On interactions between Packaging and Logistics - Exploring implications of technological developments

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– Exploring implications of technological developments

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Thesis for the degree of Doctor of Philosophy in Engineering

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Daniel Hellström

Abstract

Packaging is a fundamental element in logistics systems. Packaging not only affects every logistical activity; it is also recognised as having a significant impact on logistics costs and performance. In order for logisticians and packaging professionals to gain insight into packaging-dependent costs and performance, the interactions between packaging systems and logistics systems must be understood. This is instead of dividing packaging and logistics into separate systems which are analysed on their own, and assuming that the "whole" is the sum of the systems. Therefore, the overall purpose of this thesis is to explore interactions between packaging and logistics.

The research is applied and interdisciplinary, and bases itself on inductive reasoning. Methodologically, this thesis is qualitative, primarily using case study as research strategy. A case study involving four retail supply chains is conducted in this research to obtain insights into interactions between packaging and logistics. A single case study is also conducted to explore the packaging, logistics, marketing, and environmental consequences of introducing an innovative unit load carrier. Moreover, two case studies are conducted to study the use of RFID technology in managing and controlling returnable transport packaging.

This research provides a comprehensive overview of the physical interactions between packaging systems and logistics systems in retail supply chains. The research serves as an elementary step towards understanding the role of packaging in logistics, and as an aid in showing how packaging-related decisions might impact on supply chains. This research implies that understanding the interactions between packaging and logistics makes it possible to make decisions, such as changing the packaging system or logistics system, or both, based on a holistic packaging approach. Moreover, this research provide insights into the cost and process of implementing radio frequency identification (RFID) technology, and highlights significant savings and benefits, as well as the potential benefits and risks of implementing RFID in packaging systems. As a result, the research provides the means to bridge the gap between packaging and logistics professionals and presents a model of the impact of decisions on packaging and logistics systems. Moreover, a model of the RFID implementation process is proposed, where implications for management are identified to guide managers in the process of implementing RFID.

Summary

Packaging is a fundamental element in logistics systems. Packaging not only affects every logistical activity; it is also recognised as having a significant impact on logistics costs and performance. In order for logisticians and packaging professionals to gain insight into packaging-dependent costs and performance, the interactions between packaging systems and logistics systems must be understood. This is instead of dividing packaging and logistics into separate systems which are analysed on their own, and assuming that the "whole" is the sum of the systems. Consequently, an understanding of how packaging systems and logistics systems interact is fundamental in order for packaging and logistics professionals to identify the opportunities for packaging improvements, and the implications for those opportunities. By considering interactions between packaging and logistics, decisions can be made which take into account the impact and trade-offs of packaging along supply chains. Therefore, the overall purpose of this thesis is to contribute to the further development of packaging and logistics research and practice by exploring interactions between packaging and logistics systems. Moreover, this thesis explores packaging and logistics implications of technological developments.

The research is applied and interdisciplinary, and bases itself on inductive reasoning. Methodologically, this thesis is qualitative, primarily using case study as research strategy. Several case studies are performed to explore interactions between packaging and logistics systems and the impact of technological developments on these systems as a whole.

A case study involving four retail supply chains is conducted in this research to obtain insights into the influence of the packaging system on the retail supply chain. To do this, the study provides a comprehensive overview of the physical interactions between packaging systems and logistics systems in retail supply chains. This study also provides meaningful reference points for logisticians and packaging professionals, by identifying, describing and highlighting packaging logistics activities (see table 4-2) and interacting packaging aspects (see table 4-1). The interacting packaging logistics activities may serve to identify inefficiencies and encourage a logistics focus on packaging-related value addition. The interacting packaging aspects provide the necessary means

to evaluate packaging aspects related to logistics from a value-adding perspective and show what packaging aspects are important in various processes along the supply chain. These reference points, combined with the comprehensive overview of the physical interactions between packaging system and logistics system, can be used to bridge the gap between logisticians and packaging professionals since together they represent the link between packaging and logistics decisions. To encourage an integrated decision-making process this study also presents a model of the impact and affect of packaging and logistics decisions on packaging and logistics systems (see figure 3-1). Thus, this study serves as an elementary step towards understanding the role of packaging systems in logistics and as an aid in showing how packaging-related decisions might impact on the supply chain.

A single case study is also conducted to explore the overall consequences of introducing an innovative unit load carrier throughout the distribution network of a large global retailer. Numerous packaging, logistics, marketing, and environmental consequences are identified and described in the study. The multiple consequences of introducing the unit load carrier illustrate and emphasise the need for a holistic approach in order to evaluate the total impact of packaging on supply chains. This study implies that understanding packaging interactions makes it possible to make decisions, such as changing the packaging system or the logistics system, or both, based on a holistic packaging approach. A holistic packaging approach carefully considers the overall impact and trade-offs of packaging along supply chains in order to avoid sub-optimisation. Moreover, this study offers insights into potential trade-offs between standardised and differentiated packaging solutions, thereby providing practitioners with a better basis for making decisions on packaging design and development.

Furthermore, two case studies are conducted to study the cost and process of implementing radio frequency identification (RFID) technology to manage and control the rotation of returnable transport packaging. These two case studies provide insights into the cost and process of implementing RFID technology and highlight significant savings and benefits, as well as the potential benefits and risks of implementing RFID to track returnable transport packaging. Cost is often mentioned as one of the main barriers for the adoption of RFID technology, however, this study indicates that cost should not generally be considered as an implementation barrier. In the process of implementing RFID this study sheds light upon some technological and organisational issues. These technological and organisational issues indicate that managing organisational interactions in RFID implementations is as important to implementation success as ensuring technology integrity. Based on the two case studies a model of the RFID implementation process is proposed, where practical implementation steps are presented (see table 3-3). Furthermore, implications for management are identified to guide managers in the process of implementing RFID technology.

Even though case study is the major research method used, it is not the only method used. A methodological contribution of this thesis is the further development of research practices by presenting and discussing the concept of combining case study and simulation methods. Case study is combined with simulation in order to gain greater insights into a phenomenon than if a single method had been employed. Combining case study and simulation methods into a multi-method study allows the researcher to harmonise the weaknesses and assess the relative strengths of the various methods. A model for combining the methods is provided in this thesis, providing guidance and insights into the process of combining the methods (see figure 3-2).

Ultimately, this thesis builds on previous research within the field of packaging logistics by providing a comprehensive overview of the physical interactions between packaging and logistics systems in retail supply chains. The influence of the packaging system on logistics is often implicitly and fragmentally recognised, but seldom directly shown and discussed in a comprehensive way. This research emphasises the importance of considering the interactions between packaging and logistics in order for the "whole" system to be understood. Thus, this research implies that understanding interactions between packaging and logistic systems is a step towards understanding the role of packaging in logistics. A contribution to the field of packaging logistics is also represented by the various conceptual models, tools and framework proposed in this research. The proposed conceptual models, tools and framework shed some new light on to the concept of packaging logistics by addressing physical interactions between packaging systems logistic systems in retail supply chains and the impact of technological developments on these systems and interactions.

This thesis also serves as a fundamental step towards adopting a holistic packaging approach by exploring the nature of its interrelationship with logistics. This research implies that understanding packaging interactions makes it possible to make decisions such as changing the packaging system or logistics system, or both, based on a holistic packaging approach. The studies illustrate adoption barriers and potentials of a holistic packaging approach and serve to show how packaging-related decisions might impact on supply chains. The thesis explicitly shows that there are extensive interactions between packaging systems and logistics systems. However, as the nature/interactions of packaging change via innovations and technology, the studies on the implications of RFID technology and the introduction of the innovative unit load carrier provide insights into how these technological developments impact on packaging systems, logistics systems, and on the interactions between the two. One should bear in mind that the packaging system also interacts with a number of other business and management areas besides logistics, such as marketing and the environment. These also need to be considered when adopting a holistic approach to packaging and are in need of further research.

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Separate volume, the Licentiate thesis:

Hellström, D., 2004, *Exploring the Potential of Radio Frequency Identification Technology in Retail Supply Chains - A Packaging Logistics Perspective*, Licentiate thesis, Division of Packaging Logistics, Department of Design Sciences, Lund University, Lund, Sweden.

1 INTRODUCTION

This chapter provides a brief background to the research area, and discusses why this research is needed. The overall research question, objectives and focus of the thesis are also described in order to provide an overview of the thesis and the research subject.

1.1 Background

A theory is about the use of a set of ideas to try to understand and explain the world. One particular theory which plays a dominant role in a wide range of fields is the systems theory. The concept of system is described by Checkland (1999 p.3) as: "*The central concept 'system' embodies the idea of a set of elements connected together which form a whole, this showing properties which are properties of the whole, rather than properties of its component parts"*. The systems theory stresses holistic thinking to prevent reductionism, and is based on the assumption that the whole (system) does not have to be equal to the sum of its parts (elements) (Churchman 1968; Von Bertalanffy 1969). The interactions among the elements forming the system make the sum of the system greater or less than the sum of the elements; a change in one element can have a negative or positive impact on other elements. So if one wishes to gain insight into the performance of a system, the interactions among the elements which form the system must be understood. This is rather than reducing the system to separate elements which are analysed on their own, and assuming that the whole is the sum of the elements. Thus, a main issue in systems theory is how elements interact with other elements of the system.

The systems approach, building on systems theory, is a methodological concept which plays a dominant and important role in the field of logistics (Gammelgaard 1997; Gammelgaard 2004). Persson (1982) indicates that during the 1970s the field of materials management developed into the field of logistics partially due to the use of the systems approach. According to Lambert, Stock, and Ellram (1998 p.7) "*The systems approach is a critical concept in logistics.*" Bowersox and Closs (1996 p.456) share this view and argue that *"a basic understanding of the system concept is desirable for a full appreciation of integrated logistics"*. Moreover, Stock, Greis and Kasarda (1999) claim that the *"system approach within the firm has been the underlying premise of much of current logistics management, thought, and practice"*. Viewing logistics as a system, Stock and Lambert (2001 p.4) state that *"Logistics is, in itself, a system; it is a network of related activities with the purpose of managing the orderly flow of material and personnel within the logistic channel"*. Logistics-related activities, which are central components of logistics systems, are presented in table 1-1. The logistics system is not limited to these activities Coyle, Bardi, and Langley (2003), and Ballou (2004) present other similar logistics-related activities. As the systems approach and its underlying assumptions underpin the logistics discipline, an understanding of the interactions among logistics elements is central.

Table 1-1. Key logistics activities according to Stock and Lambert (2001).

Customer service	Parts and service support
Demand forecasting	Plant and warehouse site selection
Inventory management	Procurement
Logistics communications	Reverse logistics
Materials handling	Traffic and transportation
Order processing	Warehousing and storage
Packaging	

A fundamental element in the logistics system is packaging. Packaging is recognised as having a significant impact on logistics costs and performance (Bowersox, Closs, & Cooper 2002; Ebeling 1990; Twede 1992). Packaging affects the cost of every logistical activity (Bowersox, Closs, & Cooper 2002). Moreover, packaging affects the efficiency of many logistics activities such as transport and warehousing. Nevertheless, packaging is often regarded as an unavoidable non-value-added cost containing little to no strategic value (Lockamy III 1995), resulting in that packaging-dependent costs in the logistics system are frequently overlooked by packaging and logistics professionals (McGinnis & Hollon 1978; Twede 1992). This may depend on that the "total" picture is not embraced or understood. The fundamental functions that packaging must perform are manifold. Paine (1981), Robertson (1990) and Livingstone and Sparks (1994) stress the fundamental functions of packaging: protection, containment, preservation, apportionment, unitisation, convenience, and communication of the product. Some of these functions relate to logistics and some to marketing. Different and conflicting needs and requirements from a variety of organisations along supply chains on the fundamental functions of packaging results in potential trade-offs among the marketing and logistics functions of packaging. In order for the "total" picture to be understood, Lambert, Stock and Ellram (1998) claim that packaging decisions require the use of a systems approach. As early as the nineteen-seventies, Wills (1975) argued that there is a need for a systems approach to packaging. However, few firms manage their packaging through a systems approach (Bowersox & Closs 1996).

Paine (1981) provides a broad and well-established definition of packaging in the three following statements:

(1) *Packaging is a coordinated system of preparing goods for transport, distribution, storage, retailing, and end use*
(2) *Packaging is the means of ensuring safe delivery to the ultimate consumer in sound condition at minimum cost*
(3) *Packaging is a techno-economic function aimed at minimizing costs of delivery while maximizing sales (and hence profits)*

Packaging can be classified as primary, secondary or tertiary (Johansson et al. 1996; Jönson 2000). This classification is used when considering packaging as a system, and illustrates the components/elements and levels of hierarchy in the packaging system (see figure 1 in appended paper I). A systems approach to packaging highlights the interactions between the different packaging levels and facilitates an understanding of the interdependence among the levels of hierarchy in the packaging system. The performance of the packaging system is not only affected by the performance of each packaging level, but also by the interactions among the packaging levels. Considering the interactions among the packaging levels is therefore critical to the overall performance of the packaging system. The packaging system and its interactions among the packaging levels are illustrated in figure 1-1. The figure also includes the product as a system component since it is an interacted part of the packaging system (Esse 1989; Griffin, Sacharow, & Brody 1985). Moreover, the figure illustrates the multiple roles of packaging in which it tries to fulfil requirements placed on it from logistics, marketing, production, product development, and from the environment (Johnsson 1998; Jönson 2000; Klevås 2005a; Prendergast 1995; Saghir 2004a).

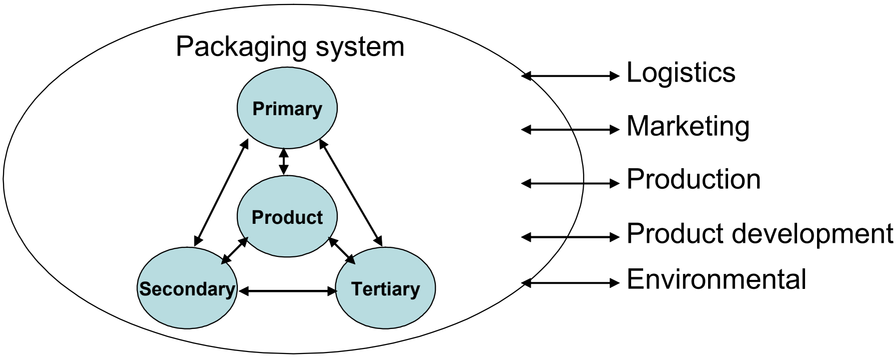

Figure 1-1. The packaging system and its adjoining areas.

1.2 Problem

Even though packaging has a significant impact on logistics, research coverage of the area is fragmented (Öjmertz 1998; Stahre 1996). Stock (2001) found in a review of logistics and logistics-related doctorial dissertations that "*packaging* historically *has been viewed as having a minor role within logistics, especially from a research standpoint*". Saghir (2004a) argues that this may depend on the general consideration of packaging as a minor sub-system of logistics, with limited influences on the overall performance of the supply chain. In order to change this limited perception, Johnsson (1998) suggests an integrated approach to packaging and logistics, i.e. packaging logistics, which can lead to added value, and improvements to the systems. A similar approach is suggested by Twede and Parsons (1997) who stress that an integrated logistics approach to packaging can yield significant logistics value. Moreover, Saghir (2004a) presents a platform for the development of an integrated approach to packaging and logistics from a supply chain perspective where antecedents, procedures and expected consequences are described based on the use of the integrated approach. A central theme in the approach of integrating packaging and logistics is the emphasis and recognition of packaging and logistics interactions.

To deal with an integrated approach to packaging and logistics in a practical way Johnsson (1998) and Saghir (2004a) stress that there is a need for methods and tools to measure the performance of packaging and logistics systems in order to identify areas for improvements and adding value in the systems. Based on a proposal by Johnsson (1998), Olsmats and Dominic

(2003) developed a packaging performance evaluation method, i.e. packaging scorecard, which provides an overview of packaging performance throughout supply chains. However, a weakness of the packaging performance evaluation method is that it only identifies packaging improvements and does not suggest any solutions for improvements. In order to understand the opportunities for improvements, and the implications for those opportunities, there is a need to understand packaging and logistics systems and the interactions between them. Based on this understanding, decisions can be made which take into account the impact and trade-offs of packaging along supply chains.

In order to gain insight into the packaging performance throughout supply chains, the interactions between the packaging system and the logistics system must be understood (see figure 1-2), rather than dividing packaging and logistics into separate systems which are analysed on their own, and assuming that the "whole" is the sum of the systems. Consequently, an understanding of **how packaging systems and logistics systems interact** is fundamental in order for packaging and logistics decision-makers to identify and understand the opportunities to improve the overall supply chain performance. Johnsson (1998) concludes that organisations recognise the role of packaging in the logistics system but that there is generally a lack of knowledge about how the logistics system affects the packaging system and vice versa. Moreover, literature reviews reveal the lack of research in the interface area of packaging and logistics (Saghir 2004). Even though research such as that carried out by Johnsson (1998) and Saghir (2004) recognises and stresses the importance of considering interactions between packaging and logistics, little research, empirical or theoretical, has been done on how packaging and logistics systems interact. Johnsson (1998) shows that interactions and relations exist between the logistics system and the packaging system while Saghir's (2004) platform deals with overall logistics and marketing relations with packaging from a supply chain perspective. Therefore, there is a need for research on interactions between packaging and logistics for the purpose of improving supply chain performance.

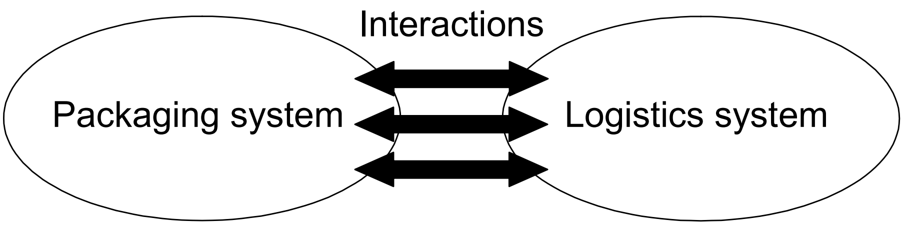

Figure 1-2. A schematic illustration of the interactions between packaging and logistics systems.

An integrated/systems approach to packaging and logistics requires an extension of the scope of the traditional logistician and packaging professional. As might be expected, logisticians focus on the logistics system while packaging professionals focus on the packaging system. This often results in a mismatch in the interaction between the two systems causing adverse effects on the total cost and performance. It is therefore necessary to bridge the gap between logistics and packaging professionals by exploring **how packaging decisions impact on logistics and how logistics decisions impact on packaging**. Bridging this gap extends the scope of the traditional logistician and packaging professional and enables her/him to understand how packaging decisions and logistics decisions can impact on packaging and logistics systems (see figure 1-3).

