found and in different ways addressed in the empirical findings. In Study B, performance aspects considered important were explicitly listed, and the results indicated mostly delivery-, customer service- and quality-related aspects as highly ranked. In the analysis so far information-related aspects (quality and availability) have been found important especially during improvement work; they were also emphasised as a success factor in Study B. For internal logistics in general but especially when automation has been addressed, the importance of robustness as well as a strong need for flexible solutions has been mentioned in Studies A, C, E and F. During the improvement project in Study E, robustness and flexibility were, together with feasibility, the highest ranked evaluation criteria. In all of the studies, ergonomics, staff safety and work environment were mentioned, possibly as a step towards achieving sustainable processes.

An interesting finding from Study B was, however, that all cost-related aspects were ranked low. Also in Study E, cost was ranked in the lower half when it came to the evaluation criteria. This might suggest a shift in focus from the previous view of logistics from only a cost perspective (Gattorna, 2012; Michalos et al., 2010) to other performance aspects being the most important. However, as evident in Study E and mentioned in Studies A and F, most improvement-related decisions in the end came down to being based on cost.

From the analysis it can thus be concluded:

Different performance aspects have been lifted as important in/for internal logistics depending on the topic of discussion.

Although not explicitly stated, it is indicated that cost is still one of the most important performance aspects.

5.2 THE USE AND DEVELOPMENT OF AUTOMATION IN INTERNAL LOGISTICS

Challenges of using automation in internal logistics

The findings from Study A indicated that despite many possible applications and a positive attitude towards automation, the degree of automation in internal logistics activities was in general low. This is in line with previous research (e.g. Frohm et al.,

2006) that concluded that logistics activities are automated to a smaller extent than typical production activities.

In the frame of reference, the need for structure, proper integration and understanding of the system and the processes to be automated before automating them was highlighted (Fasth et al., 2007; Hammer, 1990; Meredith, 1987b; Tu et al., 2011). As concluded above, these prerequisites are often poor or missing when it comes to the internal logistics system, which is thus assumed to influence the possibility of successful use of automation. Since the general prerequisites for improving the internal logistic system were analysed in the previous section, this section will focus on and analyse challenges and facilitators more directly connected with automation and its development in internal logistics systems.

As indicated in Studies A, C (case C1) and D, one main reason for the low degree of automation in internal logistics is the inexperience of using automation and lack of knowledge about automation. As both clearly expressed by the respondents and made evident during observations, there is a lack of knowledge of what is possible to solve using automation and what possible applications there are. Just as facilitating improvement work in general, benchmarking proved successful for this purpose in Studies A (case A6), C (case C3), D and F.

Benchmarking could also give knowledge about and better prerequisites for identifying problems or possible improvement areas, a step in the automation development process that many in Study A found difficult and needed help with. This is supported by Arvanitis and Hollenstein (2001), who identify benchmarking as one of the most determining factors for the adoption of advanced technology such as automation. Also Durrani et al. (1998 p. 525) have incorporated it as one of the pre-steps before technology acquisition since it *"facilitates decision making"*.

From the analysis so far it can thus be concluded:

Benchmarking is one possible way to address the lack of knowledge about automation and its possible applications.

In Section 2.2.3 results from previous studies (Material Handling Industry of America, 2011; Baker and Halim, 2007; Dadzie and Johnston, 1991; de Gea Fernandez et al., 2007; Frohm et al., 2003; Frohm et al., 2006; Naish and Baker, 2004) regarding common concerns and problems associated with using automation in internal logistics were compiled. Also in the findings from the empirical studies, several of these were identified as reasons for the current low level of automation:

- High cost of equipment/difficulty of financial justification (Studies A, E and F)
- High demand for flexibility (Studies A, C, D, E and F)
- Concerns regarding robustness/reliability of equipment (Studies A, C and F)
- Integration of equipment into existing systems (Studies A and F)
- Staff acceptance of automation (Studies A and F)
- Lack of commitment from top management (Studies A, C (case C1) and F)
- The need for training of staff (Studies C, D and F)

Further, in case C1 in Study C, physical limitations hindering the use of many standardised automated applications were also highlighted as a challenge of using automation in internal logistics.

Worth noting is that in none of the studies potential problems related to the implementation phase were mentioned and, as found in Study A, none of the respondents considered the actual implementation of automated equipment to be the most difficult step when automating. This is contrary to the view in literature of implementation as the most difficult step to handle and the risk of disruption and service-level failings during it as one of the main downsides to automation in internal logistics (Baker and Halim, 2007; Naish and Baker, 2004). Hofmann and Orr (2005) however concluded that it is mostly the operators that are worried about interruptions during the installation, while middle management worry more about staff acceptance of the new technology. The empirical findings support Hofmann and Orr's (2005) conclusions, but also indicate them being related. In Studies A and F the interviewees, mostly belonging to middle management, expressed resistance against automation among the workers as one of the obstacles for automating. The resistance was however often caused by previous bad experiences of automated equipment that had malfunctioned and caused problems and interruptions.

The challenges identified and ways to address and thus potentially overcome them will be dealt with in the analysis that follows.

The process of developing automation in internal logistics

As dealt with and concluded both in the introduction and in the frame of reference, the chances of a successful use of automation are strongly dependent on the way the automation development is conducted (Baines, 2004; Ceroni, 2009; Daim and Kocaoglu, 2008; Durrani et al., 1998; Fasth et al., 2007; Frohm, 2008; Sambasivarao and Deshmukh, 1995; Spath et al., 2009).

The identified inexperience of using automation implies inexperience in developing automation. The findings from Studies A and D also indicated unfamiliarity with conducting automation development work and a lack of knowledge about what steps and actions to take in the development process, sometimes to the extent that the company had refrained from automating. Even in companies more experienced with automation development, as in Study F, the automation development was often conducted ad hoc and a formal and appropriate process model was lacking. The lack of a structured process model is one possible explanation of why documentation and evaluations of automation projects were often poor or missing since there is no routines for it. This in turn is believed to be one of the causes why the company experienced the same problems over and over with its automation investments. In Study D, effort was spent on carefully documenting the development process to have a base for evaluation.

Building on Bennett and Forrester (1993), Wu (1994) and Bellgran and Säfsten (2010), formal and appropriate process models for automation development are believed to give structure and guidance and thus increase the probability of a proper automation development process. But, as concluded in Section 2.2.4, there is little support addressing the entire automation development process and being suitable for automation development in internal logistics systems.

In Study F it was also evident that there was a lack of routines, guidelines and other types of support documents that were intended or appropriate for automation development. Support documents such as for planning, authorising, controlling and reporting are important during technology development projects (Archibald, 2003) and can facilitate the automation development process.

It is thus concluded:

There is inexperience and lack of structure in conducting automation development.

Formal and appropriate process models are needed but lacking. There is also need for support documents intended or appropriate for automation development.

Base for automation decisions

Hackman et al. (2001) conclude that inefficiencies in automated logistics systems (i.e. unsuccessful use of automation) often depend on inappropriate selection of system types. In the findings from Studies A, C (case C2) and F, several unsuccessful automation investments were identified and these can in several cases be traced to inappropriate selection. The reasons for this inappropriate selection can be argued to be dependent on and caused by two related things, the lack of process structure during development addressed above and/or the lack of clear goals, demands, needs and prerequisites and thus a lack of a proper base for evaluation and decisions. The latter need has been both pointed out in literature (eg. Baines, 2004; Durrani et al., 1998; Fasth et al., 2007; Frohm, 2008; Frohm et al., 2003; Winroth et al., 2007) and proven useful and supportive in the development process in Study D. It is however important to point out that it refers to goals, needs, etc. connected with the internal logistics system and specifically with the automated equipment, addressed separately below.

As analysed in Section 5.1, there was a lack of an overall view and understanding of the internal logistic system and its performance but also a lack of a strategic view including unclear goals, requirements and objectives regarding the system. It was concluded that these findings in different aspects affected the process of improving the system and they will thus have the same negative effects on the automation development process since they contribute to this poor base for evaluation and decision. They are also considered to be one of the causes of the difficulty of integrating automation into the existing system identified above.

Further, high demands on the flexibility, robustness and cost of the automated equipment were listed above as challenges to the use of automation in internal logistics. These are examples of aspects that thus should be clearly addressed when specifying the requirements for automated solutions in internal logistics. This is to be able to evaluate whether suggested solutions can meet the requirements and thus are appropriate and have the possibility to become successful. Building on Hill (2000), the requirements could also favourably be of order qualifier and order winner character as well as give guidance on how important different aspects are in relation to each other.

From the findings in Study F, the importance of a clear specification of requirements for the successful implementation and use of automation was made evident and also identified by the experienced employees involved in automation development. In Study D the specification of requirements, together with the overall identified need and requirements, provided the base for evaluation and decision but also facilitated and guided the development process. Since the key issue is why the decision is made and on what facts it is based (Winroth et al., 2007), it is of the highest importance that the specification of requirements for the automation equipment is based on and supports the overall goals, needs and demands of the organisation, specifically for the area the automation is intended to be part of, in this case the internal logistics.

From the analysis it can thus be concluded:

Having a clear base for evaluation and decisions and a clear and well-founded specification of requirements facilitates the automation development process and increases the chances of successful use of automation.