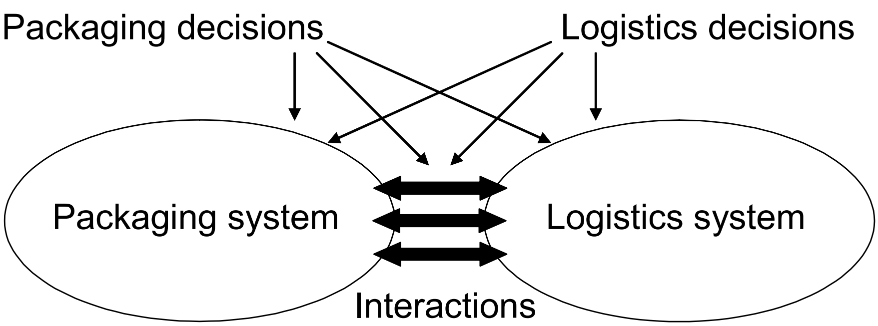

Figure 1-3. The impact of packaging decisions on logistics systems and vice versa.

1.3 Technology implications

Understanding the implication of packaging and logistics decisions is a prerequisite for managers to be able to systematically improve and develop the packaging system and the logistics system. Managers are constantly faced with new packaging and logistics demands, requirements and opportunities. Technology facilitates exciting new opportunities and enables managers to meet these demands and requirements. Technology is also, without a doubt, one of the most important contributory drivers underpinning the development of packaging and logistics. However, technology in isolation does not cause change or improvements. Technology is an enabler or facilitator of new structures, new organisations, new processes, new products etc (Dicken 1998). In order to introduce packaging and logistics-related technology, managers need to understand its implications on packaging systems, logistics systems, and on the interactions between the two (see figure 1-4). This highlights the need for managers to understand **how technological developments impact on packaging and logistics systems**.

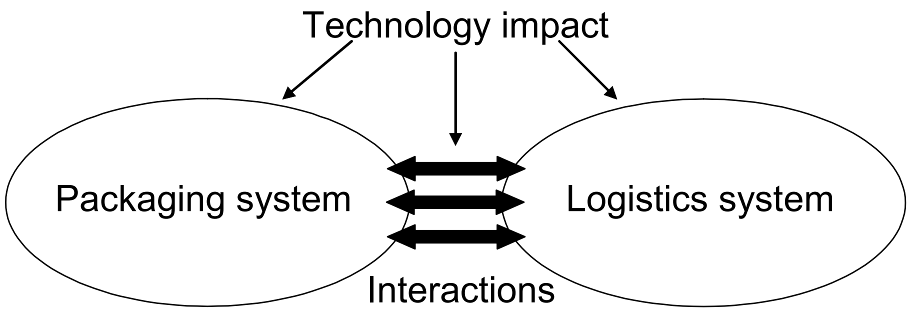

Figure 1-4. Technology impact on packaging systems, logistics systems, and on the interactions between the systems.

In logistics, information technology is seen as the key factor for development and growth (Grant et al. 2006). In recent years there has been increased interest from industry and the scientific community in advanced automated data capture and identification technologies, particularly radio frequency identification (RFID[1]) technology. The interest in RFID technology partly originates from mandates created by the US Department of Defense and large international retailers, such as Wal-Mart, Tesco and Metro. These retailers have announced that their suppliers need to apply RFID tags on tertiary (pallet) and secondary (case, tray) packaging levels in the near future. The application of RFID technology to packaging emphasise the information and communication functions of the packaging system. Researchers and practitioners believe that over the next few years, RFID will be widely and rapidly implemented throughout supply chains to the same extent as bar coding is used today. Research studies indicate that advanced Automated Identification (Auto-ID)[2] technologies such as RFID, have the potential to improve supply chain efficiency and effectiveness, as well as to restructure supply chains (Kambil & Brooks 2002; Kärkkäinen 2003; Kärkkäinen & Holmström 2002). Furthermore, it has been argued that introducing RFID represents an opportunity to improve inventory management, returns management, tracking and tracing systems, process control, security, sales, and enhance consumer experiences (Fleisch & Tellkamp 2005; Jones et al. 2004; Lumsden & Acharjee 2005; McFarlane & Sheffi 2003; Smith 2005). Based on this, it is interesting (in the light of packaging and logistics interactions) to explore the packaging and logistics implications of RFID technology. With a better understanding of how the application of RFID technology to packaging impacts on packaging and logistics systems, it is possible to identify and develop models and methods to design both the packaging system and the logistic system. This could also lead to a better understanding of how supply chain performance and behaviour are affected by RFID technology.

In packaging, technology such as materials, system and machinery, generates great opportunities to improve packaging and is one of the principal drivers of growth and development (Jönson 2001). From a logistics point of view, the development of standardised packaging has made it easier to develop efficient logistics systems because it enables similar demand on routines and transportation and material handling equipment (Stock & Lambert 2001).

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[1] See the licentiate thesis and appended paper number III for more detailed overview of the functionality and potential of RFID technology.

[2] Auto-ID, also called Automatic Identification and Data Capture (AIDC), facilitate data collection and the data handling process by identification and/or collection of data into a computer system without the manual use of a keyboard.

Standardised packaging has indisputably played a central role in shaping most logistics systems and has provided firms with handling and transport efficiency (see Koehorst, De Vries, & Wubben 1999 for example). Nevertheless, in an ever-changing global marketplace, new emphasis and requirements are placed on packaging and logistics systems, questioning the efficiency of using standardised packaging. For example, in industrialised countries, the majority of the material flow is based upon different standardised unit load carriers, such as EUR pallets. However, in recently industrialised countries, such as those in East and Southeast Asia and Latin America, unit load carrier standards are rare. This makes it necessary to explore the implications and trade-offs between standardised and differentiated packaging. Understanding them provides practitioners with a better basis on which to make decisions relating to packaging design and development.

1.4 Overall research question and purpose

Discussion of the problems above indicates that there is a scientific and industrial need for research on the interactions between packaging and logistics systems. Based on this need, I pose the following overall research question:

How do packaging and logistics systems interact?

Based on this ambitious question, the overall purpose of this thesis is to contribute to the further development of packaging and logistics research and practice by exploring, from a systems approach, interactions between packaging and logistics systems for the purpose of improving supply chain performance.

The overall research question and purpose is wide in its scope and leaves a great deal of room for exploration. For example, the question can be approached from a variety of viewpoints and consist of several different and interdependent contextual aspects. This makes it very difficult to answer the questions in a straightforward manner. However, this thesis is guided by the overall research question during the entire research process. A metaphor for this guidance is “Aim for the stars and maybe you'll reach the sky”.

The discussion of the problem above elaborates on the overall research question and ends in two additional and interdependent sub-areas:

1) ***How do packaging decisions impact on logistics systems and how do logistics decisions impact on packaging systems?***

2) ***How do technological developments impact on packaging and logistics systems?***

These questions are also wide in their scope, but indicate in what direction this research has been heading. More specifically and accordance with the metaphor above, this thesis aims to provide understanding and guidance to packaging and logistics professionals making packaging-related decisions, to enable them to enhance their supply chain considerations.

1.5 Research objectives

The overall research question and the two additional interdependent sub-areas are rendered concrete in a number of interdependent research objectives. In order for insights to be gained into the issues of importance to the questions the context of the retail supply chain is investigated (a discussion why the context of retail is motivated below). The research objectives have been reached in the appended papers. The first objective is directly connected to the overall research question. Objectives two, three and four are primarily connected to sub-area one while the last two objectives are primarily connected to sub-area two. The objectives are the following:

1. To identify, structure and describe interactions between packaging systems and logistics systems in the retail supply chain.

2. To identify, describe and investigate where and how packaging and logistics decisions/technology can impact on packaging systems and logistics systems in the retail supply chain.

3. To develop a tool/model of the impact of packaging and logistics decisions on packaging systems and logistics systems designed to encourage and support decision-makers in their integration efforts, i.e. facilitate bridging the gap between packaging and logistics professionals.

4. To identify, describe, and analyse potential trade-offs between standardised and differentiated packaging solutions in order to provide

practitioners with a better basis on which to make decisions regarding packaging and logistics design and development.

5. To describe and investigate benefits, cost and the process of implementing RFID technology to manage and control the rotation of returnable transport packaging in order to facilitate and encourage packaging and logistics development.

6. To develop tentative guiding principles on how to implement RFID technology to manage and control the rotation of returnable transport packaging.

1.6 Focus and demarcations

The focus of this research is on packaging systems, logistics systems, and especially on the interactions between them. However, packaging influences a number of other business and managerial areas besides logistics (see figure 1-1). In marketing, packaging is not only a vital tool in the marketing mix (Rod 1990); Nickels and Jolson (1976) have introduced packaging as a fifth “P” along with the four P’s (price, place, product, promotion) in the marketing mix, stressing the importance of packaging in marketing. Environmental aspects are also of great importance for packaging (Livingstone & Sparks 1994). Furthermore, packaging influences product development and design, and production (Bjärnemo, Jönson, & Johnsson 2000; Bramklev 2004). Due to the diversity of aspects which need to be considered in packaging, trade-offs among the different areas of interest are unavoidable, (see for example Bowersox & Closs 1996; Jahre & Hatteland 2004; Klevås 2005b; Prendergast & Pitt 1996; Robertson 1990). This means that other important packaging aspects, such as marketing, production, product development, and environment, are always present, and influence packaging and logistics systems. These aspects have therefore been considered in this research. However, as the focus of this research is on packaging and logistics systems the above-mentioned aspects will only be touched upon to clarify a point or to demonstrate a certain phenomenon.

The general packaging levels and types of packaging treated in this research are primary level (consumer and sales packaging), secondary level (distribution and multi-unit packaging) and tertiary level (transport packaging, i.e. different kinds of unit load carriers such as pallets and roll containers). As the focus of this research is on packaging and logistics, most attention is given to secondary and tertiary packaging levels. However, this does not mean that the research has focused exclusively on these two packaging levels. Even though these levels are treated extensively, one should remember that a systems approach is used, requiring the whole packaging system to be addressed.

There are extensive interactions between packaging systems and logistics systems (Jahre & Hatteland 2004). The logistics system involves a number of logistics activities, which all more or less interact with, and are influenced by, packaging. This research does not focus on specific logistics activities and their interactions with packaging systems. The focus of this research is primarily on the physical interactions between packaging systems and logistics systems. The physical interactions are those directly connected to the physical flow of products and packaging material, i.e. packaging system components. These interactions are on an operational level and can be considered as the basic and fundamental interactions between packaging and logistics systems. Moreover, the physical interactions are a subset of all the logistics activities interactions with packaging systems. Thus, the boundaries of which logistics activities are treated in this thesis are not very obvious. The main logistics activities which physically interact with packaging systems are materials handling, reverse logistics, and warehousing and storage. However, even though packaging systems mainly have physical interactions with these logistics activities, it is important to bear in mind that packaging systems interact with and influence all logistics activities, and that this thesis only treats a subset of the interactions between packaging and logistics systems.

As indicated in the objectives, this research has been conducted in the retail industry. The retail industry is probably the largest packaging material consumer in the world, where enormous amounts of packages are procured and handled throughout the retail supply chains. In Sweden alone, the retail industry handles approximately one billion retail packaging units each year. According to DULOG[3] (1997), the potential savings for packaging handling at Swedish distribution centres and retail outlets, are about five million EURO for every second which can be saved in the packaging handling process. This

[3] DULOG is the former Development and Logistic group of the Wholesale and Retail Trade in Sweden.

constitutes an excellent reason for focusing on interactions between packaging and logistics in the retail supply chain. However, one should not assume that the results of this research can be applied to the whole retail industry and to all retail supply chains, or be limited to them. It is important to look at the investigated phenomenon as such, before conclusions are transferred to other contexts.

While the focus of this thesis is on interactions between packaging and logistics systems in retail supply chains, the perspective from which the retail supply chain is studied is not self-evident. A conceptual perspective is used in this thesis, where a generic retail supply chain is considered as the "whole" system. From this perspective this research focuses on the interactions between packaging systems and logistics systems from the product-filling point at the manufacturer's, where the product is merged with the primary packaging, via distribution centres and carriers, and eventually to the point of sale at retail outlets, where the products are sold to the end consumer (See figure 1-5 for an illustration of the retail supply chain members and operational processes studied and discussed in this research). In contrast to a generic supply chain perspective most supply chain members have more than one customer and one supplier, which means that they are inevitably part of more than a supply chain i.e. part of multiple, interlinked supply chains. Christopher (1998) highlight this and state that the supply chain is a network. The research in this thesis does not focus on a single supply chain, but, as a package is handled through a single supply chain and as the interactions between packaging and logistics systems are quite universal, a generic supply chain perspective is used.

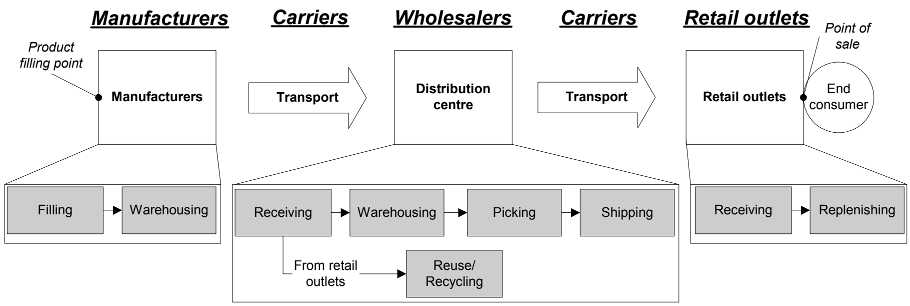

Figure 1-5. Supply chain perspective in the research.

1.7 Definitions

Some definitions are provided below to clarify the meaning(s) of some terms used in this thesis. The terms are closely related and are sometimes used as synonyms in the appended papers.

Logistics

Logistics can be defined in many ways. One commonly used definition of Logistics Management is provided by the Council of Supply Chain Management Professionals, CSCMP[4], formerly known as Council of Logistics Management Professionals (CLM): "*Logistics Management is that part of Supply Chain Management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements*". In this definition logistics management is a (supply chain) process within and between companies involving the management components of planning, implementation and control. According to Stock and Lambert (2001) the key logistics activities to be managed that make up logistics management are presented in table 1-1.

Processes

Processes share many similarities with systems (Näslund 1999). A system is a part of a larger system and can be divided into sub-systems. Similarly to a system, a process belongs to a larger process (or system) and can be divided into sub-processes (Jacka & Keller 2002). Larsson and Ljungberg (2006 p.103) define a process as "*a repetitively used network of activities linked in an orderly manner using information and resources for transforming "object in" into "object out", extending from the point of identification to that of the satisfaction of a customer's needs.*" A difference between a logistics system and a logistics process is that a logistics process describes structure and how (process) activities are carried out, while a logistics system describes what logistics activities the system and its components consist of.

[4] http://www.cscmp.org/Website/AboutCSCMP/Definitions/Definitions.asp, 2006-11-21

In licentiate thesis and appended papers I and II the term logistics processes is used to describe sets of activities linked to the physical flow of products and packaging material, i.e. packaging systems components. These logistics processes are on an operational level. However, as previously stated there are numerous, different levels of logistics processes and this thesis only deals with a few operational processes.

Activities

Activity is defined as: "a situation in which a lot of things are happening or people are doing things"(Longman, 2005). There is a difference between the logistics activities (see table 1-1) which constitute the logistics system, and the (process) activities carried out in the logistics processes. Logistics activities are involved in the flow of products between the point of origin and the point of consumption. The (process) activities carried out in logistics processes are specific to the processes and can be on an operational, tactic or strategic level.

In paper I the term "logistics activities related to packaging" is used as a synonym to "packaging logistics activities". These terms are not to be confused with logistics activities forming the logistics system. To prevent confusion only the term "packaging logistics activities" will be used in this thesis. A packaging logistics activity is defined as an operational activity which physically interacts with the flow of packaging system components.

Interaction

Relation is sometimes used as a synonym to interaction. However, there is a difference. Interact is defined as follows "if two or more things interact, they have an effect on each other and work together"(Longman, 2005). Interaction is then "a process by which two or more things have an effect on each other and work together". Longman (2005) defines relation as "a connection between two or more things… and is usually about a simple fact." Thus, the term "relation" is on a higher abstraction level than "interaction", which is more operative.

1.8 Thesis outline

This thesis is made up of seven chapters which constitute the framework of this research and where the four appended papers are the core of the research.

The appendices which contain complementary case descriptions and an interview guides are included to provide additional insights into the research studies. The chapters are briefly described below.

Chapter 1 – Introduction

From the departure of the systems approach, and its underlying role in logistics, the need for a systems approach to packaging is emphasised. Based on this, problems are highlighted and elaborated on, resulting in the formulation of an ambitious overall research question and purpose from which more tangible research objectives are presented. The focus and demarcations of the research are also addressed in this chapter.

Chapter 2 – Licentiate thesis summary

The licentiate thesis, which is the first half of this thesis, is briefly summarised in this chapter, to provide a starting point.

Chapter 3 – Results from appended papers

The results from the appended papers are presented in this chapter. The connections between the appended papers and the research objectives are pointed out. Moreover, the results which connect the appended papers and the licentiate thesis with the synthesis are outlined in this chapter.

Chapter 4 – Concluding discussion

The results from the appended papers and the licentiate thesis are synthesised in this chapter. Based on the overall research question and purpose, the interactions between packaging and logistics systems, and the interconnection between packaging and logistics decisions are discussed.

Chapter 5 – Research process

This chapter provides an overall description and discussion of the research process setting out methodological considerations and assumptions, research design and data collection.

Chapter 6 – Contributions

This chapter presents some of the main contributions this research has provided, both theoretically and practically. The methodological contribution of this research is also presented.

Chapter 7 – Further research

With the knowledge and experience gained from carrying out this research a number of interesting proposals for further research are suggested in this chapter.

2 LICENTIATE THESIS SUMMARY

A summary of the licentiate thesis is hereby provided, as it represents the first part of the research and is the foundation for the research in general. The title of the licentiate thesis is: Exploring the potential of using radio frequency identification technology in retail supply chains - a packaging logistics perspective.

2.1 Background and purpose

During the last couple of years RFID technology has attracted interest from various industries where it is being presented as a possible key technology in creating more efficient and effective supply chains. Studies of the potential benefits of applying RFID technology to packaging in retail supply chains have suggested that there is a great opportunity to reduce labour and shrinkage, and improve inventory management, customer service and sales (Agarwal 2001; Alexander et al. 2002; Chappell et al. 2003; Kambil & Brooks 2002; Småros & Holmström 2000). Moreover, large retail chains like Wal-Mart, Tesco and Metro have announced that their suppliers should implement RFID technology on secondary and tertiary packaging levels. This indicates that the application of RFID technology to packaging is an emerging technology in the retail supply chain.

If RFID technology is to be deployed in retail supply chains, it is necessary for organisations to understand how the technology affects activities and processes along retail supply chains. Moreover, with the application of RFID technology to packaging, the information and communication functions of packaging will be emphasised. The initiative was therefore taken to develop an understanding of how RFID technology in packaging influences packaging and logistics. Accordingly, the overall purpose of the licentiate thesis was **to explore how the application of RFID technology to packaging could affect packaging logistics activities in retail supply chains**. It should also be made clear that the licentiate thesis focused on the whole packaging system, i.e. primary packaging (consumer packaging), secondary packaging (case) and tertiary packaging (pallet and roll container).

2.2 Research design

The licentiate thesis was based on multiple research strategies; a case study and a modelling and simulation study. The case study was conducted to describe and gain insights into existing packaging logistics activities in retail supply chains. Based on understanding the existing packaging logistics activities, a modelling and simulation study was conducted to explore how the application of RFID technology to packaging could affect material handling activities at distribution centres.

2.2.1 Case study

A Dutch retail supply chain was chosen as a single-case study. However, in order to strengthen the external validity of the case study and to expand the understanding and description of packaging logistics activities in retail supply chains, the Dutch case was data-triangulated and investigator-triangulated with three Swedish case studies. The case study resulted in a framework of packaging logistics activities in retail supply chains. The framework describes what and how packaging logistics activities are performed in retail supply chains. Process mapping was used to describe and structure the identified packaging logistics activities forming the framework. With the process maps a holistic perspective of the processes is obtained, which still contains specific and detailed information so that it is patently clear how the packaging logistics activities were performed. In addition, the input and output of different types of packaging are described in the process maps to highlight the packaging system. The reason for developing such a framework was not only to gain a better understanding of packaging logistics activities, but also to create a platform from which packaging logistics activities in retail supply chains could be analysed and discussed.

2.2.2 Modelling and simulation study

The modelling and simulation study explored and analysed possible future activities and behaviours of the retail supply chain, thereby providing insights into how RFID technology in packaging could affect packaging logistics activities in retail supply chains. A conceptual model and a simulation model were developed in the modelling and simulation study. The conceptual model describes and analyses "could-be" processes and activities in retail supply chains when RFID technology is applied to the packaging system. The framework which was developed in the case study, was used as a tool to identify on an operational level what the consequences are if RFID technology is applied on different packaging levels and where the consequences occur in the retail supply chain. Thus, the framework served as a means to investigate where the expected costs and benefits of RFID technology are to be found among different members along the retail supply chain.

Process mapping was used to develop the conceptual model. The process maps were also used in the development of the simulation model where the process maps described the structure, components, operating rules and material flow through the retail supply chain. Discrete-event simulation was the simulation technique used to develop the simulation model. The discrete-event simulation model was used to explore and analyse how the Dutch retail distribution centre (studied in the case study) could behave and perform over time, if RFID technology was applied to packaging throughout the centre's supply chain. The simulation developed primarily focuses on how applying RFID technology to packaging could affect material-handling activities and the order process in the distribution centre. Figures 2-1–2-3 show some snapshots from the simulation model.

Figure 2-1. An overview of the Dutch retail distribution centre.

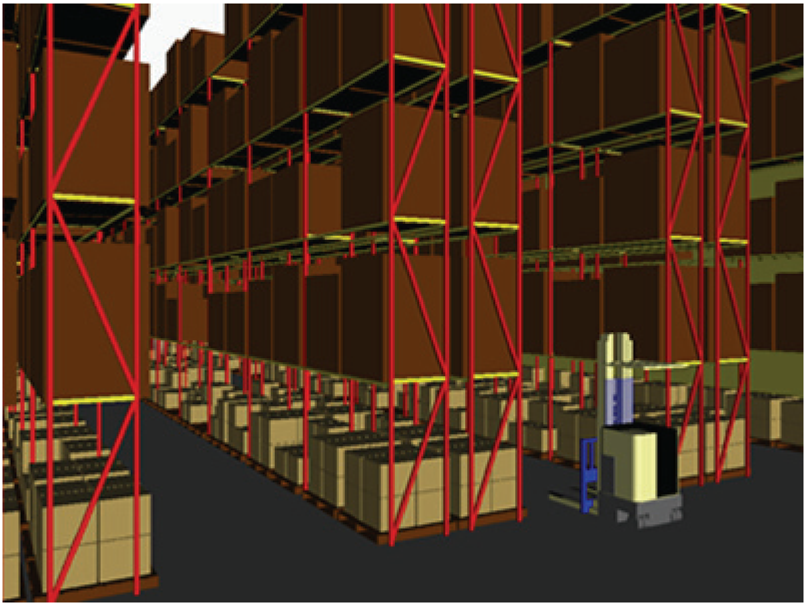

Figure 2-2. A snapshot of the warehouse area.

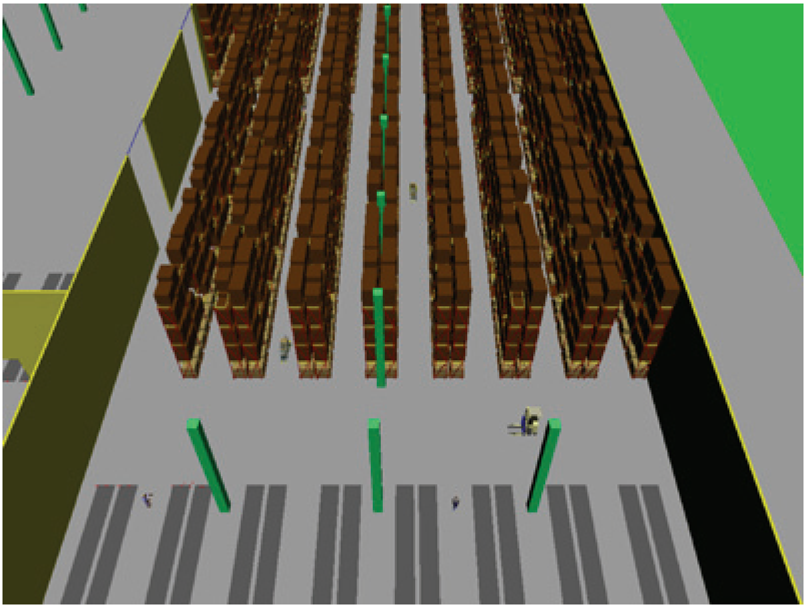

Figure 2-3. A snapshot of the receiving and shipping areas.

Both the conceptual model and the simulation model increased the understanding of how RFID technology in packaging could affect activities and processes, while at the same time creating an understanding of how it could affect retail supply chains as a whole. Furthermore, the models illustrate the opportunities of using RFID technology in packaging and indicate that there are significant benefits to be obtained from using RFID technology in packaging.

2.3 Findings

The findings of the licentiate thesis were drawn from the outcome of the case study, the simulation model and the conceptual model. From a bottom-up perspective, the licentiate thesis elaborates on how RFID technology in packaging could affect packaging logistical activities, then the processes, and finally the whole retail supply chain.

2.3.1 Impact on activities and processes

The conceptual model indicates what packaging logistics activities are replaced, added, eliminated, and influenced when RFID technology is applied in packaging. In general, RFID technology in packaging facilitates more frequent identification and verification activities than today when bar code technology is used, since these activities become automated and are therefore more economically viable. The automated identification and verification activities enabled by RFID technology, increase the accuracy of identification and verification activities, which are otherwise exposed to human errors.

RFID technology in packaging would increase the efficiency and effectiveness of the retail supply chain by reducing labour and increasing the accuracy, co-ordination and speed of the activities within the processes. The conceptual model and the simulation model indicate that there are significant benefits to be obtained from using RFID technology in packaging. Table 2-1 illustrates the possible benefits of RFID technology in packaging that can be observed in the processes for the different retail supply chain members. In the table an X indicates an opportunity whereas numbers indicate the opportunity to reduce performed activities by the same amount as the number.

Table 2-1. The opportunities RFID technology in packaging offers in the different processes.

Processes / Opportunities	Manufacturer		Distribution centre					Retail outlet		
	Filling process	Warehousing process	Receiving process	Storing process	Picking process	Shipping process	Order process	Receiving and shipping	Replenishing process	Order process
Automated inventory count		**X**		**X**				**X**	**X**	
Automated proof of delivery		**X**	**X**					**X**		
Automated proof of delivery, shipment etc.		**X**				**X**		**X**		
Improvements in responsiveness					**X**		**X**		**X**	**X**
Utilisation improvements; warehouse space, truck		**X**	**X**			**X**		**X**		
Product shelf-life improvement		**X**		**X**					**X**	
Product availability improvement				**X**			**X**		**X**	**X**
Out-of-stock reduction		**X**		**X**	**X**		**X**		**X**	**X**
Inventory reduction		**X**		**X**			**X**	**X**	**X**	**X**
Shrinkage reduction		**X**	**X**	**X**		**X**		**X**	**X**	
Verification activity reduction		**1-3**	**1**	**1**		**2**		**4**		
Labelling activity reduction		**0-1**	**1**		**2**					

The costs of RFID technology in packaging and potential benefits vary, depending on the packaging level being tagged. Figure 2-4 illustrates the extent and influence tagging different packaging levels has on processes along the retail supply chain. RFID tags on tertiary packaging (pallets) may be used from the filling process to the storing process. Furthermore, the tags on tertiary packaging (e.g. roll containers) may be used from the shipping process of the distribution centre to the receiving and shipping processes of the retail outlet. RFID tags on secondary packaging could be used further downstream in the supply chain than on the tagged tertiary packaging, i.e. from the filling process and all the way to the replenishing process, depending on the activities within the replenishment process. Irrespective of the activities within the replenishment processes, tagging of primary packaging may be used in the whole supply chain, from the point of filling at the manufacturer to the point of sale in the retail outlet. One should bear in mind that tagging of primary packaging could also provide opportunities beyond the point of sale in retail outlets, e.g. in recycling, reuse, and post-sales service and support.

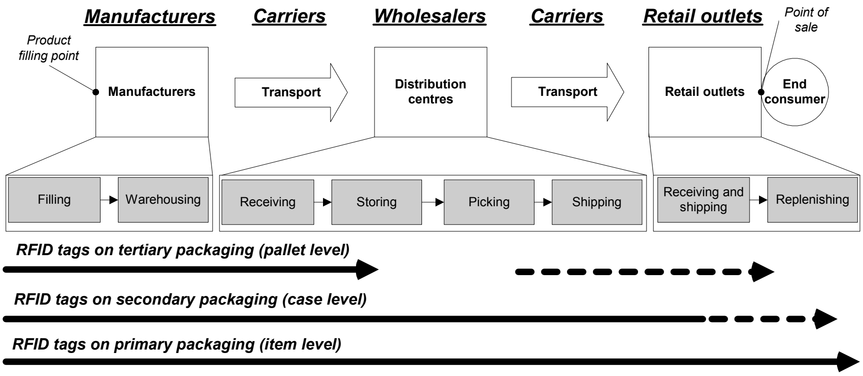

Figure 2-4. The extent and influence tagging different packaging levels has on retail supply chains.

Although tagging on a primary packaging level will bring about the greatest level of benefits for the retail supply chain, tagging on secondary and tertiary packaging levels could provide valuable benefits for the supply chain. The conceptual model indicates that the manufacturer who applies the tags to primary, secondary and tertiary packaging does not gain any direct benefits from secondary and primary packaging tagging. It is also important to observe that in the filling process at the manufacturer's, no potential benefits are gained by applying RFID tags to primary, secondary or tertiary packaging. However, the manufacturers could ensure direct benefits in their warehousing process through the use of RFID tags on tertiary packaging.

The conceptual model and the simulation model indicate that many of the possible benefits for a distribution centre can be achieved by tagging secondary packaging. The simulation model indicated that the average time to pick an order decreased by roughly 25 per cent when RFID technology was used in secondary packaging. This means that the workforce conducting the picking activity, which is the core and the most labour-intensive activity in the distribution centres, could be reduced by approximately 25 per cent. The simulation model also indicated that the ability to automatically generate orders, by capturing the inventory levels through tagging of primary packaging, could reduce out-of-stock situations by approximately 50 per cent. It is important to point out that the simulation model is context-dependent i.e. only describes the Dutch retail distribution centre studied. Thus, the simulation findings are not statistically generalisable to other distribution centres. However, the simulation model indicates that a major potential benefit of RFID at distribution centres is reduced labour costs. From a retail outlet perspective, RFID tags on secondary packaging would provide limited, but still considerable, opportunities, while tagging on primary packaging would provide the greatest level of opportunities.

2.3.2 Organisational issues

The success of implementing RFID technology along the retail supply chain is likely to depend on the ability of manufacturers and retailers to collaborate and agree upon how they can share the costs and benefits of the technology. Table 2-1 indicates that the different potential benefits appear unequal to the supply chain members. Combined with figure 2-4 they indicate that there are different potential supply chain benefits and costs of applying RFID technology, depending on what packaging level is being tagged (item level tagging is associated with higher cost compared to case or pallet level tagging since more tags are needed). For example, the processes at manufacturers' premises will be positively affected by pallets being tagged, while processes at retailers' premises will mainly benefit from case and item level tagging. To enable manufacturers to obtain benefits such as greater visibility of point of sales from case and item level tagging, retailers need to agree to share information that they may currently consider confidential.

However, from figure 2-4 it can be seen that the organisational barrier of implementing RFID to packaging has one exception. The tertiary packaging used between distribution centres and retail outlets is often returnable transport packaging such as roll containers. These assets are often owned and managed by an organisation and used within a limited set of organisations. Thus, the sharing of cost and benefits are more confined and tangible in this application of RFID technology to packaging.

2.4 Licentiate thesis contributions

The practical contribution of the licentiate thesis is the description of what and how packaging logistics activities are affected when RFID technology is applied to packaging. RFID technology in packaging is gaining acceptance throughout the retail industry and to be able to introduce the technology, we need to develop an understanding of how the technology affects activities and processes throughout retail supply chains. The conceptual model and the simulation model provide insights into how activities and processes are affected by RFID technology and illustrate potential benefits and barriers of introducing the technology in packaging throughout retail supply chains.

The methodological contribution of the licentiate thesis is the combined use of case study and simulation study methodology in logistics research. Combining the case study method and simulation demonstrates that there are several synergies of intrinsic value to research in this area. Advantages of combining these two different research strategies are that of using the ideographic aspects of case study strategy as a way to identify and measure relevant characteristics of the studied system, helping the development of simulation model. The ability to explore different scenarios by using modelling and simulation strategy provides further insights into the behaviour and performance of the system and the ability to expand the time horizon of the study.

The theoretical contribution of the licentiate thesis is to the field of packaging logistics. A framework is developed which demonstrates overall packaging logistics activities in the retail supply chain. The framework also describes the packaging logistics activities in detail which can facilitate awareness of value-adding activities and thus help to improve the efficiency and effectiveness of retail supply chains. Furthermore, the framework can be used as a platform from which to communicate and discuss packaging logistics issues in retail supply chains.

3 RESULTS FROM APPENDED PAPERS

In this chapter, the results from the four appended papers are presented. Table 3-1 highlights the connection between the appended papers and the research objectives. In the table a capital X indicates a strong connection and a lower-case x indicates a weak connection. Paper I mainly focuses on providing an outline of the physical interactions between packaging systems and logistics systems. The interactions are used in the paper to develop a model of the impact of packaging and logistics decisions on packaging systems and logistics systems. Papers II and III investigate the implications of two technological developments. Paper II explores the consequences of introducing an innovative unit load carrier and discusses trade-offs between standardised and differentiated packaging. Paper III explores the cost and process of implementing RFID technology to manage and control returnable transport packaging. Based on implications which were identified for management an implementation model is proposed in this paper. It is designed to guide managers in the process of implementing RFID technology.

Table 3-1. The connections between research objectives and appended papers.

	Paper I	Paper II	Paper III
Research objective 1	X	x	x
Research objective 2	X	x	x
Research objective 3	X	x	x
Research objective 4	x	X	x
Research objective 5			X
Research objective 6	x	x	X

Appended paper IV does not have any direct connection to the research objectives. However, paper IV has had an affect on, and is a result of, the research studies conducted in papers I-III. Paper IV contributes to the further development of research practices by presenting and discussing the concept of combining case study and simulation. The results from each of the four appended papers are presented below.

3.1 Paper I – Packaging and logistics interactions in retail supply chains

The aim of the research presented in this paper is to provide a comprehensive overview of the physical interactions between packaging systems and logistics systems in retail supply chains. The influence of packaging on logistics is often implicitly and fragmentally recognised, but seldom directly shown and discussed in a comprehensive way by logisticians. This may depend on the general consideration of packaging as a minor sub-system in logistics, with very limited influences on the overall performance of the supply chain. The awareness of the physical interactions between packaging systems and logistics systems along the supply chain is a fundamental step in changing this limited perception. Thus, the research presented in this paper strives to highlight the need for a better basis for packaging decision-making and to provide tools for extending traditional and limited packaging perspectives to a supply chain level. It may also serve as an elementary step towards understanding the role of packaging systems in logistics and as an aid in showing how packaging-related decisions might impact on the supply chain.

In order to gain insight into the influence of the packaging system on the retail supply chain, it is necessary to understand the nature of the interaction between packaging and logistic systems on an operational level. To accomplish this, the packaging logistics activities[5] in the retail supply chain were explored and analysed using four case studies. The four case studies were used to identify, describe and gain in-depth understanding of packaging logistics activities in retail supply chains. Three of the case studies involved two Swedish retail supply chains and one involved a Dutch retail supply chain. Even though the packaging and logistics interfaces identified and described are quite universal, the use of more than one national context strengthened the quality of the research. Triangulation was used to analyse the different case studies. The analysis enhanced understanding of the conditions of the packaging logistics activities in retail supply chains. The synthesis of the triangulation resulted in generic process maps illustrating in detail the packaging logistics activities and the physical path of the packaging system

[5]In the paper packaging logistics activities is sometimes called logistics activities related to packaging

from the filling point at the manufacturers, via distribution centres, and eventually to the point of sale at the retail outlets, and including the reverse flow of products and packages.