Strategic view on the use of automation

Automation in an internal logistics system is a strategic decision that will have a long-term impact on the system (Baker and Halim, 2007; Ceroni, 2009). This was in different ways made evident by the findings from Study C: in one of the sites in case C2 the existing automated solutions had become obsolete and were not adapted to today's requirements and in both case C2 and C3 automation of the logistics operations in the new hospitals was addressed as a strategic decision early in the design phase.

Since automation decisions have this long-term impact, it is important that they are well aligned with and thus help fulfil the overall goals of the firm as well as other functional strategies and performance goals (Ceroni, 2009; Daim and Kocaoglu, 2008; Naish and Baker, 2004; Sambasivarao and Deshmukh, 1995; Säfsten et al., 2007; Winroth et al., 2007). This is to make sure that a future investment fits well into the system and adherent needs and prerequisites, i.e. that an appropriate selection is made. It can also help overcome the problem and challenge of integrating automation into existing systems identified above and made evident in Study A. But the findings from Study F rather indicated that automation decisions were often based on a gut feeling. This is in line with Winroth et al. (2007), who conclude that automation decisions are of an ad hoc nature and based on other issues than solid facts and a well defined strategy.

As argued above, in connection with the need for a strategic view on internal logistics, a strategic view on automation could provide support for what should be automated but also guidance on why and how (Porter, 2004b). It should thus help provide the basis for specifying requirements and also other goals and demands related to the use and development of automation. For example, as in Study A, one of the case companies had found a type of and application for automation that well suited the company's needs, goals and prerequisites. Having this clear view both facilitated the development process and supported successful investments. This is supported by Frohm (2008), who concludes that one of the main reasons why an automation project ends in failure is unrealistic or undefined objectives.

During the development project in Study E, automation appeared as one of the evaluation criteria, i.e. a high level of automation was rewarded during the evaluation of the different concepts and solution. The motivation for using this criterion was however unclear, and automation can thus in this case be interpreted as being a goal on its own and not a result of or aligned with an overall strategic decision which is lifted as important in literature (e.g. Arvanitis and Hollenstein, 2001; Ceroni, 2009; Daim and Kocaoglu, 2008; Greenfield, 2003; Hax and Majluf, 1991; Kotha and Swamidass, 2000; Sambasivarao and Deshmukh, 1995; Trudel and Goodwin, 1990).

In Study F, several interviewees had through experience developed a similar idea of what they wanted to automate, why and how. Developing a strategic view however demands a good overall understanding of both the operations and the automation development process as well as a certain knowledge of automation and its possible application areas.

It is concluded:
A well-aligned, strategic view on the use of automation provides a base for automation decisions and thus supports appropriate selection.

Commitment and understanding
As discussed when highlighting challenges of using automation in internal logistics, the findings from Studies A and F indicated strong resistance against automation, especially among operators. As mentioned in Section 5.1, the use of cross-functional teams is considered to enable and support successful improvement (e.g. Ulrich and Eppinger, 2012; Wu, 1994), and the importance of the composition of the teams is also argued when it comes to automation projects (Winroth et al., 2007). In Studies C and F the use of cross-functional teams and early involvement of staff from different levels during automation development was considered to contribute to more viable solutions and increased commitment as well as understanding and acceptance of new equipment.

In Studies A, C (case C1) and F there was a lack of commitment and support also from top management related to the use and development of automation. The strategic view addressed above can be generated either top-down or bottom-up (Burgelman, 1983; Nonaka, 1988). Winroth et al. (2007) conclude that when it comes to automation, both top-down and bottom-up decisions can be successful as long as they are aligned with and based on solid knowledge of the company's long-term goals and an understanding of the prerequisites.

The key issue is thus not who makes the decisions or at what level they are made (Winroth et al., 2007). In Study F it was predominantly production engineers, who were the employees most involved in automation development, that had started to develop a strategic view on the use of automation. In case C3 in Study C the strategic plan was the result of a collaborative effort while in case C2 it was the result of a top-down standpoint. Regardless of how and from what level the strategic view and plans for the use of automation are developed, it is important to secure understanding of and commitment to them on all levels in the company (Langley and Truax, 1994). This since the decision to adopt and implement automation may cause psychological stress and concerns over potential job losses, which in turn is bound to create resistance from employees and thus could affect the adoption time (Dadzie et al., 2000). If the strategy and its adherent goals and plans are well explained and justified (for example the need to increase the level of automation to secure quality and thus profitability), these concerns and the resistance may decrease.

From the analysis it is concluded:
During automation development, cross-functional teams can reduce the resistance against automation.

Understanding of and commitment to automation plans on all levels are important.

Dependency on and collaboration with third parties

In line with Baker and Halim (2007), the findings from Study A indicated a strong dependency on third parties (such as consultants, systems suppliers or integrators) during automation development in internal logistics. In both Studies A and F there were also accounts of how the strong reliance on third parties had caused unsuccessful automation investments that poorly met the companies' needs and prerequisites.

It is however argued that the cause of these unsuccessful investments is not necessarily in the actual involvement of third parties but rather in the way that they are involved and how the responsibility is divided. Involving third parties during automation development is an excellent way to compensate for and help overcome the lacking knowledge about automation and its possible applications, especially when it comes to new technology (Daim and Kocaoglu, 2008). However, as found in Study A, the identification of problems and possible areas of improvements was the step in improvement work that the companies most often chose to do themselves and not involve third parties, i.e. not taking advantage of them in one of the steps perceived as most difficult.

Also, previous unsuccessful investments identified in the studies can also be traced to the customer's (the company buying the service from the third party) lack of insight into and understanding of the automation development process and the poor base for decisions (such as poor understanding of the operations) that leads to inappropriate selection. This is especially a risk when relying too heavily on the third party and letting them take the decisions without proper insight into either prerequisites, requirements or goals, something that should be provided by the customer for a successful supplier-driven approach (Säfsten, 2002). Based on its previous bad experiences, case company F had for example realised that a thorough specification of requirements was even more crucial when third parties were involved.

As discussed by Daim and Kocaoglu (2008) and Hax and Majluf (1991), the extent to which a firm will rely on third parties is one of the strategic decisions that need to be actively addressed. It should thus preferably be one part of the strategic view addressed above. From the findings in Studies A and F, elements of how to engage in this collaboration could be found in the desire to work more closely together with the third party during the development process or in parts of it. In order to achieve this, a rigorous supplier selection is necessary (Baines, 2004) to find a third party suitable for that specific type of collaboration.

It is concluded:

The involvement of third parties can support the use of automation but it is important to have a clear view on how and when they with most benefit should be involved.

A successful involvement of third parties is dependent on the customer's understanding of the development process and its ability to provide the base for appropriate evaluation and decisions.

Plan ahead

The lack of, or unclear, ownership of and responsibility for automation equipment emerged in different aspects as a challenge in the empirical findings. In case C1 in Study C, where parts of the logistics operations were outsourced, neither the hospital nor the service provider wanted to take on the ownership and thus the cost of automation equipment and had hence refrained from making investments that in the long run would have been profitable for both parties. Several other case companies witnessed that lack of ownership and responsibility, not only for the automated equipment but also the operation/process that it was included in, led to problems. In case A7 in Study A there had during previous automation development projects been discussions and disagreement between the different parties regarding who was responsible for what part in the development process. In case A2 in Study A there had instead been disagreement between the company and the systems supplier, where both claimed ownership of the equipment developed.

As analysed in the previous section, clear roles and responsibilities are important during development work but their importance when it comes to automation has also been highlighted in previous studies (Säfsten et al., 2007; Winroth et al., 2007). Having clear responsibilities and roles in general and related to automation specifically (both including the equipment and development projects) is thus something that can be assumed to support the use of automation in internal logistics but also to facilitate the development of automation. The clarifying of roles and responsibilities can be seen as a part of the important planning before and during automation development (Archibald, 2003; Baines, 2004; Meredith, 1987a; Sambasivarao and Deshmukh, 1995). This planning should also involve assessing needs and planning for education and training of staff early in the automation development process. The operators' lack of knowledge about properly handling automated equipment was emphasised as a cause of previous problems as well as a challenge to/when automating in Studies A, C, D and F. The increased demand on the competence of the staff when automating was also highlighted in the findings from Studies C and D as well as pointed out in literature (Frohm et al., 2003; Sambasivarao and Deshmukh, 1995; Säfsten et al., 2007; Trudel and Goodwin, 1990; Winroth et al., 2007). As found in Study B, competence was also generally considered the most critical resource in internal logistics.

Another important aspect to be addressed during the automation development concerns maintenance (e.g. Sambasivarao and Deshmukh, 1995; Trudel and Goodwin, 1990), especially since maintenance-related aspects are common concerns or problems associated with automated equipment in logistics operations (Baker and Halim, 2007; Dadzie and Johnston, 1991). As evident in Study F, the maintenance department was often reluctant to take over the responsibility for automated equipment after it was installed. Therefore it is important to have agreed on the responsibility but also the plans for how maintenance should be performed. In many of the cases the company chose to outsource for example maintenance due to lack of knowledge or time while others preferred to handle everything in order to have a complete view of the operations. Regardless of how, the important thing is considered to be to make an active choice, understand the implications of your actions and have a plan for them.