The generic and detailed process maps of packaging logistics activities can be used as a platform from which to analyse and discuss tangible packaging and logistics issues along the retail supply chain. The process maps show the physical environment for the overall packaging system in the retail supply chain. Understanding the packaging environment is a prerequisite for making packaging decisions based on a supply chain perspective. However, more importantly, the detailed descriptions of packaging logistics activities provide decision-makers with a comprehensive overview of the interactions between packaging and logistics.

A trivial, but important, result of this research is the conclusion that there are three areas where packaging and logistics-related improvements can be made: 1) in the logistics system, 2) in the packaging system and 3) in the interactions between the two. As might be expected, logisticians often focus on the logistics system while traditional packaging engineers often focus on the packaging system. However, the majority of the hidden and indirect costs, value-adding attributes and profit improvement potentials are represented in the interaction between the packaging system and the logistics system. Recognising the importance of the interactions redirects the focus from the packaging system or the logistics system to the interactions. In table 3-2 the paper summarises where the physical interactions between the packaging system and logistic are located along the retail supply chain (interactions are marked with X). The interactions between the packaging system and the logistics processes identified in this paper can be used to bridge the gap between logisticians and packaging professionals by enabling them to engage in a dialogue, and understand where and how packaging and logistics decisions can impact on the performance of packaging system and logistics processes in the retail supply chain.

Table 3-2. Interactions between packaging system and logistics processes.

Supply chain members	Manufacturer			Distribution centre					Retail outlet		
Logistics processes / **Packaging system**	Filling process	Warehousing process	Transport	Receiving process	Storing process	Picking process	Shipping process	Transport	Receiving and shipping	Replenishing process	Reuse and recycle
Primary	X									X	X
Secondary	X					X			X	X	X
Tertiary	X	X	X	X	X	X	X	X	X	X	X

This paper also provides meaningful reference points for logisticians and packaging professionals, in the form of two tables describing and highlighting *packaging logistics activities*[6] (see table 4-2) and *interacting packaging aspects* (see table 4-1). The table of packaging logistics activities can serve to identify inefficiencies and encourage a logistics focus on packaging-related value addition. The table of interacting packaging aspects provides the necessary means to evaluate packaging aspects related to logistics from a value-adding perspective and shows what packaging aspects are important in the various processes along the supply chain. It may also serve to identify where there are opportunities for packaging-related improvements and to encourage a packaging focus on logistics-related value addition.

Understanding where and how logistics and packaging decisions impact on supply chains is central to identifying the potential for improvements in efficiency. However, packaging and logistics decisions are interrelated and sometimes inseparable, which stresses the necessity for an integrated decision-making process. An integrated approach is, however, difficult to adopt and implement if it cannot be presented in a manageable manner. The identification of interactions between packaging and logistics systems could be of use in the process adopting and implementing such an approach. It is in these interactions that packaging and logistics decisions have an impact on the overall supply chain. This means that table 3-2, table 4-2 describing packaging logistics activities, and table 4-1 describing interacting packaging aspects can

[6] In the paper packaging logistics activities is called interacting logistics activities

be used to bridge the gap between logisticians and packaging engineers since the three tables represent the link between packaging and logistics decisions.

To encourage an integrated approach this paper presents a cause-and-affect model of the impact of packaging and logistics decisions, see figure 3-1. The core of the model is represented by the interactions between packaging system and logistics processes since they represent the link between packaging and logistics decisions. With an understanding of how logistics and packaging decisions impact on packaging system and logistics processes, it is possible to take decisions such as changing the packaging system or the logistics system, or both, based on a holistic packaging perspective which enables increased overall supply chain efficiency. Any packaging decision must take into consideration the impact of the chosen packaging solution or feature on the identified interface processes. Accordingly, efforts must also be made to adapt the operations and features of the logistics interface processes to the packaging system used. Combined, these interrelated considerations can make it possible to achieve considerable performance improvements in packaging systems and logistics systems.

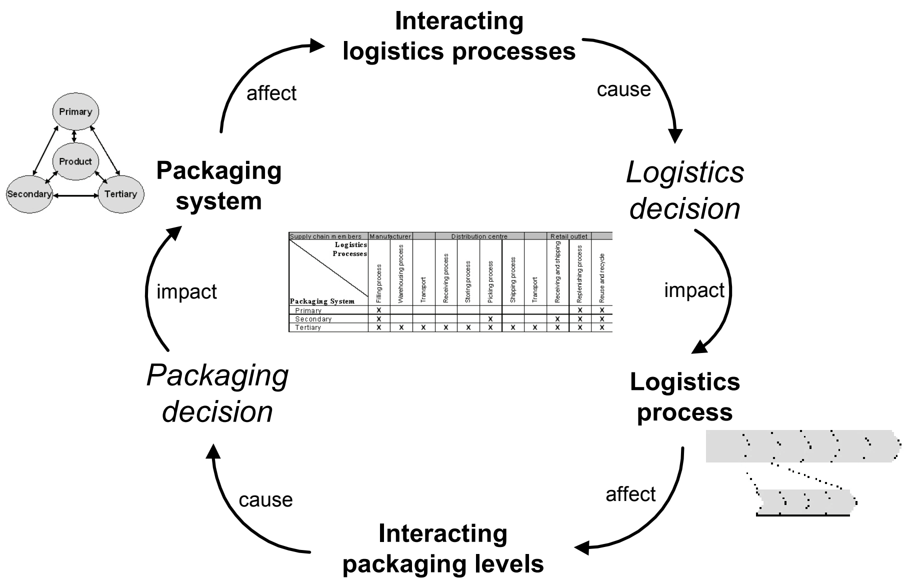

Figure 3-1. The cause-and-affect loop of packaging and logistics decisions.

3.2 Paper II – Consequences of introducing an innovative unit load carrier in a retail supply chain

In this inductive research paper, an in-depth case study was conducted at a global retailer (IKEA of Sweden) and its supply chain to explore the impact of introducing an innovative unit load carrier on different echelons across a retail supply chain. The case study also explores the logistics, market, packaging and environmental consequences of introducing an innovative unit load carrier. The innovative unit load carrier addressed in this paper is based on the idea of adjusting the load carrier dimensions to the dimensions of the products, instead of adjusting the products to the dimensions of the load carrier, as today's traditional unit load carriers do. Introducing a load carrier which enables varying unit load dimensions has had a profound effect on logistics processes along the supply chain since they are heavily influenced by standardised unit load carriers. It was thus of interest to investigate the consequences of introducing the innovative unit load carrier.

The consequence of introducing the innovative unit load carrier for manufacturers, distribution centres, retail outlets, and the impact this had on transport and return/recycling systems are described in this paper. It provides explanations as to why the innovative unit load carrier is introduced as well as illustrative examples of how the innovative unit load carrier affects packaging, logistics, markets and the environment. Hopefully, this will trigger new ideas and concepts among managers, promoting packaging and logistics innovations and technological developments. The overall consequences of introducing the innovative unit load carrier are:

- Logistics consequences - Introducing the innovative unit load carrier has influenced logistics processes along the whole supply chain. Some parts of the supply chain have benefited at the expense of others. From a logistics perspective, the major benefit is the increase in cube utilisation of transport units, while the main drawback is additional time-consuming activities at distribution centres. A rough estimate indicates that the current decrease of transport costs is more than ten times greater than the cost of additional handling at distribution centres. However, policy, and process changes, and investments in material handling equipment have been required throughout the supply chain in order to accommodate the load carrier.

- Market consequences - An underlying reason to introduce the load carrier was to be able to meet new needs and requirements from different markets, which would assist IKEA in reaching and sourcing in new markets. The innovative load carrier is one additional option in the choice of load carriers, enabling the company to give more consideration to differences in infrastructure and equipment between markets. Moreover, being able to physically shape the unit load by using innovative unit load carrier has facilitated IKEA's introduction of new products.
- Packaging consequences - Introducing the innovative unit load carrier has had far-reaching consequences on packaging systems. Using the load carrier has resulted in new requirements but also enables more freedom in product and packaging design. Traditionally, product development has been constrained by the fixed dimensions set by standardised unit load carriers. Using the innovative unit load carrier places fewer restrictions on product development as less consideration is given to the dimensions of load carriers. However, a fundamental requirement when using the innovative unit load carrier is that the products and the packaging solutions have to form a self-supporting construction and function as bearing support for the unit load.
- Environmental impact - Using the innovative unit load carrier instead of wooden pallets has the potential to reduce the environmental impact of transportation. A life-cycle assessment comparing the environmental performance of using innovative unit load carrier and EUR pallets indicated that there are negligible differences in the environmental impact of the unit load carriers. However, the life-cycle assessment measured the environmental transport impact per tonne-kms. This does not include unit load carriers capability to increase the cube utilisation of transport units, which reduces the amount of vehicle movement, i.e. truck-kms. Hence, loading ledges themselves do not make a smaller environmental footprint than the EUR pallet, but enable higher cube utilisation of transport units which reduces the environmental impact of transportation.

Based on the empirical evidence of the case study this paper contributed to understanding of potential trade-offs between standardised and differentiated packaging solutions, thereby providing practitioners with a better basis for making decisions on packaging design and development. Packaging professionals need to be able to meet different and conflicting packaging needs and requirements, but must often prioritise whether to provide a standardised or a differentiated packaging solution. This decision is a tough compromise between facilitating an integrated or a flexible system, and improving compatibility or performance. Thus, in deciding on standardised or differentiated packaging, it is not only the packaging system that is of interest, but also how it interacts with logistics systems and markets.

The trade-off between facilitating an integrated or a flexible system is unambiguous in the case of introducing the innovative unit load carrier. From a material handling point of view standardised load carriers, such as the EUR pallet, are outstanding and are often seen as the obvious choice in order to achieve an efficient logistics system. This is because nearly all logistics systems are designed to handle these standardised load carriers. However, the integration of standardised load carriers in a logistics system involves the risk for companies of not being able to change to new business situations and needs. The introduction of the innovative unit load carrier is a measure to increase the flexibility of IKEA's packaging system, making it more adaptable to different logistics processes and markets. Furthermore, the innovative unit load carrier offers more freedom in product and packaging design, since the product does not have to fit certain fixed dimensions set by traditional carriers. However, to attain this flexibility, investments had to be made. Manufacturers, carriers, distribution centres and stores had to modify or change their material handling equipment, processes and policies to some extent to accommodate different unit load carriers, sometimes with great impact on corporate finances and organisation.

The packaging trade-off between compatibility and performance is particularly evident in the introduction of the innovative unit load carrier, which is a measure for improving supply chain performance. For packaging engineers at IKEA, the innovative load carrier represents a new alternative. By combining different unit load carriers, packaging engineers are able to choose the one which offers the best total value. This means that even if a standardised and a integrated unit load carrier system leads to efficient processes, the flexibility of using alternative load carriers generates an opportunity to improve overall supply chain performance. It is not strictly a question of using a standardised or a differentiated packaging system, but the combination of both which

IKEA uses in order to improve supply chain performance. This indicates that packaging should not be considered as a sub-system of logistics or marketing, but a strategically important area which contributes to overall supply chain performance.

The multiple consequences of introducing the innovative unit load carrier illustrate and emphasise the need for a holistic approach in order to understand the total impact of packaging on supply chains. Making a packaging decision, such as introducing an innovative unit load carrier, is a difficult process involving a variety of actors, many functions, different requirements and conditions. Packaging decision-makers then need a holistic approach which carefully considers the impact and trade-offs of packaging along supply chains in order to avoid sub-optimisations. The introduction of the innovative unit load carrier implicitly demonstrates the potential of a holistic packaging approach. As mentioned earlier, the multiple consequences of introducing the innovative unit load carrier influenced activities throughout the supply chain. Some parts of the supply chain benefited at the expense of others. However, from a holistic approach, the new unit load carrier decreased total distribution costs, total environmental impact and increased packaging system flexibility. Moreover, in the introduction of the innovative unit load carrier careful consideration was given to its interacting elements, i.e. changes were made to the packaging system and the logistics system, which made it possible for IKEA to improve overall supply chain performance. This implies that understanding packaging interactions makes it possible to make decisions, such as changing the packaging system or logistics system, or both, based on a holistic packaging approach.

3.3 Paper III – The cost and process of implementing RFID technology to manage and control returnable transport items

The aim of this paper is to explore and describe the cost and process of implementing RFID technology to manage and control the rotation of returnable transport items. Due to the novelty of using RFID technology in logistics and supply chain management, in-depth case studies were conducted at two global firms in the retail industry to investigate how and why organisations implement and assess the use of RFID technology to manage and control returnable transport items. One case study focuses on an RFID trial conducted by IKEA, while the other focuses on an RFID implementation conducted by Arla Foods. From the results of these in-depth case studies this research is able to provide insights into the cost and process of implementing RFID technology and highlights significant savings and benefits as well as the potential benefits and risks of implementing RFID to track returnable transport items.

As a result, a stage model of the RFID implementation process is suggested in this paper (see table 3-3). The model is based on Cooper and Zmud's (1990) model of the information technology implementation process. In it different activities are presented, which may occur in parallel and in an iterative way. Furthermore, implications for management are identified to guide managers in the process of implementing RFID technology. The implications for management identified in the different stages are discussed below.

Initiation - The cases showed that an important ingredient in performing an RFID implementation is to obtain a match between RFID technology and business processes. Thinking about RFID should be in term of how it supports new business processes, and business processes should be considered in terms of the capabilities RFID can provide. RFID technology does not in itself bring benefits; it is in the interaction with business processes that benefits are attained. One can too easily be blinded by the functionalities and the extensive opportunities offered by RFID technology, causing one to focus on the technology and overlook the business processes. Performing RFID projects for the sake of technology may end up in a business application with limited benefits.

Table 3-3. Model of the RFID implementation process.

Stage	Activity description	Reason/motivation
Initiation	*Problem identification:* Identify the problem/opportunity and define an objective.	Focuses efforts.
	Concept development and system design: Develop different concepts of how to solve the problem. The concepts lead to different system designs which have various information and technology needs.	Find solutions and a match between business processes and technology.
Adoption	*Cost-benefit analysis:* The result of the concept development and system design is assessed economically.	Define and compare benefits and costs.
	RFID trial: The technology is tested and put though its working environment in order to verify that it works as anticipated.	Test and verify technology performance.
Adaptation	*Choose system integrator:* Based upon software and hardware requirements and cost etc., system integrator(s) are chosen.	Purchase software and hardware.
	Installation: Software is development and installed. Hardware is installed and adjusted. Business processes are changed and employees are trained in the new processes.	Put the system in position ready to be used.
Acceptance	*Education and training:* Inform, train and discuss with employees and end-users about the use and usefulness of the system.	Gain organisational support.
	Communication: Communicate with all involved organisations about the use and implication of the system.	Gain organisational acceptance and awareness.
Routinisation	*Improvements:* Perform installation changes to accommodate employee’s needs and improve the level of automation and performance of the implemented system.	Encourage the usage of the implemented system and increase performance and automation levels.
	Process the collected data: Analyse and interpret the data accumulated from the system.	Improve decision-making.
Infusion	*Expand the implementation:* Use the implemented system infrastructure for other applications.	Gain benefits which were previously too expensive, risky and difficult.
	Transfer the technology: Use the knowledge attained regarding the technology involved.	Generate spin-offs in other applications/problem areas.

Adoption and adaptation - Conducting a cost-benefit analysis and a trial are important activities when adopting RFID. RFID is a novel and complicated technology with numerous internal and external interdependences. Performing an RFID trial helps those who want to adopt the technology to reduce the perceived complexity of the technology. Both IKEA and Arla Food conducted an RFID trial to verify that RFID technology could be used to track their returnable transport items. Carrying out an RFID trial increased IKEA and Arla Foods' proficiency in and understanding of the technology used by providing insights into RFID system components, functionalities, performance, standards and influential factors. Conducting a trial also increased the general awareness of RFID technology throughout the organisations, resulting in suggestions for other potential RFID application areas. Both companies chose to perform the RFID trial at an implementation site and not in a laboratory environment. This enabled the companies to verify the technology in an implementation environment with electromagnetic interference, shifting temperatures etc.

Performing a cost-benefit analysis helps those who want to adopt RFID technology to define and compare benefits and costs, and serves as an aid to decision-making. However, one should bear in mind that there are intangible benefits, such as sociotechnical (staff satisfaction) and strategic (development of competencies) outcomes which are difficult to include in a cost-benefit analysis. Neither IKEA nor Arla Foods included any strategic benefits in its cost-benefit analyses, even though gaining competence concerning RFID technology was an important part of their RFID projects.

Acceptance – Gaining user and organisational acceptance of RFID implementations is as important to implementation success as ensuring technology integrity. This suggests that managers should view RFID implementations as an organisational problem rather than one strictly of technology or economics. In Arla Foods' implementation process the major shortcoming was not actively involving the receiving organisation. The receiving organisation went through major restructuring and other information technology implementations and because of this it did not prioritise actively participating in the RFID implementation process. This project co-ordination problem finally resulted in a lack of acceptance from the receiving organisation. Organisational support and acceptance were gained by informing and communicating with the organisation about the use and importance of tracking the returnable transport items. Communicating the need for and use of the RFID system with the organisation spread information concerning the RFID system to lorry drivers and customers and made people aware that the returnable transport items were tracked. This awareness resulted in rules and procedures concerning the control of the returnable transport items being followed. Communicating the need for and the use of the RFID system contributed considerably to the outcome of Arla Foods' RFID implementation, i.e. elimination of the expected loss of returnable transport items.

A drawback of the IKEA trial was not involving and interacting with all the supply chain organisations which would be involved in an RFID implementation. Even if the trial was limited to a distribution centre, co-operation with other supply chain organisations would have been beneficial since they, just as IKEA did, would have gained insights into RFID. The organisations would probably also provide important input and feedback on adoption of RFID technology, thus generating valuable discussions among the organisations.

Routinisation - Processing the data collected from the RFID system and using them in daily operations and routines by integrating them in scorecards, internal reports etc., is crucial to fully using the benefits of an implemented RFID system. Analysing and interpreting all the accumulated data from the RFID system was something that Arla Foods embarked upon late in the implementation process. Arla Foods has been able to learn the fundamentals of the rotation of the roll containers. However, it expects to handle the uncertainty of roll container demand through the granulised data provided by the RFID system.