From the analysis it is thus concluded:

Planning during the automation development process is important and should include aspects such as roles, responsibilities and maintenance.

Dependency on individuals

In Studies A, D and F the dependency on individuals, from different aspects, emerged as an issue and potential challenge to the use and development of automation. In some of the cases (such as A2-A4, D and F) there was extreme pressure with responsibility (for example related to initiating automation development, providing automation knowledge, managing automation projects or handling/maintaining equipment) solely resting on one or a few individuals. However, as in Study F, there was a large amount of automation knowledge, experience, well established contacts, etc. in the company but only linked to a few individuals, and it was often their know-how and gut feeling that had contributed to the success of previous automation projects. This is also highlighted by Meredith (1987b), who addresses "automation champions" and their role in successful automation projects.

Having clear, structured and well supported routines for the automation development process (a need concluded above) as well as for handling and maintenance of the equipment would support especially inexperienced staff during this process and thus help share responsibilities and even the workload but also support additional individuals building experience and knowledge in automation and its development.

The key employees with much knowledge and experience of automation and its development should profitably be actively involved during the development of these routines and support documents to take advantage of their experience and knowledge. Also Baines (2004) addresses the importance of explicitly documenting knowledge in his suggested technology acquisition process by creating databases and portfolios in the first steps of the process.

From the analysis it is concluded:

There is a strong dependency on key individuals that could be relieved with structured and well-supported automation processes. It is important to take advantage of and spread the competence and experience that does exist.

5.3 SUMMARY OF THE ANALYSIS

In the analysis, challenges of successfully using and developing automation in internal logistics systems as a means of improving the system have been addressed and can be summarised as follows.

Automation development in internal logistics is often conducted in an unstructured and poorly supported manner. There is a lack of suitable process models and the findings indicate insecurity regarding what steps and actions to take in the development process. Routines and support documents suitable for process improvements and automation development are also often missing.

Particularly in the smaller case companies there were also difficulties observed and experienced in identifying possible applications and application areas for automation. Further, there is often a strong dependency on both individuals in the company and third parties during automation development. There were also difficulties and problems connected with involvement of third parties. Employee resistance against automation as well as a lack of top management commitment was also highlighted as challenges.

Primarily the findings indicate a poor base for proper evaluation and decisions during automation development. This was analysed as a cause of unclear goals and requirements regarding both use and development of automation and the internal logistics operations. With reference to the former the high demands for flexibility or robustness were for example often seen as hindrances, but with unclear demands and requirements it is rather a challenge to properly select or identify available technology that could be suitable. Referring to the latter, there was often a poor awareness of both current and desired performance in and of the internal logistics system. To some extent there were also lacking data as well as difficulties in assessing customer needs and requirements.

Lastly, responsibilities were often unclear both regarding automation and the internal logistics; especially strategic responsibility was often lacking. Many of the above-mentioned challenges can be concluded as caused by a lack of strategic view on the internal logistics systems as well as on the use and development of automation.

Possible ways to overcome the identified challenges and factors facilitating successful automation development in internal logistics systems have also been analysed. The overall conclusion from the analysis is that the central part of a framework supporting automation development in internal logistics should be a *structured process model for automation development* suitable for the internal logistics context and covering the entire automation development process.

Further, a strategic view on the internal logistics system and its operations as well as a strategic view on the use of automation and its development is concluded as important for guiding and providing a proper base for the automation development process. The framework should thus incorporate *an internal logistics strategy* and *an automation strategy* supporting the automation development process and give support in what these strategies should include.

From the analysis it is concluded that in order to facilitate the automation development process, an internal logistics strategy should with benefit include performance goals and directives and give guidelines on how to evaluate, follow up on and work with improvements of internal logistics operations and performance. The strategy should also clarify aspects such as responsibilities and interface with the customer.

Based on the analysis it is further concluded that an automation strategy preferably should include goals of the use of automation and give guidance on identifying suitable application areas and on identification, evaluation and selection of suitable automated equipment. The strategy should also give guidance on how to conduct the automation development for example in aspects such as how to work with third parties and how to secure necessary resources, knowledge and commitment needed for successful use of automation.

6. PROPOSED FRAMEWORK

In this chapter a framework facilitating automation development in internal logistics systems is proposed. The framework is divided into three parts, a model for internal logistics strategy, a model for automation strategy and a process model for automation development in internal logistics systems.

In the previous chapter, a number of challenges for successfully using and developing automation to improve the internal logistics system were identified. Possible ways to overcome these challenges and factors facilitating successful automation development in internal logistics systems were also analysed and concluded. Building on this, a framework facilitating automation development in internal logistics systems and thus supporting the successful use of automation is proposed in this chapter.

Based on the analysis and the conclusions made from it, the core of the framework is a process model for automation development. Due to the significance of this process being linked to and supported by strategy, the elements of internal logistics strategy and automation strategy are important to include. As illustrated in Figure 17, the framework is therefore structured in three parts in the form of (1) a model for internal logistics strategy, (2) a model for automation strategy and (3) a process model for automation development in internal logistics systems, each separately described and motivated in the following sections.

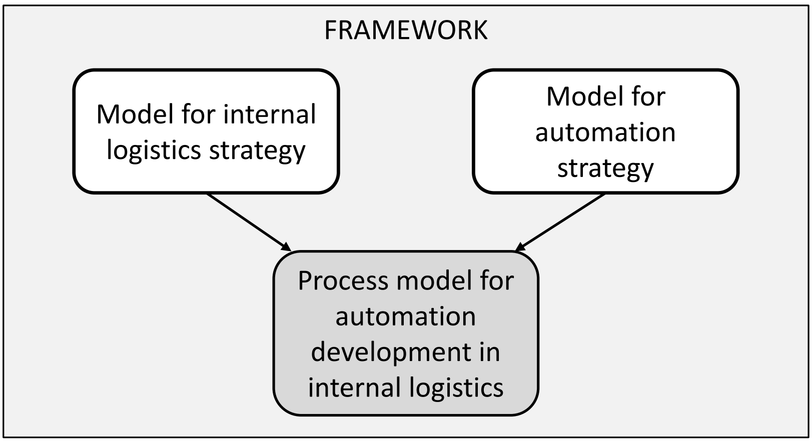

Figure 17 The three parts of the proposed framework.

The structure and content of the three models are based on the findings from the literature review and the empirical studies and incorporate both identified facilitators for successful use and development of automation as well as own propositions made based on the findings and analysis.

6.1 A PROPOSED MODEL FOR AN INTERNAL LOGISTICS STRATEGY

The first research question was posed to investigate the prerequisites for using and developing automation as a means of improving the internal logistics system. From the analysis it was concluded that, with reference to the internal logistics system, there was a lack of an overall strategic view and guidelines for improvements, an understanding of the system and its performance as well as clear responsibilities, which all affected the possibilities to perform successful improvement work. An internal logistics strategy, which most often was lacking, is proposed to help overcome these challenges and give support, structure and guidance for improvement work by providing a base for

- strategic goals and plans for development
- improvement incentives
- requirements specifications for improvements
- evaluation and decisions of improvement suggestions/solutions
- support during the process of improving the system

Having an internal logistics strategy can also be one step in setting increased focus on the internal logistics systems, something concluded as needed in the analysis.

The internal logistics strategy is a functional strategy, which implies that the aim of this strategy is to help the company pursue the business level strategy (Hill, 2000). The hierarchy of different strategies in a company in relation to the internal logistics strategy is illustrated in Figure 18. In the figure it can be seen that the internal logistics strategy is subordinate to the business level strategy but also to the logistics strategy and the strategy for the overall system of which the internal logistics system is part, such as a production system and thus the production strategy even though these are also considered functional strategies.

As stated by, among others, La Londe and Masters (1994), Tan (2001), McGinnis et al. (2010) and Jonsson (2008), it is of utmost importance that the logistics strategy and adherent plans (and thus the internal logistics strategy) are integrated not only with the overall business strategy as mentioned above but also integrated and aligned with the company's other functions and strategies. This is illustrated in Figure 18 by the horizontal arrows indicating interchange and alignment between the different functional strategies.

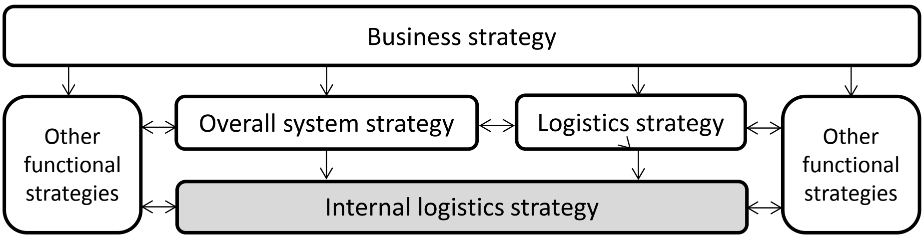

Figure 18 The hierarchy of strategies in relation to the internal logistics strategy.

Figure 19 shows an overview of the proposed internal logistics strategy model and illustrates what influences the formulation of the internal logistics strategy. As a functional strategy it is implicated that the content in the internal logistics strategy should be derived from and help fulfil the overall business mission, vision, strategy and goals of the company. It is proposed that these aspects, through the mission, vision, strategy and goals of the overall system (e.g. the production or warehouse system) provide the base for an internal logistics vision. This vision should reflect the desired future state for the internal logistics system and thus the essence of the internal logistics focus of the company. This should in turn shape the formulation of the strategy that aims at fulfilling the vision.