Infusion - The cases show that having implemented an RFID system might provide a company with the opportunity to expand the implemented system and gain benefits which were not previously economically viable. RFID implementations can be expensive, risky and difficult. However, with RFID infrastructure (readers and information system) installed and knowledge attained about the technology involved, RFID technology can be more easily transferred to other parts of the organisation and put to higher levels of use to generate spin-offs in other application areas. For example, an outcome of Arla Foods' implementation is that it will expand the implemented system to include other sites. Moreover, it is thinking of tracking other returnable transport items, for example, its traditional roll containers. To track its traditional roll containers Arla Foods already has the necessary software, information systems, RFID readers installed and knows how to attach the RFID tags and where. In conclusion, installed RFID infrastructure which other applications can pave the way for other applications which were previously considered too expensive, risky and difficult. This indicates that tracking returnable transport items is a feasible starting point for organisations during the process of getting started with RFID and trying to adopt RFID technology.

Cost is often mentioned as one of the main barriers for the adoption of RFID technology. According to Persson's and Stefansson's (2006) survey on RFID in Swedish companies, the difficulty in getting back the cost of investment is the most important barrier to implement RFID. The estimated cost-benefit analyses presented in this paper point out that the payback for IKEA's RFID investment would be less than two years, while for Arla Foods' investment the payback period would be approximately 14 months. This indicates that in implementing RFID technology, cost should not generally be considered as a barrier. The cost-benefit analyses also indicate the magnitude of and the relation among the different costs and benefits for implementing RFID technology to mange and control returnable transport items. In applications where large numbers of tags are used and then disposed of, the running cost of the tags is a central issue. In tracking returnable transport items where the tags are continuously reused, the cost of the tags is not a central issue. System integration, the number of readers and the process of applying the tags are issues which in themselves may involve higher costs than the cost of the tags.

In conclusion, this paper contributes to the general understanding of the cost and the process of implementing RFID technology to track returnable transport items. Just like information technology implementations in general, RFID implementations are expensive, risky and difficult due to their complexity, both technically and in the organisational issues they involve. This paper sheds light upon some technological and organisational issues which are involved in the process of implementing RFID. These technological and organisational issues indicate that managing organisational interactions in RFID implementations is as important to implementation success as ensuring technology integrity.

3.4 Paper IV – Combining case study and simulation methods in supply chain management research

In contrast to the other appended papers, this paper aims to contribute to the further development of research practices by presenting and discussing the concept of combining case study and simulation. Two research studies are briefly presented in order to describe the possibilities of combining theses methods in practice. The results of the paper show that combining case study and simulation into a multi-method study allows the researcher to gain synergies, harmonise weaknesses and assess the relative strengths of each method. Combining the methods facilitates:

- an iterative and interlinked research process, which in turn provides:
    - a way to identify and measure relevant characteristics of the system studied
    - further insights into the behaviour and performance of the system
    - a way to strengthen the theorising process
- triangulation between the methods and among different data sets
- systemic data collection process with synergies
- an expanded time horizon of the study

Iterative and interlinked research process - In case study research the aim is to gain in-depth understanding of the phenomenon and context under investigation, while in simulation the aim is to gain insight into the behaviour and performance of the system. However, in order to gain insight into the behaviour and performance of the system the researcher must have in-depth understanding of the system and its context, and vice versa. Combining case study and simulation in an iterative and interlinked research process (as illustrated in figure 3-2) provides the researcher with synergies and input on the individual methods which facilitate handling of complexity in real-life settings. Combining the methods in an interlinked and iterative process, going back and forth between the methods, also strengthens the theorising process. By combining the methods the research may generate a theory, test it, further develop it, and experiment with it.

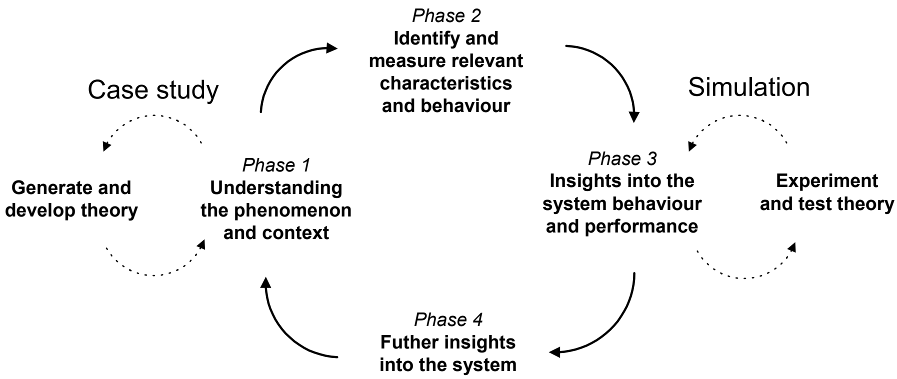

Figure 3-2. A model of the iterative and interlinked research process.

A motive for combining case study and simulation is that the researcher is helped by the case study in identifying and measuring the relevant characteristics and behaviour of the system under study. This is because the case study provides a deep understanding of the phenomenon and the context under investigation (phases one and two in figure 3-2). When a researcher is trying to represent phenomenon and its context in a computer simulation, extreme demands are placed on him/her in order to replicate real-life behaviour as well as possible. The researcher needs to possess a great deal of knowledge about the relationships among sub-systems and their components as well as the purpose of a variety of activities and processes going on in these sub-systems, all of which change dynamically. Should this knowledge be lacking, the simulation model will not represent what is being examined. These demands make it difficult for methods such as simulation, designed to predict system behaviour, to reflect the variety among systems and their constituent components. Through the in-depth understanding provided by a case study, knowledge is gained about relationships and patterns of behaviour. This means that a simulation combined with case study would help researchers to identify the relevant characteristics and behaviour of a system.

Another motive for combining simulation and case study is that the researcher is able to obtain help from the simulation in identifying and gaining insights into the system behaviour and performance by validating and experimenting with the model (phases three and four in figure 3-2). Some of the factors influencing the performance and the behaviour of a system may be easy to observe, while others are ambiguous, but vital. To produce a reliable simulation, extensive and precise knowledge of real-life behaviour is needed. Furthermore, the combination of several factors might also influence the behaviour and performance of the system. In simulation influential factors could be identified and insight into the importance of these factors could be gained. In a case study the ability to experiment with influential factors is much more difficult, making it difficult for the researcher to identify influential factors in case study.

Triangulation - Another motive for combining case study and simulation is the opportunity to triangulate between the two methods. A strength of triangulating between case study and simulation is the mixing of a qualitative and a quantitative method. In addition, combining case study and simulation offers the researcher the opportunity to triangulate between the data sets collected in the studies. Different data sets have different strengths and weaknesses. Data sets collected from a simulation perspective might focus more on quantitative data, e.g. variances and distributions of events through time, while data collected from a case study perspective might focus more on qualitative data. With two different data sets collected from two different perspectives multiple perceptions are gathered which increase the validity of the research.

Systemic data collection - Combining case study and simulation in an interlinked and iterative research process systematically enhances the data collection process. When case study and simulation are combined the different data sets gathered in the studies overlap one another creating synergies in the data collection process. The case study provides simulation with an in-depth description and understanding of activities and processes, facilitating the development of a conceptual model for the simulation model. In addition, the data collected for the simulation provides the case study with an enriched understanding of the dynamics, variances, dependences and relationships between events and activities. Simulation might also provide the case study with additional input data derived from the results of verifying and conducting experiments using the simulation model.

Expand the time horizon - Another motive for combining the methods is the opportunity to expand the time horizon of the study. A case study focuses on understanding a contemporary set of events, whereas simulation could be used to look back in time using historical data and/or look forward in time by running different scenarios. Rather than only focusing on the current situation using case study, a combination of the methods provides the opportunity to look back and/or forward in time using simulation.

This paper also discusses the feasibility of combining case study and simulation, since these originate from different methodological assumptions. The paradigmatic differences between case study and simulation require that the researcher assesses the trade-offs between the methods and integrates positivistic and hermeneutic assumptions in the research. Adopting two methodological perspectives may provide an extended view of a supply chain phenomenon, for example, incorporating soft aspects such as individual subjective interpretations and understanding, and hard aspects which are measured or quantified. Thus, combining case study and simulation enables researchers to go beyond the methodological limitations researchers place on themselves by strictly adhering to only doing case or simulation research. Even though, to some extent, there are paradigmatic differences between case study and simulation, this paper shows that the methods can be successfully combined.

3.5 Interconnections among the research components

From the licentiate thesis four research directions and papers were pursued. Paper III continued to explore the application of RFID technology to packaging, but with a focus on returnable transport packaging applications. Paper IV further developed and discussed the concept of combining case study and simulation methods; a concept which is only sketchily presented and discussed in the licentiate thesis research process.

Based on the focus of paper III, which explores the application of RFID technology to returnable transport packaging, the choice was made to investigate another tertiary packaging technology and its impact on logistics systems, i.e. paper II. Paper II explores the overall consequences of introducing an innovative unit load carrier in a retail supply chain. The common denominators of papers II and III are their focal point on technology developments related to tertiary packaging and its impact on logistics.

Based on improved insights and experience, from appended papers II and III regarding interactions between packaging and logistics systems, appended paper I was written. Paper I is based on the empirical data and framework presented in appended paper one in the licentiate thesis, i.e. "Framework of packaging logistics activities in retail supply chains". Figure 3-3 illustrates how results from the licentiate thesis and the appended papers serve as input to other papers as well as to the synthesis of the research presented in the next chapter of this thesis. A more detailed discussion of the research directions and empirical paths taken during the research process is presented in the research process chapter.

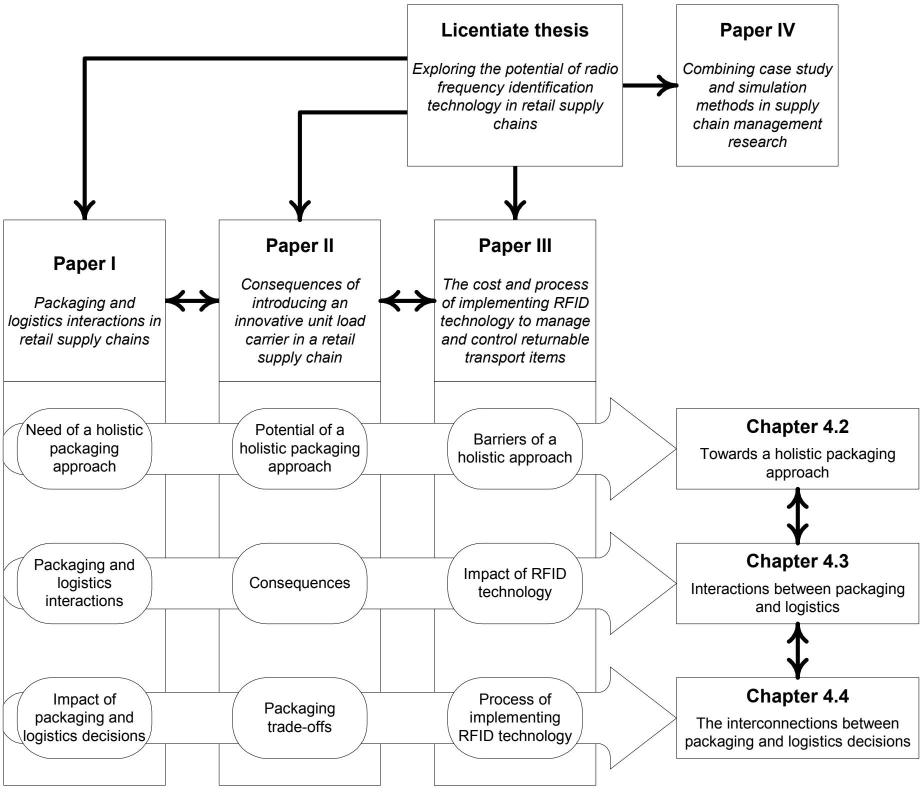

Figure 3-3. Outline of vital results interconnecting research components and the synthesis presented in the next chapter of this thesis.

4 CONCLUDING DISCUSSION

Based on the overall research question and purpose this chapter provides a concluding discussion on interactions between packaging and logistics. In particular, the impact of technology on interactions between packaging and logistics systems, and the interconnections between packaging and logistics decisions are discussed. Moreover, the potential and barriers of considering the multi-functions of packaging systems along supply chains are discussed. First however, previous packaging logistics research is briefly reflected upon to position this research alongside other research thoughts and suggestions.

4.1 Packaging Logistics

In the past ten years the concept of packaging logistics has attracted increased attention from both academia and industry (Dominic et al. 2000; Henriksson 1998; Johnsson 1998; Öjmertz 1998; Twede & Parsons 1997). There is an ongoing discussion about the concept as such, where several views and definitions have been proposed. Bjärnemo, Jönson and Johnsson (2000) describe packaging logistics as: *"The interaction and relationship between the logistical system and the packaging system that add value to the combined, overall, system - the Enterprise".* Saghir (2002) expands the scope to a supply chain level and includes other aspects than logistics, such as environmental and marketing aspects in his definition of packaging logistics, i.e. *"The process of planning, implementing and controlling the coordinated packaging system of preparing goods for safe, efficient and effective handling, transport, distribution, storage, retailing, consumption and recovery, reuse or disposal and related information combined with maximizing consumer value, sales and hence profit."* Based on the definitions above one can safely conclude that the interactions between packaging and logistics represent a fundamental aspect in the concept of packaging logistics.

This research on interactions between packaging and logistics systems is based on and builds on previous packaging logistics research. In "Packaging Logistics – a value added approach" Johnsson (1998) presents an integrated approach to packaging and logistics and shows "*that there exist interactions and relations between the logistics system and the packaging system that may improve both the value and cost efficiency*". Saghir (2004a) continues on Johnsson's (1998) research path of and explores packaging logistics from a systems approach using Checkland's (1999) soft systems methodology in order to provide a fundamental platform for the concept of packaging logistics. The platform is made up of a number of packaging logistics antecedents, procedures and conceptual models which may be useful to better understand the core of the concept. According to Saghir (2004a) "*The core of the concept Packaging Logistics is a packaging-focused view which seeks to integrate the multidisciplinary aspects of packaging and co-ordinate the various levels of the packaging system*." In the platform for packaging logistics development the relation and overlap between packaging and logistics is discussed. This illustrates the connections between the two and the influences of packaging on logistics. However, the platform does not directly deal with, or focus on, interactions between packaging and logistics. Even if this research does not directly aim to further develop the packaging logistics concept as such, it provides insights into, and understanding of, interactions between packaging and logistics and thus represents a fundamental step in understanding the concept of packaging logistics.

The concept of packaging logistics can be viewed from two perspectives. A packaging-focused perspective, such as Saghir's (2004a), emphasises the multidisciplinary aspects of packaging and the co-ordination of the various packaging levels. A logistics-focused perspective, such as that of Twede and Parsons (1997), emphasises the logistics value of packaging systems. From the latter perspective, it could be argued that packaging logistics research is all about the interactions between packaging and logistics. However, from the former perspective interactions between packaging and logistics are only a limited part of packaging logistics research which stresses the need of a holistic view of packaging.

4.2 Towards a holistic packaging approach

Making sound packaging decisions is difficult. The functions which packaging must perform are manifold and it needs to fulfil different requirements and conditions for a variety of organisations along supply chains, from the very first point of packaging use, until the product is consumed and the packaging material is disposed of. Conflicting organisational needs and requirements packaging has to satisfy, result in potential trade-offs among marketing, logistics and environmental functions of packaging. Packaging decision-makers then need a holistic approach which carefully considers the impact and trade-offs of packaging along supply chains in order to avoid sub-optimisations.

As previously pointed out in this thesis, many researchers have called for a holistic approach to packaging, e.g. Prendergast and Pitt (1996), Saghir and Jönson (2001). Johnsson (1998) suggests a value-added approach through the integration of packaging and logistics, which can be used to increase the value of the product. A similar approach is proposed by Twede and Parsons (1997) who emphasise that an integrated logistics approach to packaging can yield significant logistics value. However, Johnsson (1998), and Twede and Parsons (1997) conclude that a more holistic view to packaging must be taken. Saghir (2004a) presents a platform for the development of a more holistic approach where an integrated approach to packaging, logistics and marketing is suggested from a supply chain perspective. In such a scenario antecedents, procedures and expected consequences are described, based on the use of the integrated approach.

A systems-oriented perspective towards packaging is used in this research to investigate the overall impact of packaging along supply chains. From a system-oriented perspective this research agrees with previous research and stresses the need for a holistic approach to packaging. Paper I concentrate on the increased need for a better basis for packaging decision-making, and strives to provide a tool/method to extend the traditional and limited packaging perspective from a firm-based view to a supply chain level. Appended papers illustrate the potential and adoption barriers of a holistic approach which considers the logistics, marketing and environmental functions of packaging systems along supply chains.

4.2.1 A systems-oriented perspective on packaging

A systems-oriented perspective on packaging highlights the interactions among the different levels of packaging and emphasises their interdependence, see figure 4-1. Packaging system performance is thus affected by the performance of each level and by the interactions among them. However, when making packaging decisions the challenge lies in fulfilling all the different logistics, marketing and environmental functions of the packaging system.

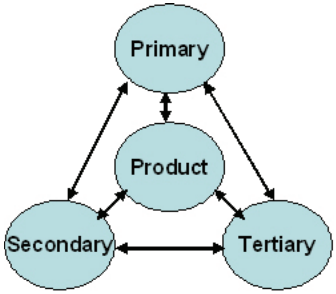

Figure 4-1. The interactions among packaging system components.

Evaluating the total impact of packaging on a supply chain from a systems perspective aims to assess the overall system (supply chain) which consists of a set of sub-systems, such as logistics and marketing (see Lambert, Cooper, & Pagh 1998 for a further description), connected together, which form the overall system. The strength of a packaging solution in one sub-system may be a weakness in another. This means that there are not only different "best" packaging solutions for different packaging systems, but also different "best" solutions for logistics systems and markets. The "total value" or "total cost" which a packaging solution contributes to a supply chain therefore depends on its interactions with various sub-systems. A holistic packaging approach considers all interacting sub-systems. Consequently, the main issue when evaluating the "total value" or "total cost" of packaging is how it interacts with various sub-systems. Understanding how packaging interacts and the impact of the interactions on the overall system is fundamental to making packaging-related decisions based on a holistic approach.