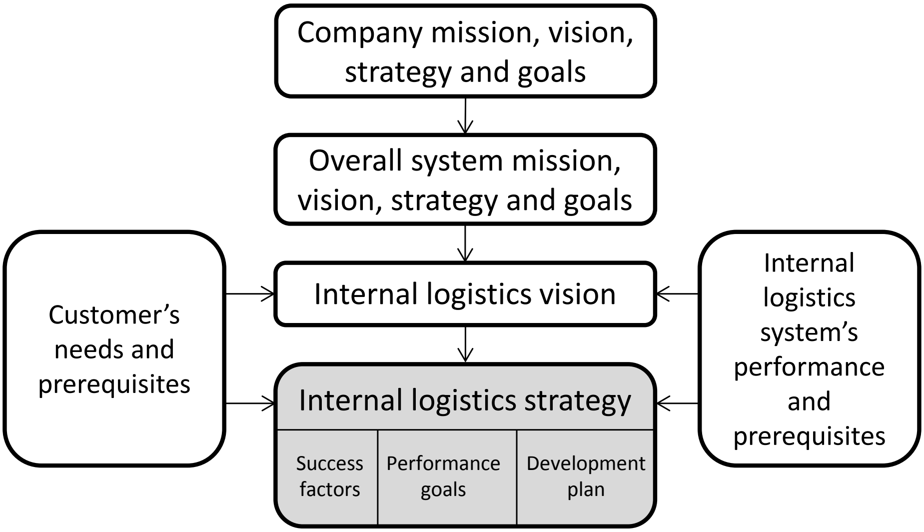

Figure 19 Overview of the proposed internal logistics strategy model.

But it is also of great importance that the internal logistics visions and the content in internal logistics strategy fit the unique environment of the internal logistic system. In order to achieve this there is first a need for a good overall view and understanding of the system, its performance and the prerequisites and factors influencing and affecting it. For example, in Study B, only 26 % of the respondents ranked critical resources in the same way in internal logistics as in the organisation in general. In addition, the specific needs and prerequisites of the (internal) customer must be well understood since they also should shape what to strive for, in other words the goals and thus how you should work to reach them. These two contextual conditions are illustrated in Figure 19 by the fields to the left and right, influencing the internal logistics vision as well as strategy.

Based on the literature and empirical findings, it is proposed that the content in the internal logistics strategy should be based on three main parts: success factors, performance goals and a development plan. The internal logistics strategy and its subparts thus form an important basis for all decisions concerning the strategic and operative development of the internal logistics system. The attributes and content of the three subparts (also presented in appended Paper IV) are in overview presented in Figure 20 and separately addressed in the following.

Internal logistics strategy		
Success factors	**Performance goals**	**Development plan**
Identify basic functions, aspects and features necessary for the overall function of the internal logistics system and specify structure and way of working to ensure these.	Specify which performance criteria are most important and specify how important certain aspects and resources are compared with each other. Set targets.	Specify how the internal logistics system should be developed and systematically improved. Develop principles and structures for working with improvements.
Examples of success factors: • Delivery precision/times • Information systems • Balanced flow without disturbances • Commitment and responsibility • Roles and responsibilities • Instructions and process models • Measurement and follow up • Dialogue/interface with customer	*Examples of performance aspects:* • Delivery aspects • Customer service • Quality aspects • Information aspects • Ergonomics, staff safety and work environment • Robustness • Flexibility • Cost	*Examples of aspects to include:* • Organisation, responsibility, ownership • Assignment of time and resources • Process models • Benchmarking • Economic aspects • Decision points and basis for decisions • Documentation • Follow-up and evaluation • System alignment

Figure 20 Proposed content of the internal logistics strategy.

Success factors indicate basic functions, aspects and features necessary for the overall function of the internal logistics system thus needing to be fulfilled, implemented and working correctly to ensure desired system performance. These success factors, together with the performance goals, should work as guidelines when allocating resources and initiating improvement work. The success factors also include aspects and features affecting the internal logistics operations and thus need to be in place to support the operations and ways of working, for example when improving the system. When identified, decisions or guidelines on how these functions, areas and features are supposed to be structured should be developed to ensure a standardised, correct and supportive way of working.

The findings and conclusions from the studies propose some generic categories for success factors for overall system function and performance (FP) and for supporting operations (SO) such as the following:

- Delivery precision, delivery/lead times (FP)
- Comprehensive, updated and dependable information systems (FP)(SO)
- Balanced flow without disturbances (FP)
- Commitment and responsibility of the humans working in the system (FP)(SO)
- Clear roles and responsibilities (FP)(SO)
- Work instructions and process models (FP)(SO)
- Measuring and follow-up on operations (SO)
- Dialogue/interface with internal customer (FP)(SO)

Performance goals specify which performance criteria are most important and specify how important certain aspects and resources are compared with each other. The performance goals have many similarities with the success factors. However, the former aim at finding the most important aspects and criteria for success and strategy fulfilment; hence they are more company- and system-specific than the success factors. The performance goals are influenced by and should, among other things, reflect the organisation's goals and core competence and the customer's prerequisites and needs. The performance goals should help identify areas for improvement, since they draw attention to the most important aspects to consider.

Thus they also work as a base for evaluation and decisions during improvement work with the goal to identify appropriate and successful solutions and avoid suboptimisation. But it is also important to set targets for the different performance criteria to understand what the goal are and to be able to know when they have been reached.

Even though the performance goals are and should be unique to each organisation and, as concluded in the analysis, different performance aspects are often highlighted as important in/for internal logistics depending on the topic of discussion, the findings and analysis did offer some general trends:

- Delivery, customer service and quality-related aspects, are traditionally highly ranked (Study B).
- Information-related aspects (quality and availability) are found important especially during improvement work (Study E).
- Ergonomics, staff safety and work environment are beginning to come more into focus (Studies A, B, C, D, E and F).
- There are high demands on robustness and flexibility of new solutions/technology (Studies A, C, E and F).
- Cost and feasibility, although not explicitly emphasised, are often the most determining performance aspects (Studies A, E and F).

The development plan specifies how the internal logistics system should be developed and systematically improved by planning and initiating improvements to constantly conform to the success factors and the effort to reach the performance goals. The development plan should also include principles and structures for working with improvements and specifically support for the improvement process.

Based on the analysis it is concluded that the development plan preferably should include aspects such as the following:

- Clarification of organisation, responsibilities and ownership, in general and specifically concerning improvement work, e.g. how project/steering groups should be manned, who is responsible for taking decisions, who is the owner of investments made, etc.
- Assigned time and resources for improvement work.
- Suitable and updated process models for improvement work.
- How to benchmark in order to assess performance and identify possible and potential improvement areas and solutions.
- Economic aspects such as a budget and plans for a business case.
- Clear decision points and bases for decisions.
- Routines for documentation of processes and improvements and how to make use of the documentation.
- Follow-up and evaluation of both system performance and improvement projects and measures.
- Structures for ensuring system alignment and integration, especially towards the customer.

It is important that someone in the company acknowledges ownership of and governs the internal logistics strategy, making sure that it is always up to date and that the internal logistics operations and organisation conform to the strategy.

6.2 A PROPOSED MODEL FOR AN AUTOMATION STRATEGY

From the analysis it was concluded that a well-aligned, strategic view on the use of automation provides a base for automation decisions and thus supports an appropriate selection. This conclusion was well supported by the findings from the theoretical review, where the value and importance of strategy connected with the use, development and selection of automation was addressed in different ways (e.g. Arvanitis and Hollenstein, 2001; Ceroni, 2009; Daim and Kocaoglu, 2008; Greenfield, 2003; Hax and Majluf, 1991; Kotha and Swamidass, 2000; Sambasivarao and Deshmukh, 1995; Trudel and Goodwin, 1990).

Based on the findings and the analysis, a model for automation strategy is proposed and is, in overview, presented in Figure 21. The model is also presented in appended Paper VI. It is important to note that the model is purposely kept on a generic, company level and not directed towards internal logistics only. The reason for this is the importance of all functions in a company working towards a shared automation vision/goal and thus on a corporate level having a cohesive strategic view on the use and development of automation. Also, an automation strategy should be on a corporate level in order to, among many other things, make better use of existing knowledge and resources in the company and improve chances of compatible and standardised systems and solutions, thus reducing complexity. However, it is important to link the automation strategy specifically to the internal logistics context when automating in this system; this will be addressed in Section 6.2.1.

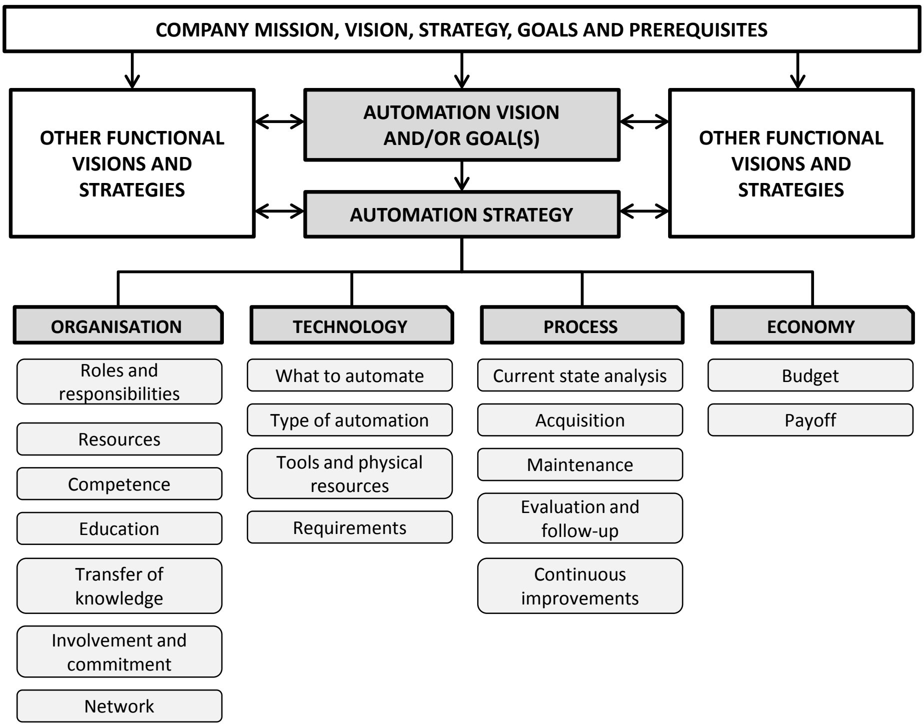

Figure 21 Overview of the proposed automation strategy model.

Overall structure and content of the model

The automation strategy takes its origin in a formulated overall vision for automation and/or more specific goal(s) possibly to be completed within a set time frame. The vision and/or goals should be derived from and based on the company mission, vision, strategy, goals and prerequisites. This is because the automation strategy cannot be created in isolation from the corporate objectives, capabilities and competitive need in the business operations it is intended to support (Baines, 2004; Hax and No, 1992; Meredith, 1987b; Winroth et al., 2007).

The aim of the content in the strategy is to specify what needs to be done and how the company should work with automation to fulfil the vision and/or achieve the goals. In line with the methodology by Lindström (2008), the focus is thus first on knowing what the right things to do are and then making sure that they are done right.

Since automation should be seen as a tool, and since the automation strategy is one of several functional strategies in a company, it is of utmost importance that the automation strategy is integrated and aligned with the other functions and strategies, indicated by the horizontal two-way arrows in Figure 21. This important alignment is also pointed out by Winroth et al. (2007), who state that the automation strategy might either be the manufacturing strategy or be a consequence of the manufacturing strategy process. The latter view is adopted in the proposed model and the automation strategy can thus be seen as subordinate to the manufacturing strategy or the equivalent strategy for the overall system of which the internal logistics system is part.

The content in the strategy is divided into four main categories: organisation, technology, process and economy. In turn, each category consists of a number of subheadings with their own issues and aspects to consider and decisions to make. What the subheadings involve and what information is suggested to be included under each is described below. It is however important to note that the resulting strategy does not need to include all subheadings; they are only suggestions and only the ones that are applicable and relevant to the company in question and help achieve the vision and/or goal(s) should be part of the strategy.

Organisation

Roles and responsibilities: Appoint a person responsible for automation who also owns and governs the strategy. Identify other key roles and responsibilities (such as for technology, education/training or maintenance) and clearly state the responsibilities and authority of each role.

Resources: Map the resource requirements for each area related to automation, such as acquisition, development, operations and maintenance. Make an action plan to meet the requirements for example through hiring, redistribution of resources or the use of consultants.

Competence: Specify what skills/competences are needed to achieve the vision and/or goal. Map current automation-related competences and skills in the current staff and develop a competence matrix. Go through the increased competence requirements, if any, and make an action plan for how to meet them, for example through education/training, hiring or use of consultants.

Education: Based on the competence matrix, go through the possible need for education or training of staff. Make an action plan for necessary internal and external education/training, specify who is intended to give and receive it and in what time frame. If applicable, make sure that persons receiving external education will spread that knowledge internally.

Transfer of knowledge: Identify key persons with knowledge and experience of automation. Appoint them as mentors to less experienced staff to ensure transfer of knowledge. Also ensure the involvement of these persons in the creation of new routines or support documents in order to profit from their knowledge and experience and to ensure good quality and useful routines/support documents.

Involvement and commitment: Make sure that the automation vision/goal(s) and hence the automation strategy is supported by the management. Inform staff at all levels concerned and explain the automation vision and strategy and what they will lead to in both the immediate and a distant future. This is to secure commitment to and understanding of changes, new ways of working and the use of automation. Also, make clear what, and how, different functions/representatives should be involved in automation-related tasks such as during development.

Network: Settle on what main third parties such as consultants, suppliers, integrators or system suppliers to work with and make sure to maintain good relations with them. Also make sure to transfer well established contacts between employees in the company. Look into networks that can provide helpful contacts and benchmarking opportunities as well as possible collaboration with academia through thesis work, research projects, etc.

Technology

What to automate: If, based on the formulated vision/goal(s), it is appropriate, decide on a desired degree of automation. Decide what level of automation is desired for different types of activities based on the needs and prerequisites, what creates value in the organisation, what aspects are key factors for success and what performance goals are most important. Settle on what operations and activities are desired to be automated and to what degree and what is preferred to be kept manual. Also determine whether the automated activities should support the manual activities or vice versa.

Type of automation: Based on the company's needs and prerequisites, decide what level of technology (regarding simplicity and novelty) and what type of automation equipment (e.g. industrial robots, linear actuators, automated guided vehicles, automated storage and retrieval systems, feeders) are desired for different types of activities. Determine specific demands for flexibility, reuse, etc. for the automated solutions.

Tools and physical resources: List any support tools and non-human resources needed to reach the desired vision/goals and also specify how to acquire them.

Requirements: Develop a technical specification specifically for automation equipment or make sure that the general technical specification, if any, is suitable also for automation equipment. The specifications should cover areas such as preferred brands for specific system components (partly to enable proper system integration), safety, design, ergonomic regulations, environmental aspects, etc.

Process

Current state analysis: Establish routines for how to perform current state analysis in search for potential improvements. The routines should include how the analysis is to be performed (what to look for, how to evaluate, how to document and make a decision to proceed), how often it should be performed and by whom. Establish routines also for how to identify and benchmark suitable areas to be automated and available/suitable technology. Make sure proper support documents are available or created.

Acquisition: Develop and establish routines for the steps in the automation acquisition process (further elaborated on in Friedler and Granlund (2012)) such as formulation of requirements, development of concepts and solutions, evaluation of concepts/solutions, decision gates, installation, tests, handover, etc. Define what should be made during the different steps, how the work should be documented, who is responsible and which functions should be involved, when and how (strive for cross-functionality early in the process). Proper support documentation should also be established. Also determine what parts of the development work, installation, operation, maintenance, etc. should be performed internally and when third parties such as consultants or system suppliers should be involved and in those cases specify the different parties' responsibilities and obligations clear. For the internal work, make clear how the project teams should be formed and manned.

Maintenance: Establish routines for maintenance of automated equipment. Define how often preventive maintenance should be performed, what it should include and who is responsible for both corrective and preventive maintenance.

Evaluation and follow up: Specify how automation projects and investments should be evaluated and followed up on and how proper actions should be made accordingly. This is to secure transfer of knowledge and lessons learnt to future projects.

Continuous improvements: Create procedures for making sure that routines and support documents are up to date, followed and appropriate for the way of working. This also includes following up the work connected with the strategic development and the work with the automation strategy itself.

Economy

Budget: Financial means must be put aside to facilitate the vision/goal(s). A budget and time plan for how and when to use the means should be established. The budget should, besides automation investments, include posts for salaries, education, hiring, tools/physical resources and other means necessary to fulfil the goals.

Payoff: State desired/demanded payoff time for different types of automation investments and create guidelines on how to make investment budget calculations and calculate payoff.

6.2.1 Linking the automation strategy to internal logistics

As noted above, the proposed model is on a corporate level and not solely for facilitating automation development in internal logistics. However, to properly support automation development in internal logistics it is important to link and translate the automation strategy specifically to the context of the internal logistics system. With regard to the use of automation this involves addressing for example the following:

- What degree of automation is sought for in the internal logistics system?
- What type of internal logistics activities/processes is desired to be automated?
- What level of automation is desired for different types of internal logistics activities?
- What type of automation and what level of technology are desired in internal logistics?
- What specific demands are there on the automation technology to be used in internal logistics?

When it comes to the development aspects of the automation strategy, this involves addressing the following:

- How do we identify and benchmark suitable automation solutions for internal logistics?
- What financial means are there and how do we calculate payoff?
- What evaluation criteria are most important for automation in internal logistics?
- How and when are different parties/functions involved during the automation development process and who is responsible for what?

The last point is both important and complicated since automation of internal logistics activities often concerns both the internal logistics system and the overall system. The customer and the owner of the automation installation might not be obvious. Also, the main executor of the automation development is often from another function, not fully familiar with the systems affected by the automation. The interface between and involvement of all parties concerned is thus important.