4.2.2 The potential of a holistic packaging approach

In appended paper II the multiple consequences of introducing an innovative unit load carrier implicitly show the potential of a holistic approach in evaluating the total impact of packaging on supply chains. The introduction of the innovative unit load carrier led to multiple packaging, logistics, market and environmental consequences influencing activities throughout the supply chain. Some parts of the supply chain benefited at the expense of others. However, from a holistic perspective, the innovative unit load carrier decreased the total distribution costs by primarily increasing cube utilisation of transport units. In order to introduce the innovative unit load carrier manufacturers, carriers, distribution centres, and stores had to change their processes, policies and material-handling equipment to accommodate the innovative unit load carrier. This means that the interactions of the innovative unit load carrier were considered in the introduction process, i.e. changes were made to the packaging system and the logistics system. It was by considering the interactions that it was possible to introduce the innovative unit load carrier, which improved the overall supply chain performance. Moreover, the aim of the introduction was to use the innovative unit load carrier in flows where the total value (e.g. protection, cube utilisation, handling efficiency) exceeded other unit load carriers. This aim of the introduction illustrates a holistic packaging thinking where the differences among unit load carriers are recognised and where the strength and weaknesses in comparison with other unit load carriers are ignored. In order to evaluate the strengths and weaknesses of a packaging solution it has to be evaluated with respect to supply chain requirements and needs. However, in a holistic approach to packaging the question is not whether one packaging solution is functionally better than another, but how the packaging solution is congruent with supply chain requirements and needs. Olsson (2006) put forward the same way of thinking and postulated the need to change from feature/function focus to customer focus in packaging development.

4.2.3 Barriers of adopting a holistic packaging approach

Appended papers I-III indicate that the narrow functional mindset and power conditions prevailing in various organisations, influence and sometimes inhibit the applicability of a holistic packaging approach. The success of a holistic packaging approach, which considers the total impact of packaging along supply chains, is likely to depend on the ability of organisations to agree upon how they can share the cost and benefits of such an approach.

The licentiate thesis and paper III present the potential benefits and cost of applying RFID technology in packaging. However, despite the potential to improve supply chain performance a barrier to an adoption of RFID technology along supply chains is the inability of organisations to share vital information with other members of the supply chain, and their inability to agree how they can share the costs and benefits of RFID technology. The RFID mandates put forward by major retailers, who want manufacturers to apply disposable RFID tags on tertiary and secondary packaging, is a measure indicating that sharing benefits (most benefit are gained by retailers) and cost

(cost of tags is the major reoccurring cost) is a major barrier to adopt a holistic packaging approach. Rutner, Waller, and Mentzer (2004) suggest that RFID may increase the power of retailers in the supply chain relative to suppliers. Moreover, Pålsson's (2006) experiences from an interorganisational RFID implementation study confirm the collaborative difficulty of implementing RFID technology in disposable secondary packaging. The awareness of this adoption barrier was a motive for me to conduct the research in paper III where RFID technology in closed-loop systems is investigated. RFID in closed-loop applications currently has fewer adoption barriers than supply chain applications pursued by major retailers. In closed-loop applications, organisations might avoid sharing costs and benefits, and sharing 'sensitive' information among supply chain members. This indicates that closed-loop applications are a feasible starting point for organisations trying to adopt the technology involved.

As paper I makes clear, today's retail organisations have considerably increased their power and put their most important requirements, such as RFID technology, and store and picking efficiency, on the packaging decision agenda. In paper II, which illustrates the potential of a holistic packaging approach, the introduction of an innovative unit load carrier was facilitated by the retailer's vertical supply chain ownership and its in-house product and packaging development. This means that it might be difficult for less vertically integrated companies to introduce "holistic" packaging solutions or technologies, since this would require various supply chain members, who often have different agendas, to share the costs and benefits of introducing such a solution or technology. Thus, power conditions in supply chains influences the applicability of a holistic packaging approach.

4.3 Interactions between packaging and logistics

A fundamental step towards adopting a holistic packaging approach is to identify and understand the nature of its interrelationship with logistics, marketing, as well as its impact on the environment. Even though paper II deals with the overall impact of packaging, i.e. logistics, marketing, environmental and packaging consequences of introducing a innovative unit load carrier, the overall purpose of this thesis is to explore interactions between packaging and logistics. Paper I provides a comprehensive overview of the physical interactions between packaging systems and logistics systems in retail supply chains. The paper demonstrates how detailed mapping of activities and processes connected to the physical packaging flow can facilitate awareness of packaging interactions and thus help to improve the performance of retail supply chains. The licentiate thesis and paper III combined explore the logistics potential and impact of RFID technology applied to packaging in retail supply chains. As the nature of packaging changes via innovations in packaging and technology, the implications of RFID and the introduction of the innovative unit load carrier provide insights into how these technological developments impact on packaging and logistics systems.

A continued discussion of a systems-oriented perspective on packaging is provided below but with a focus on packaging interactions with logistics. Moreover, interactions between packaging and logistics are discussed from a logistics and a packaging point of view.

4.3.1 A systems-oriented perspective on packaging…continued

Venn diagrams such as figure 4-2, are often used to illustrate the overlap and relations between packaging systems and logistics systems (see Johnsson 1998 p.138; Klevås 2005a p.60; Saghir 2004b for examples). Moreover, in an Ansoff matrix Saghir (2002) and (2004a) presents different packaging logistics strategies (see figure 4-3) which are concerned with improving and developing packaging logistics by changing both packaging and logistics systems. Both figures 4-2 and 4-3 indicate that there are only two areas where packaging and logistics improvements can be made, i.e. in the logistics system and in the packaging system.

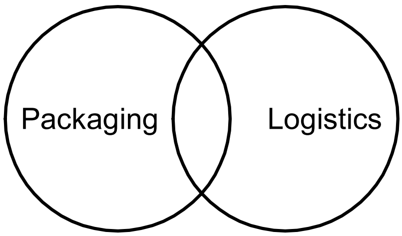

Figure 4-2. The overlap between packaging and logistics.

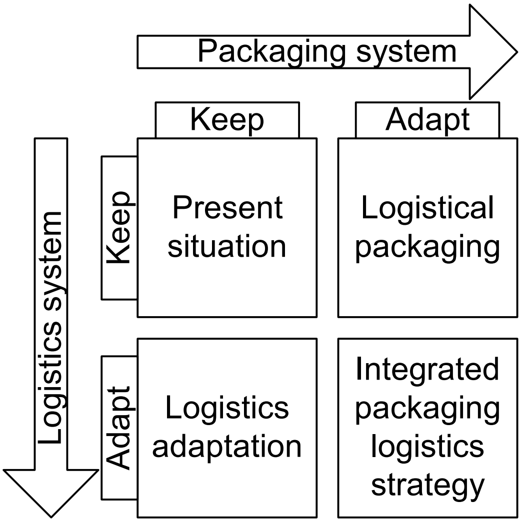

Figure 4-3. Packaging logistics strategies (Saghir 2004a p.98).

However, paper I shows that from a system-oriented perspective there are three areas where packaging and logistics improvements in the supply chain can be made: 1) in the logistics system, 2) in the packaging system and 3) in the interactions between the two. The third area represents the interactions between different packaging levels and various logistics activities and processes which constitute the logistics system, see figure 4-4. As might be expected, logisticians often focus on the logistics system while traditional packaging engineers often focus on the packaging system. This results in a mismatch in the interaction between the two since the majority of hidden and indirect costs, profit improvement potential and value-adding attributes are to be found in this interaction. Consequently, understanding packaging interactions makes it possible to take decisions, such as changing the packaging system or the logistics system, or both, based on a holistic packaging perspective enabling supply chain performance improvements. Decision-makers need to understand and focus on the interactions, and not individually on the packaging system or the logistics system. However, one should bear in mind that the packaging system and the logistics systems also have interactions with other business and managerial areas such as marketing. product development and the environmental which need to be considered in adopting a holistic approach.

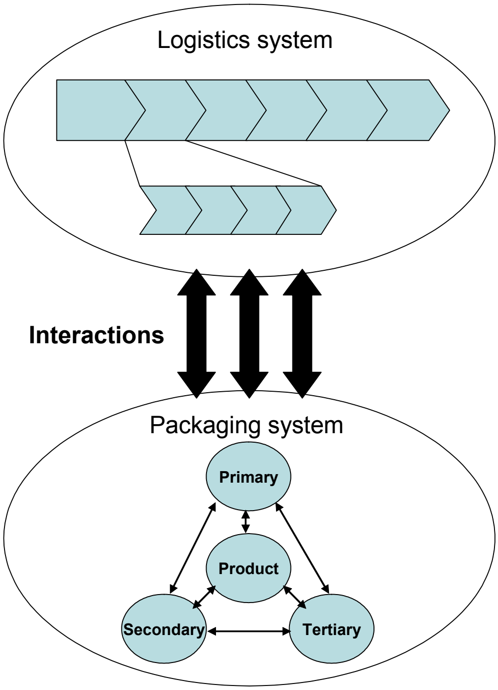

Figure 4-4. Schematic illustration of interactions between packaging and logistics.

4.3.2 Packaging interactions with logistics

From a packaging point of view, the physical interactions between packaging and logistics can be identified and described as packaging aspects related to logistics. Paper I summarises the packaging aspects which interact with logistics in the retail supply chain (see table 4-1). As discussed in the paper, the table of packaging aspects related to logistics can be used as a platform to analyse and discuss tangible packaging issues along the retail supply chain. It provides the necessary means to evaluate the packaging aspects related to logistics from a value-adding perspective and shows what packaging aspects are important in the various processes along the supply chain. It may also serve as an aid in identifying where there are opportunities for packaging-related improvements and for encouraging a packaging focus on logistics-related value addition.

Table 4-1. Interacting packaging aspects in the retail supply chain.

Supply chain members	Manufacturer			Distribution centre					Retail outlet		
Logistics processes / Packaging system	Filling process	Warehousing process	Transport	Receiving process	Storing process	Picking process	Shipping process	Transport	Receiving and shipping	Replenishing process	Reuse and recycle
Primary	Packing line efficiency Filling speed Label application Closing & sealing technology Flexibility									Handling efficiency Promoting sale Shelf adaptation Product identification	Handling efficiency Material
Secondary	Handling efficiency Packing line efficiency					Handling efficiency Identification Ergonomics Protection Stability			Handling efficiency Identification	Handling efficiency Identification Protection Shelf adaptation Ergonomics	Handling efficiency Material
Tertiary	Handling efficiency Stackability	Handling efficiency Stackability Protection Stability	Cube utilisation Stackability Weight & height Stability	Handling efficiency Stability Identification	Cube utilisation Weight & height	Handling efficiency Material	Handling efficiency Weight & height Stability	Cube utilisation Weight & height Stability Stackability	Handling efficiency Material Stability	Handling efficiency Store concept adaptation Product identification Promoting sale	Handling efficiency Material

As demonstrated in table 4-1, there are many packaging aspects related to logistics which are important for the packaging system levels and the various processes along the supply chain. Tertiary packaging interacts with all the processes and in several processes, such as transport and storing, it is the only packaging interaction. Changes to tertiary packaging levels then might influence all the processes. The magnitude of tertiary packaging interactions, and my interest in the logistics role of packaging, were major reasons as to why the consequences of an innovative unit load carrier was explored in paper II and to why implementing RFID technology to returnable transport packaging was investigated in paper III.

The introduction of the innovative unit load carrier changed the interactions between tertiary packaging and logistics. The innovative unit load carrier more or less influenced all the processes. However, its main impact was on transport, the receiving process at distribution centres, and the reuse and recycle process (see paper II). In the transport process the innovative unit load carrier improved cube utilisation while in the receiving process it reduced handling efficiency. In the reuse and recycle processes the innovative unit load carrier improved handling efficiency. Changing the interactions between tertiary packaging and logistics meant that the innovative unit load carrier was able to improve the logistics-related value of the packaging system. If the innovative unit load carrier did not change any of the packaging aspects related to logistics it would not provide any additional logistics-related value. This shows that the logistics-related value-adding attributes and improvement potential of packaging are to be found in the interactions between the systems.

The application of RFID technology to packaging emphasises the information and communication aspects of packaging. As information and communication aspects of packaging interact with logistics activities such as materials handling and logistics communications, the application of RFID technology to packaging obviously influences logistics systems. However, the influenced logistics activities in turn influence packaging systems. For example, as shown in paper III, RFID technology enables organisations to manage and control the rotation of returnable transport packaging more efficiently. There are several operational benefits of using returnable transport packaging such as providing better protection for products, improving working environments, enabling more efficient handling and cube utilisation, and reducing packaging material (Maloney 2001; Twede & Clarke 2004; Witt 1999). However, returnable transport packaging items are often managed with limited visibility or control, even though they are often of high value, vulnerable to theft, and critical for production and distribution (McKerrow 1996; Twede 1999; Witt 2000). As RFID technology enables organisations to manage and control the rotation of returnable transport packaging more efficiently, RFID technology facilitates and endorses the use of returnable transport packaging in organisations.

4.3.3 Logistics interactions with packaging

From a logistics point of view, the physical interactions between packaging and logistics can be identified and described as packaging logistics activities. Paper I summarises the distribution of the packaging logistics activities carried out in retail supply chains (see table 4-2, the numbers in the table state the number of activities in each process). As discussed in the paper, the table of packaging logistics activities can be used as a platform to analyse and discuss tangible logistics issues along the retail supply chain. The table can also be used to identify unnecessary and excessive activities along the supply chain. It can also serve to encourage a logistics focus on packaging-related value addition.

Table 4-2. Packaging logistics activities in retail supply chains.

Supply chain members	Manufacturer			Distribution centre					Retail outlet		
Logistics processes / Activities	Filling process	Warehousing process	Transport	Receiving process	Storing process	Picking process	Shipping process	Transport	Receiving and shipping	Replenishing process	Reuse and recycle
Control and verifying	1	1	-	1	1	0	1	-	3	0	2
Labelling	3	1	-	1	0	2	0	-	0	0	0
Automated handling	4	0	-	1	0	0	0	-	0	0	2
Manual handling	1	7	-	1	3	11	5	-	6	16	4
Transport	0	4	-	0	2	0	0	-	0	0	4
Storage or waiting	0	4	-	1	2	0	1	-	1	2	4
Packaging material											
Input	6	0	-	0	0	1	0	-	1	0	0
Output	0	0	-	0	1	1	0	-	0	3	0

As demonstrated in table 4-2, there are numerous packaging logistics activities carried out in the various processes along the retail supply chain. For example, several different bar code-based labelling activities occur in retail supply chains. Furthermore, numerous control and verification activities are manually carried out today. The need for re-labelling, control and verification is extensive and this indicates a lack of integration between supply chain members. One way to eliminate and improve re-labelling, control and verification activities is to introduce more advanced automated identification technology than bar code technology, such as RFID. Compared to bar codes, the advantages of RFID technology are that an RFID tag can be read through non-metallic obstructions not requiring line-of-sight, and that an RFID reader has the ability to read several tags simultaneously. Hence, RFID represent a major opportunity to overhaul and improve the shortcomings of these activities.

By applying RFID technology to packaging the interactions between packaging and logistics are changed. To illustrate and discuss how RFID technology applied to packaging can impact on activities in retail supply chains the conceptual model in the licentiate thesis was developed. The conceptual model indicates what packaging logistics activities are replaced, added, eliminated and influenced by RFID technology applied in packaging. In general, RFID technology facilitates more frequent identification and verification activities than when bar code technology is used. The automated identification and verification activities enabled by RFID technology also increase the accuracy of identification and verification activities, which are otherwise exposed to human errors. The conceptual model also indicates that RFID technology in packaging would increase the efficiency and effectiveness of the retail supply chain by reducing labour and increasing the accuracy, co-ordination and speed of activities. One should bear in mind that potential benefits (see table 2-1) and costs of RFID technology in packaging vary depending on the packaging level being tagged (see figure 2-4 and its accompanying discussion). However, benefits to be obtained from using RFID technology in packaging goes further than just to activities and processes. Research claims that advanced Auto-ID technologies such as RFID, have the potential to improve supply chain visibility as well as to restructure supply chains (Fleisch & Tellkamp 2005; Kärkkäinen & Holmström 2002; Lumsden & Acharjee 2005; McFarlane & Sheffi 2003).

4.3.4 Technology and organisation interactions

The impact of technology upon the development of packaging and logistics has been profound (Grant et al. 2006; Jönson & Berglund 1995). Apart from being a major driver of packaging and logistics development, technology provides organisations with opportunities to increase operational efficiencies and effectiveness as well as competitive advantages. Today, sophisticated technology can even affect business strategy and organisation structure (Bowersox & Daugherty 1995). However, an organisation must be able to implement technology, in order to achieve these benefits. Individuals who "do logistics" play vital roles in that process. According to Kanter (1983), the individuals of an organisation are crucial for success, since it is individuals rather than the organisational system who come up with new ideas, push for change, identify opportunities and develop creative responses to problems. The individuals of an organisation cannot therefore be isolated and separated from the implications of technological developments. From a sociotechnical perspective, technology and individuals are components of an organisation. The ways technology and individuals fit together and interact to create a synergistic system are critical.

There are many organisational interactions which influence the process of implementing technology (Russell & Hoag 2004). Communication, co-ordination and co-operation are three organisational interaction dimensions which play a major role in implementing technology (Stock & Tatikonda 2000). Paper III sheds light upon some technological and organisational interactions which are involved in the process of implementing technology. These technological and organisational issues indicate that managing organisational interactions in technology implementations is as important to implementation success as ensuring technology integrity. This suggests that managers should view implementation as an organisational problem rather than one strictly of technology or economics. The technological and organisational interactions identified in papers II-III are discussed below according to Stock and Tatikonda's (2000) organisational interaction dimensions.

Communication

Communicating the need for, and importance of, implementing a technology contributes considerably to the outcome of the implementation. Communicating with the individuals of an organisation, especially with the individuals involved, ensures acceptance and awareness of the technology and its consequences. Senge (1990) suggests that the communication should be in the form of a dialogue where organisation members enrich their awareness of others' perspectives, instead of a discussion where the members argue for their own views. As shown in paper III, gaining organisational acceptance of RFID implementations is as important to implementation success as ensuring technology integrity. In Arla Foods' RFID implementation a problem was gaining acceptance from the dairy organisation, since in some situations the RFID application was seen by the dairy organisation as an unnecessary and time-consuming activity. This ruined the whole idea of the RFID implementation. The lack of acceptance was tackled by communicating with the staff involved about the need for, and importance of, the implementation.

Gaining organisational acceptance was also an important issue in the process of introducing the innovative unit load carrier. The introduction of the innovative unit load carrier required different material handling policies. For example, when the innovative unit load carrier is used unit loads need to be handled more gently than when a wooden pallet is used. It was then vital that all material handlers were aware that unit loads need to be handled with care. Communicating with the material handlers and making them aware of the need for, and importance of, the innovative unit load carrier and its consequences on material handling policies were parts of a critical and fraught process. However, their acceptance of the innovative unit load carrier and the different material handling policies was vital to the positive outcome of implementation.