Linking the automating strategy to the internal logistics context can be seen as a part of the important alignment of the automation strategy and the internal logistics strategy. This alignment involves managing how automation can and should be used to realise the internal logistics strategy and plan for how to work to ensure this.

6.3 A PROPOSED PROCESS MODEL FOR AUTOMATION DEVELOPMENT IN INTERNAL LOGISTICS SYSTEMS

As previously discussed, the successful use of automation is strongly dependent on the way the automation development is conducted (Baines, 2004; Daim and Kocaoglu, 2008; Durrani et al., 1998; Fasth et al., 2007; Frohm, 2008; Sambasivarao and Deshmukh, 1995; Spath et al., 2009). The findings however indicated an inexperience and lack of structure in conducting automation development and from the analysis it was concluded that formal and appropriate process models are needed but lacking. In the frame of reference, the need for process support suitable for automation development in internal logistics was also addressed.

A process model for automation development in internal logistics is thus proposed. The overall structure in especially the first half of the model is based on the general design framework by Wu (1994). This is due to its emphasis on both understanding the current state and setting objectives for the desired future state before developing concepts and solutions, something considered valuable and suitable in the analysis. After the first decision gate, some alterations have however been made in accordance with Pahl et al. (2007) and Ulrich and Eppinger (2012) by including an embodiment/system level design phase before the detailed design, something advocated by Johansson (2007) as important in logistics and also should help identify the most suitable automation solution.

Also, based on the findings (empirical and theoretical) and the analysis, the model has been further altered and steps, elements and aspects have been added to better fit the purpose of supporting successful use and development of automation as a step in improving internal logistics systems. Alterations of and suggestions for the content in the model have, besides the previously mentioned sources, been based on and taken from Roozenburg and Eekels (1995), Bellgran and Säfsten (2010), Tompkins et al. (2010), Frazelle (2001a) and Baines (2004), but they are also based on the researcher's own conclusions and ideas.

Baines (2004) was used as inspiration since, of the support models presented in Table 1, it is considered to offer the most structured and detailed description of the technology acquisition parts of automation development, with specified tasks (including motivations to them) and adherent outcomes. It also, compared to for example Trudel and Goodwin (1990) and Durrani et al. (1998), better covers how the automation process can be initiated as well as it includes follow-up and evaluation of the investment, something identified as important but often forgotten.

An overview of the proposed process model is illustrated in Figure 22, and the different steps in the model are described below. In line with the conclusion of the need and importance of a strategic view on internal logistics and automation for the successful use and development of automation in internal logistics, the two fields on each side of the proposed process represent the previously proposed internal logistics and automation strategies. These support the way of working during the development process as well as provide a base for and input into the process steps.

It is important to note that the model and its steps include suggestions for actions. A stepwise sequence is implied but not necessarily required since all suggested actions might not be applicable or relevant depending on the circumstances. The process model can be followed in full but also used as a guideline or checklist.

Initiation: There are several ways an improvement process and/or an automation development process can be initiated. Baines (2004) for example describes both a push and a pull stream for technology initiatives.

Some of the most common causes of initiation, of which many are related, are

- evident problem(s) in operations
- identifying a possible improvement area
- identifying a possible automation opportunity
- striving for continuous improvements
- not fulfilling performance goals
- new/changed need from the customer
- changed prerequisites

Thus, both the internal logistic strategy and the automation strategy can prompt an automation development process.

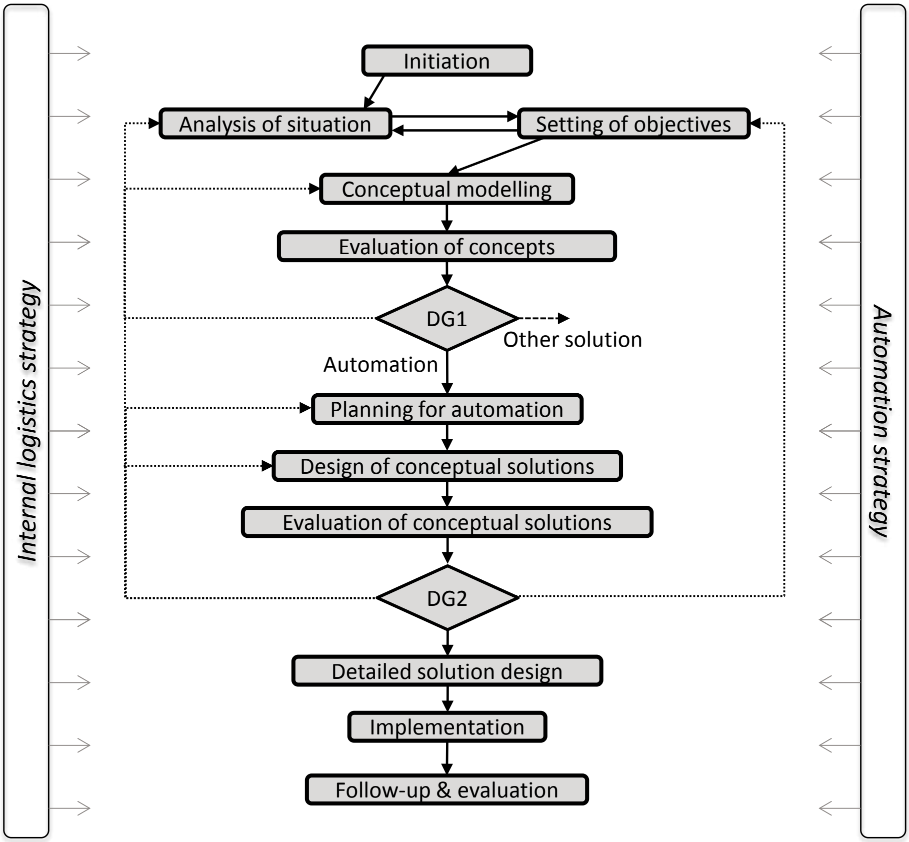

Figure 22 Proposed process model for automation development in internal logistics systems.

During the initiation, start the planning of the process and the project (by which the development will be performed). Cover establishment of the cross-functional project team and possible steering group and assign a project leader. Set up a time and resource plan including decision gates and responsibilities. The planning will continue during the first steps in the process as the task and the way of addressing it will become clearer and thus also the appropriate way of working and what people/functions and third parties to involve.

Analysis of situation: Thoroughly map, measure, analyse and evaluate current operations and logistics flows. Benchmark and study existing documentation for example of previous improvement measures.

The findings from this and the following step should provide the necessary input to the specification of requirements.

Setting of objectives: Performed in conjunction with the previous step, this step focuses on identifying the needs, goals and prerequisites in the internal logistics system and of the customer. These should adhere to the overall business strategy and follow the functional strategies, which thus also provide direct input.

Together with the input from the previous step, formulate a specification of requirements as well as a formal statement of the aim and objectives of the improvement process in which the objectives are specified and ranked in order of importance. These two elements provide the base for evaluation later in the process. Start planning for the business case.

Conceptual modelling: In this context the conceptual modelling involves analysing and elaborating on different approaches and concepts for how to undertake the improvement work in order to fulfil the requirements and objectives.

One possible concept is the use of automation technology. Alternatives can include other types of technology, work methods for organisational changes, systemisation/improvement tools, etc. The focus in this step is not on identifying specific solutions; instead, it is on distinguishing different types of concepts/improvement means.

Evaluation of concepts: Evaluate the different concepts based on the formal specification of objectives and the possibility of the concept to fulfil the specification of requirements.

Decision Gate 1 (DG 1): The first decision gate involves choosing the improvement concept expected to best fulfil the requirements and objectives and thus provide the best result. Communicate the outcome and its justification to secure understanding and commitment. If none of the concepts is considered to fulfil the requirements and/or objectives, do not proceed. Instead cancel the process or go back to reanalyse the situation and/or search for new concepts.

The following steps in the process described are based on the decision that automation is chosen as an improvement means.

Planning for automation: Plan for the automation development process and adjust the setup of the cross-functional team to be appropriate for automation development. Supplement the requirements specification by adjusting it for automation. These supplements/adjustments should of course be based on and fulfil the previously formulated specification of requirements and formal objectives but include more automation-specific requirements based on the automation strategy.

Design of conceptual solutions: Develop potential automation solutions. Assess whether all necessary competence exists within the organisation or if there is a need for hiring or engaging consultants/third parties for specific tasks during the development, implementation, operation or maintenance of the potential solutions. This is both to be lifted in the following evaluation and if chosen be able to plan for it accordingly. Draw up an investment calculation, an action plan for implementation and an analysis of consequences and possible risks connected with each conceptual solution.

Evaluation of conceptual solutions: Evaluate the different conceptual solutions based on the formal specification of objectives and the specification of requirements. Assess and consider consequences and potential risks.

Decision Gate 2 (DG 2): Select the conceptual solution that best fulfils the requirements and formulated objectives (and thus supports the internal logistics strategy and the automation strategy) and is expected to provide the highest payback and potential benefits.

If none of the solutions is considered to fulfil the requirements and/or objectives, cancel the process or go back and redo the steps in search for other concepts/solutions and/or to make sure that the current situation and the requirements are correct assessed or in need of alterations. Communicate the decision/choice and the reasons for it and adherent plans to secure commitment and understanding.