Communicating the use of the technology to be implemented can also contribute to the outcome of implementation. In Arla Foods RFID implementation the communication of using RFID to track its roll containers made organisations aware that Arla Foods control the rotation of its roll containers. This awareness resulted in that rules and procedures concerning the control of roll containers were being followed by individuals in organisations. This in turn contributed to the elimination of roll container loss, which was the underlying reason for implementing RFID technology.

Co-ordination

The co-ordination of business processes and individuals with technology plays an important role in implementing technology. Co-ordination refers to the nature of the planned structure and the process of interactions and decision-making between organisations (Parkhe 1991). In order to introduce and implement technology, managers need to understand its implications on business processes and individuals. Individuals have often had to make way for financial and technological developments (Sundin 2001). Forgetting the role of individuals and being blinded by the potential technological and financial benefits may result in a struggling implementation process with limited benefits.

As suggested in paper III, RFID technology should be viewed as a support for, and a part of, business processes rather than the technology being seen strictly as the solution to a problem. RFID technology does not itself bring benefits; it is in the interaction with the business processes and individuals of an organisation that benefits are attained. In Arla Foods' RFID implementation, the business processes and individuals constituted a major reason for implementing RFID technology. The business processes necessitated tracking roll containers by identifying them at two locations. Scanning bar codes was regarded by some workers as laborious, resulting in a situation where Arla Foods chose to implement RFID technology.

Co-operation

Co-operation between organisations is an important issue in order to succeed in implementing technology. According to Schermerhorn Jr (1975), co-operation is ”*the presence of deliberate relations between otherwise autonomous organisations for the joint accomplishment of individual operating goals.*” As previously discussed in this chapter and indicated in appended papers I-III, the narrow functional mindset and power conditions prevailing in various organisations, influence and sometimes inhibit the implementation of technology. In implementing technology which influences various organisations differently, some organisations gain benefits while some might see increased costs, thereby rendering the implementation process more difficult and emphasising the importance of co-operation between organisations. In addition, organisations might have different agendas and priorities which also highlight the importance of co-operation between organisations when technology is being implemented.

4.4 The interconnections of packaging and logistics decisions

In order for packaging decision-makers to avoid sub-optimisations, they need to carefully consider the impact and trade-offs of packaging along supply chains. As discussed in paper I, logisticians often focus on the impact on logistics systems when making decisions while traditional packaging engineers often focus on the function of the packaging system. However, a majority of the hidden and indirect costs, value-adding attributes and profit improvement potentials are represented in the interaction between packaging systems and logistics systems. Hence, packaging and logistics decisions are interrelated and sometimes inseparable. However, paper I and II explicitly show that there are extensive interactions between packaging system and logistics systems, indicating a difficulty for decision-makers to consider interactions between packaging and logistics systems. To ensure congruence between the packaging and logistics systems throughout supply chain organisations, the inter-dependability and impact of packaging and logistics decisions are discussed below. Moreover, packaging trade-offs evident in the interactions between the packaging and logistics systems are also discussed.

4.4.1 The interdependability and impact of packaging and logistics decisions

To illustrate the interdependability and impact of packaging and logistics decisions in an comprehensible format a cause and affect model was presented in paper I (see figure 3-1). The core of the model is the physical interactions between packaging and logistics (see table 3-2) since they represent the connections between packaging and logistics decisions. The model enables packaging and logistics professionals to understand where and how packaging and logistics decisions can impact on packaging system and logistics system. Having gained the understanding of where and how logistics and packaging decisions impact on packaging systems and logistics systems, it is possible to take decisions such as changing the packaging system or the logistics system, or both, to improve supply chain performance. Any packaging decision must take into consideration the impact of the chosen packaging solution on the identified interface processes. Accordingly, efforts must also be made to adapt the operations in the interacting logistics processes to the packaging system used. Combined, these interrelated considerations can make it possible to achieve considerable performance improvements in both the packaging system and the logistics system.

To verify and demonstrate the applicability of the model, the impact of the packaging and logistic decisions made in the introduction of the innovative unit load carrier will be described. To illustrate the overall impact of packaging decisions, the model is further developed to incorporate the impact of marketing and environmental decisions.

The decisions made in the introduction of the innovative unit load carrier

The packaging decision to introduce the innovative unit load carrier had an extensive impact on the packaging system. A fundamental requirement when using the innovative load carrier is that the products and the packaging solutions have to form a self-supporting construction and function as bearing support for the unit load. However, using the load carrier places fewer restrictions on product development as less consideration is given to the dimensions of load carriers. Moreover, for products which are relatively small compared to their unit load dimensions, a supporting platform is needed when the innovative unit load carrier is used. As demonstrated by the table of interactions (table 3-2) tertiary packaging interacts with all the logistics processes identified, meaning that the decision to introduce the innovative unit load carrier affects all the logistics processes identified in the retail supply chain. However, warehouse and material-handling systems do not tolerate varying dimensions of unit loads which are enabled by the innovative unit load carrier, and adjusting the infrastructure throughout the supply chain to the load carrier was not possible. In order to handle innovative unit loads the logistic decision was taken to delimit the impact of the load carrier by strapping these units to wooden pallets at distribution centres. Doing so added an additional and time-consuming activity in the receiving processes at distribution centres. However to reduce the extra handling time, automated strapping equipment was introduced at distribution centres. Moreover, policy changes and investments in material-handling equipment were required in order to accommodate the innovative unit load carrier. From a logistics perspective, the major impact of packaging and logistics decisions was increased cube utilisation of transport units and reduced costs associated with return handling. Even though an additional and time-consuming activity was added at distribution centres the total impact of packaging and logistics decisions was improved supply chain performance. Figure 4-5 illustrates the decisions taken, and the consequences of introducing the innovative unit load carrier.

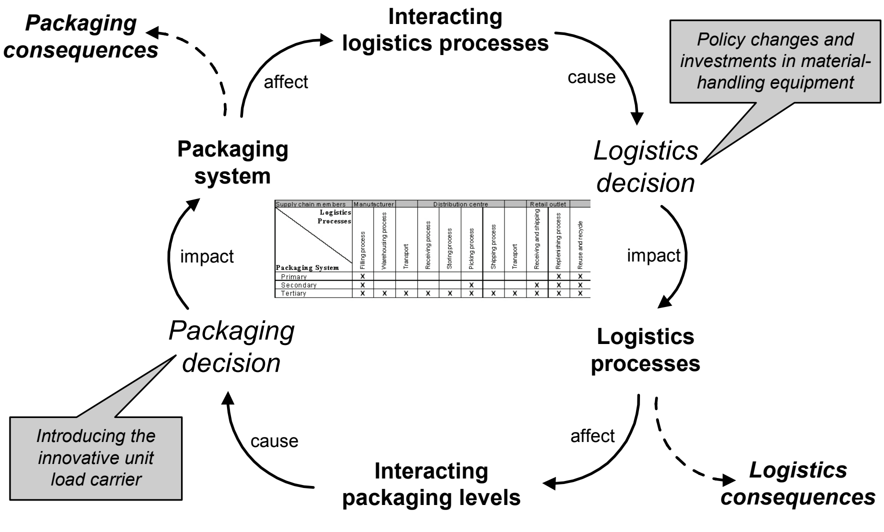

Figure 4-5. The interdependability of packaging and logistics decisions in the introduction of the innovative unit load carrier.

Overall impact of packaging decisions

A cause and affect model is proposed which offers an integrated approach to packaging, logistics, marketing and environmental decisions along the overall supply chain. The cause and affect model presented in paper I (see figure 3-1) shows the interdependability and impact of packaging and logistics decisions. However, in order to avoid supply chain sub-optimisations, packaging decision-makers also need to carefully consider the environmental and marketing impact of packaging along supply chains. Moreover, the model presented in paper I includes the packaging logistics activities at the manufacturers, distribution centres, retail outlets, as well as the reuse and recycle processes. Packaging decision-makers also have to fulfil end-consumer requirements, needs, expectations, perceptions, and provide end-consumers with convenience and value.

The proposed model (see figure 4-6) extends the limited packaging perspectives with a firm-based view to an overall supply chain view and illustrates an integrated approach to packaging, environmental, logistics and marketing decisions. In the model, the right-hand decision loop deals with logistics activities, while the left-hand decision loop deals with marketing activities. Similar to the model presented in paper I, the core of the right-hand decision loop constitutes the interactions between packaging and logistics activities, while the core of the left-hand decision loop constitutes the interactions between packaging and marketing activities.

Organisations categorise marketing and logistics decisions differently since there are decisions which affect both logistics and marketing (see Abrahamsson and Brege (2004), and Stock and Lambert (2001) for a detailed description and discussion of the interactions between marketing and logistics). In the suggested model, decisions involving logistics activities are categorised as logistics decisions, while decisions involving marketing activities are categorised as marketing decisions. Moreover, an environmental decision can be categorised as a packaging, a logistics or a marketing decision. Nonetheless, the essence of the model is for the viewer to understand the overall impact of a packaging-related decision. It thereby encourages a holistic packaging approach.

This research has not investigated all the interactions between packaging and logistics or the interactions between packaging and marketing. Therefore, to make full use of the suggested model further investigation and research are needed.

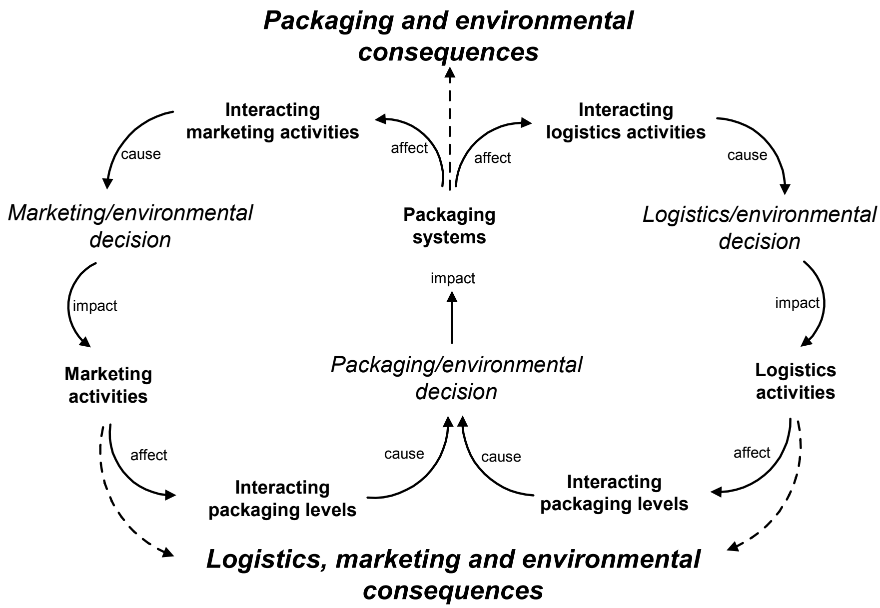

Figure 4-6. The interdependability between packaging decisions and environmental, logistics and marketing decisions.

4.4.2 Trade-off decisions

Logistics and packaging professionals need to carefully consider and be aware of the potential trade-offs among the different levels of the packaging system, and among the different functions affected by a packaging decision. The diversity of organisational needs and requirements on packaging results in potential trade-offs among the marketing, logistics and environmental functions of packaging (Bowersox & Closs 1996; Livingstone & Sparks 1994; Olsson & Györei 2002; Prendergast & Pitt 1996). Secondary packaging, for example, may need to fulfil efficiency requirements in picking and replenishment processes, as well as marketing requirements in retail outlets. Tackling packaging trade-offs is a fairly old management problem recognised by Wilson (1965). In logistics decision-making, packaging trade-offs have frequently been ignored or downplayed (Stock & Lambert 2001).

RFID technology as a packaging cost trade-off with logistics

Actions generating increased packaging costs can be motivated by improvement in logistics performance. Examples of such packaging cost trade-offs with logistics activities are described by Lambert, Stock and Ellram (1998 p. 334). Applying RFID tags to packaging increases the packaging costs, but has the potential to enhance logistics performance. Paper III illustrates that increasing packaging cost by applying RFID tags to returnable transport packaging can be motivated by improvements in managing and controlling the rotation of returnable transport packaging. These improvements e.g. less loss of items, less items in safety stock and in rotation in turn facilitates the introduction of more functional returnable transport packaging that was previously more liable to be stolen or to costly, thereby reinforcing the use of returnable transport packaging. Consequently, applying RFID tags to packaging system components can be considered as a packaging cost trade-off with logistics. Logistics and packaging professionals need to carefully consider and be aware of this trade-off situation in order to avoid sub-optimisations.

4.4.3 Standardised or differentiated technology?

In order to provide practitioners with a better basis for making decisions about packaging design and development, the trade-off between standardised and differentiated solutions is discussed from packaging and logistics points of view in paper II. Standardisation or differentiation of different levels of the packaging system could be a decision concerning graphic design, material, shape or size of a packaging component. Any of these decisions has some impact on the environment, logistics or marketing. However, the decision to provide a standardised or a differentiated packaging solution is a compromise between facilitating an integrated system or a flexible one, and between improving compatibility or performance of the packaging solution. These trade-offs are particularly evident in the case of introducing the innovative unit load carrier (see discussion in paper II). However, the same trade-offs are also evident in the choice of technology in Arla Foods' RFID implementation and in IKEA's RFID trial. The RFID trade-off decisions are discussed below, accompanied by a brief introduction of the characteristics of standardisation and differentiation trade-offs. Moreover, the packaging cost trade-off of applying RFID tags to packaging is discussed.

Compatibility versus performance

From a logistics point of view, standards are solutions for improving operational compatibility and facilitating co-ordination. Standardised packaging, such as the ISO container and the EUR pallet, makes it easier to develop efficient logistics systems because it demands similar handling and transport equipment and practices (Stock & Lambert 2001). However, Shapiro and Varian (1999) indicate that during the development of a standard, a trade-off between "compatibility" and "performance" often has to be made. An organisation can either choose to develop a new and better technology, in which users will have to change or replace existing equipment, or it can choose compatibility, i.e. a standard that fits the existing equipment, but which will probably not be the "best". Thus, in deciding standardised or differentiated packaging, it is not only the packaging system that is of interest, but also how it interacts with, and impacts on, logistics, marketing and the environment.

When IKEA selected an RFID system for its trial it required that the RFID system had to be based on EPC[7] standard. IKEA required this standard since it expects that EPC will probably become a global standard. Cost, functionality and performance are other important aspects which need to be considered when RFID technology is selected. For IKEA, however, standardisation was the primary aspect influencing its choice of RFID technology, while choosing the RFID technology with the very best performance, lowest cost or most functionality were secondary aspects. The reason for choosing a "standardised" technology is to assure compatibility. IKEA's vision concerning RFID technology is to apply tags to tertiary, secondary and primary packaging levels, i.e. to pallet, multi-packs and products sold in IKEA stores. In order to accomplish this, IKEA's internal organisations and supply chain partners need to use compatible RFID technologies (use the same frequencies, data structure etc). Another reason for assuring compatibility is that organisations will probably have different types of RFID applications. The compatibility of a "standardised" solution would enable organisations to have one fundamental infrastructure, i.e. one which contains readers, antennas and information systems.

[7] For more information about Electronic Product Code™ (EPC), see page 41 in the licentiate thesis or visit www.epcglobalinc.org.

In contrast to IKEA's choice of a "standardised" RFID technology, Arla Foods implemented the RFID technology with the "best" performance. At the time Arla Foods chose RFID technology, standard development was at its infancy. However, when choosing RFID technology Arla Foods did not take into account what RFID technology other retail organisations used at the time of its own implementation. For example, Svenska Retursystem, which runs a pool of plastic pallets for the Swedish food industry and retail trade, had equipped its pallets with tags operating on High Frequency (HF)[8] (Arla Foods implemented an RFID system operating on Low Frequency [LF][9]). The main reason for Arla Foods to choose the technology with the "best" performance was that the RFID application was only to be used by Arla Foods. Compatibility with other technologies and organisations was not an issue.

Integration versus flexibility

From a packaging trade-off perspective, Jahre and Hatteland (2004) point out that standardisation of packaging facilitates integrated systems, which in turn facilitates co-ordination of activities and more efficient processes, but also leads to less flexibility with regard to change, thus hindering further development and innovations. The inflexibility of standards emerges when standards with time becomes "locked in"(Arthur 1989; David & Greenstein 1990). The "lock-in" effect is evident when firms have numerous, heavy investments in a particular standard, leaving them little interest in abandoning it (Brunsson & Jacobsson 2002). However, the "lock-in" effect may not only be caused by the standard itself, but by the standard's interactions with other standards and resources (Fabbe-Costes, Jahre, & Rouquet 2006).

In IKEA's RFID trial, the decision to use a technology that might become a standard was not only based on achieving compatibility but also to achieve integrated systems. IKEA and its supply chain partners are currently using bar code technology and are in the process of further deploying bar code technology at organisations to improve co-ordination and supply chain efficiency. The same deployment strategy would be applied to RFID

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[8] High frequency RFID systems use the frequency 13.56 MHz as transmission frequency (Finkenzeller 2003).

[9] Low frequency RFID systems operate over a spectrum from 50 to 150 KHz (Chang 2000). Arla Foods RFID system operates on 125 KHz frequency.

technology. A drawback of achieving integrated systems is less flexibility to change the technology to a "better" one. However, the main dilemma for IKEA is that it wants to integrate its supply chain partners, but not to the extent where it does not have the option of changing partners. Implementing RFID solutions which will only be used by IKEA and its supply chain partners will reduce IKEA's flexibility to change partners. Integrating supply chain partners by using non-standardized and non-compatible systems such as Electronic Data Interchange (EDI)[10], bar codes or RFID, creates barriers for the supply chain partners' competitors. Thus, using standardised systems will lead to technology "lock-in", but will impede the "lock-in" effect of supply chain partners.

In Arla Foods' RFID implementation, the RFID technology with the "best" performance was chosen since compatibility of the technology, which facilitates integrated systems, was not considered important. Even though Arla Foods has invested in an RFID system operating on LF, while Ultra High Frequency (UHF)[11] has gained acceptance by the retail industry, Arla Foods does not regret its choice of RFID technology. According to Arla Foods, if there was any benefit or need, such as customers' wishes, to change RFID technology, this would be a relatively easy thing to do since Arla Foods' RFID system is not heavily integrated with various standards and resources. Arla Foods would like to integrate itself with its customers and regards RFID technology as a potential key technology in improving the process of information exchange in supply chains. In such application the performance of technology is inferior to the compatibility of the technology.

Implement or not?