Detailed solution design: The solution chosen should be further developed, constructed, tested and refined. Plans for implementation, operation, training/education of staff, handover, maintenance, etc. should be made.

Implementation: Implement the solution selected according to the plan. Perform tests to ensure satisfactory function before putting it into full use. Give necessary training/education and support to staff handling the equipment. Perform official handover and clarify responsibilities and routines.

Follow-up & evaluation: Evaluate the implemented solution as well as the improvement project. This is not only to provide knowledge and experience for future projects, but also to be able to make necessary corrections.

To enable proper evaluation, it is important that the process and the decisions made during it are properly documented throughout the entire process. It is suggested that routines for this be included in the strategies.

7. DISCUSSION AND CONCLUSIONS

In this final chapter the results of the research are discussed and concluded. First is a general discussion of the research area, the findings and the proposed framework. Then the research questions are revisited and their answers summarised. Thereafter, contributions of the research are discussed followed by a discussion on the quality and limitations of the research results. Finally, areas for future research are suggested.

7.1 GENERAL DISCUSSION AND CONCLUSIONS

Despite its also previously confirmed great potential to improve internal logistics, automation is not used to the same extent in the internal logistics system as in many other parts of operations. The overall aim of this research has therefore been to develop knowledge that supports the successful use of automation in internal logistics systems.

One matter of interest to discuss in relation to the aim is what characterises *successful use* of automation. This is important since it must be understood that the use of automation does not per se guarantee benefits or improve competitiveness. It can even have a negative impact (Baines, 2004; Cruz Di Palma and Basaldúa, 2009; Groover, 2008; Porter, 2004a; Spath et al., 2009) or in other words be unsuccessful. Successful use of automation is therefore related to a way of using automation that helps the user either improve something (such as competitiveness) or in other ways achieve their goals. The key to a successful use of automation lies in finding, selecting, acquiring and properly implementing the right type and level of automation in relation to the needs, goals and prerequisites (Baines, 2004; Ceroni, 2009; Daim and Kocaoglu, 2008; Spath et al., 2009). A successful automation decision can thus even be not to use automation, if it does not fulfil the need or goal or if it is unsuitable given the prerequisites.

The meaning of successful use of automation, what it entails and how it is attained is not unique to an internal logistics context, it is rather a general notion. What however does differ between internal logistics and other parts of operations are the prerequisites for the use of automation to be successful. In Chapter 5, general prerequisites for conducting improvement work in the internal logistics system, particularly related to automation use and development, were analysed. The analysis indicated inexperience and several difficulties and problems associated with conducting automation development. Also, since several identified success factors and facilitators for the successful use of automation were often missing, it can from different aspects be concluded that the prerequisites are poor. The findings indicated, for example, a lack of overall understanding of the system and a lack of strategic view on it. This can be seen in contrast to in value adding activities such as in manufacturing where it more often is a better understanding of operations, since it is measured and followed up on to a larger extent. There is also often a strategy and/or goals linked to, for example, the manufacturing system and more experience of using and developing automation in this context.

One cause of several of the difficulties identified and thus a contributing factor to the poor prerequisites in internal logistics is the fact that this system is a subsystem in a larger overall system and that internal logistics is a support function. This most likely contributes to the identified lack of focus on, clear ownership of and responsibilities for internal logistics addressed and concluded in previous chapters. Being a support function also implies that internal logistics is not an end in itself and since it is not considered value-adding it is not what directs the structure in the overall system. Instead, there is a constant demand for supporting the (internal) customer since it is the customer who creates value in the overall system. The interface between the internal logistics system and its overall system and between the service provider (of internal logistics) and its customer is therefore important and of interest to address.

The main difficulty found in Study E was related to acquiring information from the customer of internal logistics. A contributing factor to this was unclear system boundaries and responsibilities between the two parties. Another contributing factor was an experienced lack of interest on the customer's part for the project, which was initiated and run solely by the logistics department. Being a support function, it is necessary to fulfil the needs of the customer, but sometimes, as evident in Studies C and E, the customer cannot fully articulate their needs. It is therefore of interest to discuss which party is responsible for what in this service provider/customer relationship. In one aspect the customer should specify the requirements and the service provider should supply the necessary prerequisites and solutions. But it is also the service provider that is the expert in its own area with its possibilities and should hence be able to fulfil an unarticulated need and be responsible for creating better prerequisites for its customer. It is not clear which party should provide the different types of prerequisites for and of the internal logistics system. But it is clear that this ambiguity affects the possibilities of properly improving the internal logistics system by, for example, using automation. Further, it must be understood that it is neither possible nor reasonable to have an internal logistics system that can handle everything, trade-offs must be made. It is thus important to have a continuous dialogue within and between the two parties. Yazdanparast et al. (2010), who deal with the importance and difficulty of assessing customer needs in logistics suggest a logistics service value co-creation process.

The dialogue between the customer and the service provider is especially important during improvement work; during automation development it is also of the highest importance to include and have a good dialogue with the party performing the automation development (internal or external). This is to attain the important well-established and justified requirements, goals and expectations and clarify interfaces, ownership and responsibilities between all parties concerned. These elements have thus been incorporated in the proposed framework.

While the interface between the service provider and the customer is distinct and the dialogue between the parties thus especially important in large companies (such as in case company E, where there is often a separate logistics function with its own department), the situation in smaller companies is often different. As indicated by the findings from Studies A and B, the responsibility for internal logistics in SMEs is often integrated with responsibilities for the overall system, for example the production manager being responsible also for internal logistics. Since both the two systems and the service provider and customer are closely intertwined in these situations, there should be good prerequisites for the understanding of operations as well as formulation and assessment of needs, goals, etc. However, it was rather revealed that this created other problems since the internal logistics in these situations is not focused on or strategically dealt with on its own. The findings for example indicated a poor overall understanding of the internal logistics operations and needs and a lack of a strategic view on the internal logistics system, especially in SMEs.

The importance of the automation development process and its impact on the success of the use of automation is what directed the focus of the research towards this process and particularly how it can be facilitated. To contribute to the aim of the research, the objective of the thesis has been to develop a framework that facilitates the automation development process in internal logistics.

Based on the discussion in Section 2.1.4, it can be argued that successful use of automation in internal logistics systems is the result of a combination of high efficiency and high effectiveness during the development process, this with regard to the automation equipment but also in connection with and in the internal logistics system. Having a well integrated and well understood internal logistics system in terms of customers' needs and prerequisites is a first condition for improving logistics and overall performance (Fugate et al., 2009; Stock et al., 2000). A well-structured system and awareness of its performance and what affects it is also particularly important for successful use of automation (Fasth et al., 2007; Tu et al., 2011). Further, it is important to have clear and realistic objectives, requirements and goals before automating (Frohm, 2008; Frohm et al., 2003), and the goals and use of automation should be well linked to the overall strategy and goals (e.g. Arvanitis and Hollenstein, 2001; Daim and Kocaoglu, 2008; Säfsten et al., 2007; Winroth et al., 2007) and in this context realised as an important strategic part of improving internal logistics systems (Chung and Tanchoco, 2009; Gu et al., 2010; Hassan, 2010).

In other words, it is important to (1) understand what are the right things to do in the internal logistics system, (2) understand what are the right things to do linked to using automation and then (3) make sure that these things are done right if, when or by automating. The framework presented was developed to facilitate the automation development process by supporting these three steps. The suggested internal logistics strategy model is intended to give support mainly in the first step, proposing ways to make sure that the internal logistic system is well functioning and well understood and that there are clear goals as well as plans and support for how to achieve this. The suggested automation strategy model is intended to give support mainly in the second step by identifying when, why and how automation should be used. Finally, the suggested process model for automation development is intended to support mainly the third step by suggesting a structure for the processes and to make sure that decisions are well-founded and careful planning is done thus making sure that the first two steps are completed. The proposed framework is thus intended to provide support on the strategic, tactic and operative levels and therefore facilitate the automation development process in internal logistics systems.

Another important aspect to discuss regarding the objective and aim of the research is whether automation development in internal logistics differs or should differ from that in other areas and if so, how. In a most fundamental sense the answer is no. Since there is no difference between what constitutes successful use of automation and how it can be achieved, automation development should be carried out in the same way, following the same steps and covering the same aspects, regardless of the area to be automated. This is what endorsed studying the automation development processes also in other contexts than solely the internal logistics system (see Figures 12 and 14). However, as discussed above, what does differ when it comes to automation development in internal logistics compared to other areas are the prerequisites for successfully using and developing automation. These prerequisites in turn affect both what knowledge is needed to support the successful use of automation specifically in internal logistics systems and what facilitates the automation development process in this system. The proposed framework is thus primarily constructed to facilitate automation development in internal logistics systems based on the prerequisites in this particular context. However, given the similarities in conditions necessary for conducting successful automation development in other areas, it is likely that the framework with required modifications and adjustments can be used to facilitate the automation development process also in other areas. This applies especially to the proposed model for automation strategy, which is kept on a generic, company level and not directed towards internal logistics only.

7.2 REVISITING THE RESEARCH QUESTIONS

In order to guide the research in fulfilling the objective of this thesis, two research questions were formulated and answered.

The first research question, *What challenges are there to successfully use automation as a means of improving internal logistics systems?,* aimed at understanding the prerequisites for using and developing automation in internal logistics systems.

It can be argued that the importance of the internal logistics system and its potential to create a competitive advantage have still not been fully recognised. The lack of insight into and understanding of the current as well as desired future state of the internal logistics system was identified as a major challenge for successfully improving the internal logistics system in general and specifically using automation. The identified absence of clear ownership, responsibility and strategic guidance for and within the internal logistics system was considered to be strongly related to and an underlying reason for these challenges.

Further, the lack of knowledge and experience of working with and developing automation presents difficulties in seeing the potential uses of automation, finding alternative solutions, specifying reasonable requirements and evaluating and choosing the most appropriate solution.

Several common concerns and problems associated with using automation in internal logistics were listed in the analysis. These findings supported previous research and were identified as reasons for the current low level of automation but should not be regarded as obstacles since they can be handled and overcome by a correct automation development process.

The second research question, *How can the automation development process in internal logistics systems be facilitated?,* aimed at investigating how the challenges identified in the first question could be overcome and how the automation development process in internal logistics systems could be facilitated.

First it was concluded that in order to facilitate the development and thus support successful use of automation in internal logistics, the internal logistics system needs to be viewed, operated and guided in a strategic way. This is to provide the proper prerequisites for the automation development process in terms of a well-understood and well-functioning system to be automated, clear system goals, objectives, needs and requirements and thus a clear base for evaluation and decision. Further, there is need for well-specified requirements for the use of automation on both a strategic and an operative level as well as specifically for a forthcoming automated solution. A good structure for and understanding of the automation development process and its important steps and as well as clear responsibilities and roles during the process, especially when involving third parties, also facilitates the process and increases the chances of a successful outcome.

Further it was concluded that benchmarking, cross-functional teams and careful planning all facilitate successful use and development of automation in internal logistics and should be part of the important well-adjusted and well-structured routines for automation development. The automation development process can also be facilitated by making use of existing knowledge and by learning from previous experiences through evaluation and follow-up. Commitment to and involvement during automation development from all levels in the organisation are also important and valuable.

Answering the two research questions helped fulfil the objective of the thesis since their answers were synthesised in and formed the proposed framework.

7.3 RESEARCH CONTRIBUTIONS

Being of applied character, this research aimed at generating both scientific and practical contributions. The contributions of this research are discussed in the following two sections.

7.3.1 Scientific contribution

The overall aim of the research presented in this thesis has been to develop knowledge that supports the successful use of automation in internal logistics systems. This has been approached by, through six empirical studies, investigating and concluding how the automation development process in internal logistics systems can be facilitated. The research thus contributes to the limited existing research (Baker and Halim, 2007; Richey Jr. et al., 2010) on using and developing automation in the internal logistics context.

Further, this research complements previous research in the internal logistics area, which is mainly focused on large-scale automation investments and implementation of automation in warehouses or general selection of equipment including but not focusing on automation. This research thus adds to the existing body of knowledge first by studying the use and development of particularly automation but not only its implementation. Second, the research also covers other internal logistics contexts besides warehousing such as in the healthcare sector and in manufacturing companies of different sizes. Third, it studies the use and development also of small-scale automation installations and investments.

By answering the two research questions, this research has identified prerequisites and facilitators of successful use of automation as well as prerequisites and challenges of using and developing automation specifically in internal logistics. The research thus also adds to the automation field. The proposed framework particularly complements the existing body of knowledge through its comprehensive view of specifically automation development and how it can be supported and facilitated, something not well covered in existing automation-related frameworks. Another contribution is the fact that the framework is intended to facilitate automation development specifically in internal logistics systems, this by taking into consideration the identified prerequisites related to using and developing automation in this particular context.

The proposed process model for automation development provides novelty to the automation field by building on methods and models from other areas such as production system design (Bellgran and Säfsten, 2010; Wu, 1994) and product design and development (Pahl et al., 2007; Ulrich and Eppinger, 2012). The proposed process also adds to previous automation-related process models by covering the entire automation development process from initiation to follow-up.

The identification of the role of strategy in the automation development process in internal logistics and the way in which the proposed content of an internal logistics strategy and an automation strategy can support and facilitate the automation development process is also a scientific contribution.

7.3.2 Practical contribution

The research results encourages an increased focus on the internal logistics system and a strategic view of it to benefit from it as a possible competitive means. The research has pinpointed factors influencing the successful use and development of automation in internal logistics systems thus giving guidance to practitioners working with development of internal logistics. By the proposed framework, the research results also suggests how the prerequisites for proper automation development, particularly in internal logistics, can be met. By using the proposed framework as a guideline, the identified challenges for using and developing automation in internal logistics systems can be overcome and the chances of successful use of automation in internal logistics systems will increase.

In the framework the important role of strategy both in the process of improving the internal logistics system and in the automation development process is stresses. The suggestions on what should affect the formulation of an internal logistics strategy and an automation strategy and what they should include are considered to have practical contributions both to internal logistics and to automation development in general.

Further, the empirical findings indicated a limited understanding of the automation development process and a lack of structured process support. The literature review also indicated a lack of suitable process support particularly for automation development in internal logistics. The proposed process model for automation development in internal logistics systems can increase the awareness of the process and its important steps, thus facilitating the development process.

Also, as the overall framework is developed to support successful use of automation, the proposed process model reflects that automation is not the only or might not even be the appropriate solution to improve the internal logistics system, something important to keep in mind when practising automation development.

7.4 QUALITY AND LIMITATIONS OF THE RESEARCH RESULTS

Although it is considered that the objective of the thesis has been fulfilled and that the research thus contributes with knowledge that supports the successful use of automation in internal logistic systems, it is understood that the methodological choices and the research design have influenced the conclusions drawn and thus the results. The quality and limitations of the research results are therefore addressed and discussed in this section.

The external validity of the results is limited because of the research methods chosen. As discussed in Section 3.5.3, it is natural that studies where the systems approach has been applied have empirical results that to some extent are unique to the study (Arbnor and Bjerke, 2009), thus limiting the external validity and generalisability of the results. Also the use of the case study method offers limited possibilities of generalisable results (Gummesson, 2000). However, owing to the reasonably large number of cases studied (based on Eisenhardt, 1989) and thus the possibility of cross-case analysis, the choice of the supplementing survey study and the constant iteration between theory and data during the analysis, the possibility that the extrapolated knowledge is valid also outside the contexts studied is considered fair.

Building on the discussion above, it is clear that the selection of cases may have affected the results. Since the studies were not fully replicated but rather filled different purposes, the selection can in one aspect be seen as even more critical since the studies must be representative of the purpose. But since the studies together aimed at building a total understanding of the phenomena, a dispersion between representative and unique cases is positive and the individual selection is not as critical as long as the total selection is representative and provides a holistic view of the phenomena studied, thus strengthening the construct validity of the results.

Further, the selection of interviewees and respondents may have influenced the results and the research quality in terms of validity. This was a risk especially in Studies A and C, where a small number of interviewees/respondents were used to cover each case. It is not possible to guarantee that the answers from the interviewees/respondents fully describe the case and provide a complete view of the phenomena. The use of multiple sources of evidence during these studies however enabled a certain degree of triangulation and thus strengthened the validity of the results.

With the use of only retrospective cases in Studies A and C there is a risk that the respondents did not recall important events or that their recollections were biased.

The use of multiple sources of evidence in these studies and the use of real-time cases in other complementing studies reduced the risk of missing or misinterpreting important or critical aspects.

The risk of researcher bias is also a general limitation of this qualitative research in that the author's background, previous knowledge and expectations may have affected the interpretation of the data and thus the conclusions drawn. To strengthen the reliability of the research results, the thesis has been structured to increase the transparency of the research conducted. Chapter 3 explains both the research philosophy approach and the research process during data collection and analysis. The empirical findings and the analysis are separately described in Chapters 4 and 5 to distinguish the presentation of the data from the display of the analysis conducted. The overall conclusions from the analysis influencing the design of the framework are explained and justified in Section 5.3.

Aspects of the quality of the research conducted and the measures taken to secure it during the research are described and discussed in more detail in Section 3.5.

7.5 FUTURE RESEARCH

In this research, a framework with the purpose of facilitating the automation development process in internal logistics systems was proposed. With regard to the conducted research and the proposed framework there are several opportunities for further research.

While the use of case studies made it possible to investigate in detail the phenomena studied in their context and provide a holistic view of them as base for the results, the generalisability of the results is, as discussed above, limited. The data collection performed could therefore with advantage be replicated to provide a larger sample to base the analysis on. The framework can also be further evaluated and tested to investigate its applicability and value and to further develop it. This could preferably be done through an action or interactive research approach and in the next step also in a different context.

In Section 7.1 the dialogue between the internal logistics function, the customer and the party performing the automation development was highlighted as an important aspect for development of internal logistics specifically using automation. Future research should thus be directed to further study these interfaces and how the relations and dialogue could be structured and supported.

Although a further development of the framework involves tests and additional development of the three models constituting the framework, the three proposed models for internal logistics strategy, automation strategy and automation development process also individually present possible alternative targets of future research. An additional alternative opportunity for further research is to direct the research towards a specific context such as a specific line of business and thus to validate, modify and further develop the framework or one of the constituent models for that specific context.

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