Facilitating an integrated system, which leads to more efficient system or facilitating a flexible system, which allows the use of further development and innovations, are strategic decisions where time represents an important factor. Alderson (1951) states that "*The executive will not invest a large amount in equipment designed to make his plant the most efficient in his industry today if he knows that much more effective techniques will be available tomorrow*." It might

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[10] EDI is the electronic, computer-to-computer transfer of standard business documents between organisations (Lambert, Stock, & Ellram 1998, p.84).
[11] Ultra high frequency RFID systems operate over a spectrum from 868 to 956 MHz

be claimed that IKEA followed Alderson's statement since it did not deploy RFID technology, as more efficient technology, for IKEA's needs will probably be available within years to come. Alderson's statement cannot be applied to Arla Foods' decision to invest in RFID technology because the company did not have to invest a large amount in RFID equipment in order to make its system efficient. Even if RFID technology improves within the next few years, it will probably not improve the efficiency of Arla Foods' RFID application. Moreover, Arla Foods was in need of RFID technology and was not able to wait until "tomorrow".

5 RESEARCH PROCESS

The research process is to be seen as the path I have taken during my research. This chapter discusses the different choices I have made and how these choices have been made in the research process. This chapter also discusses my underlying assumptions and my attitude towards research since they both have direct implications on why different choices have been made.

5.1 Research assumptions

Like all people, researchers have explicit or implicit assumptions about the social world. These individual assumptions influence the way in which researchers investigate their subjects. Thus, it is relevant to discuss the assumptions and paradigms this research is related to. Based on the philosophy of science, Burrel and Morgan (1979) identify four sets of assumptions about the nature of science, i.e. ontological assumptions, epistemological assumptions, assumptions about human nature, and methodological assumptions. Each set of assumptions is contrasted with two extreme dimensions; the subjective and objective perspective. Ontology is concerned with the nature of "reality", where the question is whether reality is "out there" or is a product of one's mind? Epistemology is concerned with the nature of "knowledge" and poses the question: Can knowledge exist? Positivism argues that knowledge is "out there" waiting to be discovered while anti-positivism argues that knowledge is created in a subjective world. In the assumption of human nature, Burrel and Morgan (1979) make the distinction between determinism and voluntarism. Voluntarism argues that human actions are voluntary and free will exists, i.e. human free will is not subject to a predetermined path, whereas determinism argues that the human environment determine humans' actions, i.e. human free will follows a predetermined path.

Assumptions based on ontology, epistemology and human nature have direct implications on methodology. The objectivist prefers nomothetic methods which emphasise a quantitative research design, while the subjectivist prefers ideographic methods which emphasise a qualitative research design (Creswell 1994; Larsson 1993). Arbnor and Bjerke (1997) have categorised methodological assumptions into three research approaches; the analytical approach, the systems approach and the actor's approach. Each approach adheres to a continuum within the dimensions in Burrel and Morgan's set of assumptions in science. However, the research approach does not only depend on the researcher's perception of science, it also depends on the paradigm of the scientific community. As Kuhn (1996 p.26) states: "*Scientists work from models acquired through education and through subsequent exposure the literature often without quite knowing or needing to know what characteristics have given these models the status of community paradigm.*" According to Gummesson (2000) the subject of paradigms is often discussed in terms of an antithesis between two schools of philosophy; the positivistic and the hermeneutic school. The goal of the former is scientific explanation, whereas the goal of the latter is the grasping or understanding of phenomena (Denzin & Lincoln 1998). Figure 5-1 seeks to depict Arbnor and Bjerke's three research approaches and Gummesson's paradigm platforms within Burrel and Morgan's scheme of assumptions about the nature of science.

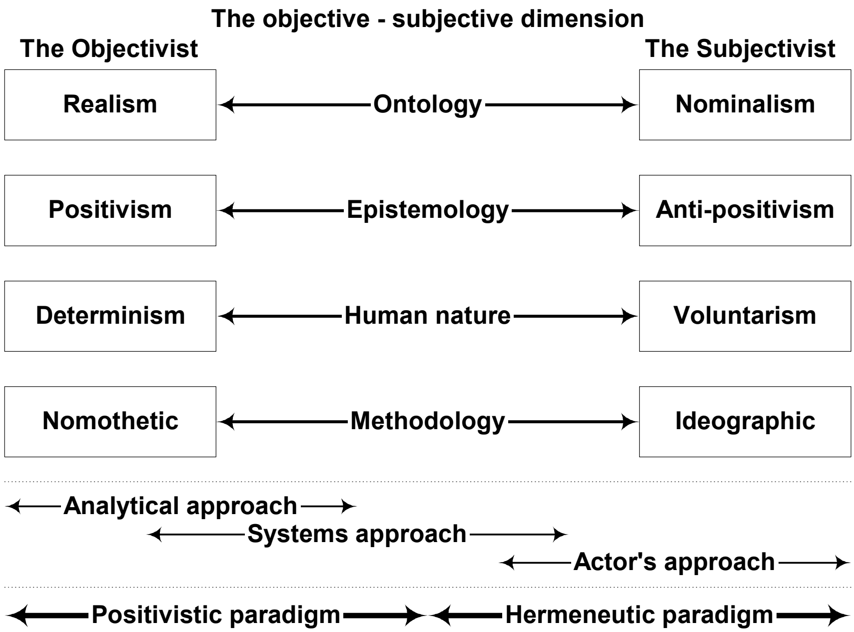

Figure 5-1. Paradigm, research approach and assumptions about the nature of science (modified from Arbnor & Bjerke 1997 p.61; Burrel & Morgan 1979 p.3).

Whilst there are researchers who adhere to each set of the extremes, my assumptions, like those of many other researchers, are pitched somewhere in the range between. Basically, I regard myself as a technician who acknowledges subjectivity. Knowledge and truth are created, not discovered by the human mind. We all have different opinions and levels of experience and interpret things differently. My "reality" and "truth" do not have to match yours. Even if I believe that there is no indisputable or absolute truth or reality, I have tried to be intentionally objective in my research. My engineering background and the positivistic paradigm dominating logistic research (Mentzer & Kahn 1995) are, I believe, the major reasons for this. By being intentionally objective I claim that my research relates to a specific group of people and to a specific context, where the majority interpret "reality" in more or less the same way. Within this group of people and this context knowledge could be seen as being created from a common understanding and "sense making". Even though I consider research to be about gaining understanding of phenomena within a context, I also acknowledge the importance of being able to explain. Based on the researcher's understanding of how and why phenomena occur, explanations might provide value for other researchers or practitioners in their search for, or creation of, knowledge.

Regarding human nature, I believe that people's actions are unconstrained in some situations and deterministic in other situations. Individuals have free will, but individual heredity and environment place boundaries on a person's actions. To a certain extent, one can control people's behaviour, but not completely. Although people have some common characteristics and behaviour, we are all unique. From my point of view a determinist argues that human actions, based on humans' environment, are rational. But we do not live in a rational world. Based on an individual's feelings, preference, mental state, background, power, culture etc decisions taken can be rational for some and irrational for others. However, for a specific group of people and context there might be such a thing as rational decisions.

From a technological point of view, determinism argues that technology causes change in society. The opposite viewpoint is voluntarism, which states that social factors shape a technology. At the beginning of this research I considered the interactions between people and technology to be more or less deterministic (see, for example, the parts of the licentiate thesis where the potential of using RFID technology in retail supply chains was explored).

However, during the research process the roles of people in shaping a technology have become more apparent (see for, example, the parts of paper III where the processes of implementing RFID technology were explored). I believe that in science it is sometimes necessary to view the interplay between people and technology as deterministic, even though it does not coincide with “reality”. However, in other situations it is central to view people and individuals as unique and unconstrained.

Regarding methodology, I agree with Jick (1979), Mangan, Lalwani, and Gardner (2004), and Tashakkori and Teddlie (1998) that quantitative and qualitative methods should be viewed as complementary rather than rival methods. The research approach and research design used are discussed below, shedding more light on my methodological assumptions.

5.1.1 Systems approach

In the introduction to this thesis I implicitly state that this research is based on the systems approach. The use of the systems approach to explore the interaction between packaging and logistics is not controversial or surprising. Thus, in logistics the systems approach is a critical concept (Grant et al. 2006). Moreover, the systems approach emphasises the central importance of interactions among logistics elements, e.g. packaging, in order to prevent reductionism. The systems approach overlaps the actor’s approach, which is the dominating approach in the hermeneutic paradigm, as well as the analytical approach, which is the dominating approach in the positivistic paradigm (Arbnor & Bjerke 1997). Due to this overlap some important systems approach issues need to be addressed for me to clarify my methodological standpoint.

Checkland (1999) describes two types of systems approaches; hard- and soft-systems thinking. The former focuses on the use of mathematical models and simulation while the latter focuses on solving problems in systems involving or interacting with people. In traditional hard-systems thinking (Churchman 1968; Von Bertalanffy 1969), the systems approach assumes that an objective reality exists where the researcher can distinguish the whole system. My way of thinking is more along the line of soft-system thinking where the “reality” is described in subjective terms and where the researcher *tries* to distinguish the whole system.

In the systems approach a distinction between closed and open systems is made. A closed system is considered self-contained and does not interact or have any relationships with its environment, while an open system interacts and has relationships with its surrounding environment. As the focus of this thesis is on the interactions between packaging and logistics systems, packaging and logistics systems are naturally considered as open systems. For packaging and logistics systems to be studied, the surrounding environment needs to be considered since it is always present and influences the packaging and logistics systems.

5.1.2 Scientific reasoning

Scientific reasoning is often divided into being inductive or deductive. Deductive research starts with existing theories and concepts, and formulates hypotheses which are subsequently tested, i.e. follow a direction from theory to facts (Alvesson & Sköldberg 1994; Chalmers 2002; Gummesson 2000). Inductive research follows the opposite path; it starts with empirical study, and categorises, concepts, patterns, models, and eventually, theories emerge from this input, i.e. follow a direction from facts to theory (Alvesson & Sköldberg 1994; Chalmers 2002; Gummesson 2000; Wallén 1996). Deductive reasoning is mostly used in testing existing theories, while creating new theory calls for a more inductive approach (Arlbjørn & Halldorsson 2002). The systems approach acknowledges both inductive and deductive reasoning. However, the positivistic paradigm favours deductive research while hermeneutic research favours inductive research.

In practice only the starting points for research separate deductive and inductive research (Gummesson 2000). After the initial stages, all type of research becomes a creative iteration between the deductive and inductive, which Dubois and Gadde (2002) call ”systematic combining”, and implies a learning loop between existing theory and empirical study. Going back and forth between empirical study and theory is often called abductive reasoning, which implies that empirical data is collected simultaneously as theory building (Kovács & Spens 2005). Abductive reasoning stems from the insight that most research is neither purely inductive nor purely deductive (Kirkeby 1994). However, I agree with Gummesson (2000), that the term abduction may be a useful to stress the combination of deduction and induction, but it is misleading if perceived as a third type of scientific reasoning.

The studies in the licentiate thesis and in the appended papers have been carried out using an inductive approach. The studies were not governed by explicitly stated theories or hypotheses. Each research study started with an empirical investigation where theoretical elements were gradually embedded in the study. Moreover, it was during the research process that my attention and research focus emerged. Gummesson (2000) stresses that in an inductive approach, researchers' attention is less focused and is allowed to float more widely. Even if it is crucial to decide which phenomenon to study at an early stage, Corbin and Strauss (1996) also stress that the focus might change after the data collection process has begun.

One could argue that an abductive reasoning may be a more adequate description of this explorative thesis as a whole. This thesis is composed of several studies which use inductive means to grasp and understand interactions between packaging and logistics. However, each study involving empirical and theoretical elements, contributed to my preunderstanding and experience. This indicates that I have been going back and forth between empirical study and theory during the research process. Nevertheless, as the research in all the papers started out with empirical study and then gradually involved literature and then related empirical findings to existing matching theories creating "local" theories and knowledge, I interpret my research approach and reasoning as inductive first and foremost.

5.1.3 Interdisciplinary and applied research

The reason for conducting research based on inductive reasoning is, to a certain extent, dependent on the nature of the research area. Logistics and packaging research are by nature interdisciplinary areas. Logistics research stems from many different scientific traditions (Arlbjørn & Halldorsson 2002; Solem 2003), primarily through the business disciplines of management and marketing, but also from engineering (Stock 1997). Packaging research involves technical properties and socio-economic aspects, and thus stems from the disciplines of engineering (e.g. mechanical engineering, chemistry, microbiology), marketing and economics (Coles & Beharrell 1990; Olsson 2006; Saghir 2004b). This interdisciplinary nature of logistics and packaging made it difficult to start with a particular existing theory and then formulate hypotheses. Starting with empirical studies and simultaneously conducting literature reviews to search for theories and disciplines which might fit within the empirical studies, eventually enabled me to describe and understand phenomenon of interest. Literature reviews were also conducted for me to understand the research field, recognise previous research findings and identify gaps in existing literature. Integrating theories (systems theory, diffusion of innovation, queuing theory (used in simulation), cost-benefit analysis are some theories used in this thesis) from other disciplines (besides packaging and logistics, disciplines such as supply chain management, operations management, technology management, organisation and production economics have been explored in this thesis) are neither simple nor straightforward. Interdisciplinary research requires extensive "set-up" time to gain adequate knowledge for the particular theories. However, it can provide additional and maybe even novel theoretical perspectives on the phenomenon of interest.

Conducting applied research within the science of packaging and logistics also contributed to the use of inductive reasoning. This thesis, like most studies in management, is concerned with understanding and improving the performance of business. We are then dealing with applied research, which is close to consultancy (Gummesson 2000). Applied research is composed of scientific investigations which are intended to solve practical problems (Rogers 2003). The research questions set out in the introduction chapter of this thesis are practical management problems. Having these questions as point of departure, I considered starting off with empirical studies a natural way to start.

5.2 Research journey

For me science is a journey with continuous generation and development of theories, models and concepts. Using a systems-oriented approach and inductive reasoning this research journey gradually resulted in a licentiate thesis and the four appended papers which finally ended up in this thesis. The focus of attention and the common denominator throughout the research has been to explore interactions between packaging and logistics. However, my research journey has, to a great extent, also been guided and influenced by my background in mechanical engineering and my personal interest areas such as technology, innovations and simulation. My personal research aim, which has been to learn and to create knowledge, has greatly influenced the research journey.

The route towards developing understanding of interactions between packaging and logistics has been a dynamic process. In scientific theory, the development of understanding is illustrated by the hermeneutic spiral (Alvesson & Sköldberg 1994). Gummesson (2000) describes the hermeneutic spiral as an iterative process whereby each stage of our research provides us with knowledge; in other words, we take a different level of preunderstanding to each stage of the research (see figure 5-2). Looking back at my research journey, it appears that the hermeneutic spiral aptly describes how I interpret my research journey. Each study conducted contributed to the growth of my preunderstanding, on which the subsequent study was based. This means that the direction of the research has been modified as new insights (generating new curiosity and preunderstanding) were gained in the evolvement of the exploration.

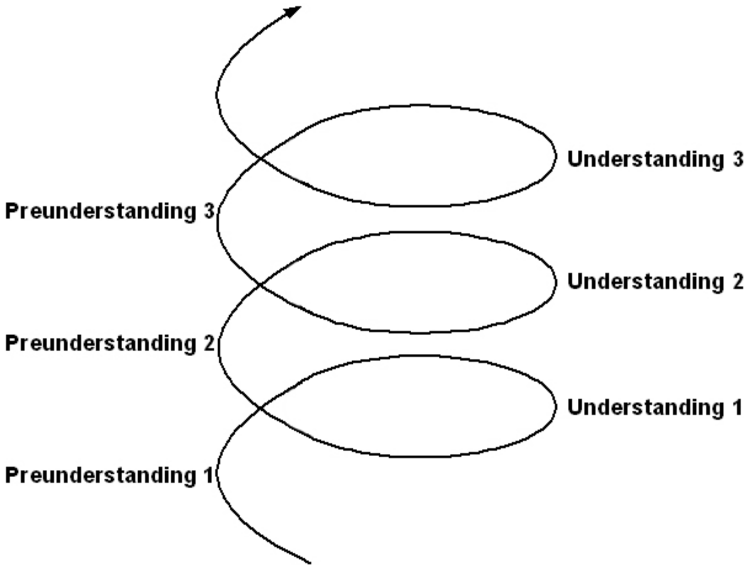

Figure 5-2. The hermeneutic spiral (adapted from Gummesson 2000).

5.2.1 Empirical paths

At the beginning of my research journey I set out with a passion to understand how the application of RFID technology to packaging could affect logistics activities in retail supply chains. However, in order to do this I needed to understand existing logistics activities related to packaging in retail supply chains. A case study was carried out where a Dutch retailer was investigated and triangulated with three case studies investigating Swedish retail supply chains. Moreover, a modelling and simulation study was carried out. These endeavours and findings are reported in the licentiate thesis and its appended papers. Based upon the experience of conducting these studies, paper IV was written together with Fredrik Nilsson, who had also experienced combining case study and simulation research (see Nilsson 2005 for complete details). The insights gained into logistics activities related to packaging and potential impacts of RFID technology, however, led me down two parallel empirical paths.

The first path originated from the insights gained in the triangulation process of the Dutch case study with three Swedish case studies. With the awareness of the fundamental role and the great impact of packaging on logistics, I fortuitously identified an interesting phenomenon, i.e. a large-scale implementation of an innovative unit load carrier. Thus, with the overall aim of exploring interactions between packaging and logistics systems, the consequences of introducing an innovative unit load carrier proved an interesting phenomenon to investigate. The case study research method was chosen, not only due to the novelty and uniqueness of the phenomenon, but also to obtain insights into how packaging and logistics systems interact (Eisenhardt 1989; Ellram 1996; Meredith 1998; Yin 2003). The findings of the case study are reported in appended paper II. Based on the improved insights and experience regarding interactions between packaging and logistics systems, the empirical data from the Dutch and the three Swedish case studies were reanalysed, reflected upon and reported in appended paper I. Even though appended paper I is based on the empirical data and framework presented in "Framework of packaging logistics activities in retail supply chains" (appended paper one in the licentiate thesis), they are two separate papers with different purposes, results and conclusions. My co-author, Mazen Saghir, and I contributed equally to "Framework of packaging logistics activities in retail supply chains" and appended paper I. However, in appended paper I, I was the author who stressed the need to focus on interactions between packaging and logistics.

The second path continued to explore the impact of RFID technology on packaging. In the licentiate thesis I tried to uncover the future impact of RFID on retail supply chains. However, the research community scepticism towards

RFID technology stressing that its practical benefits and cost of implementation are unclear, and that it is just a technological hype, made me redirect the research focus towards investigate RFID implementations. The licentiate thesis findings indicated that potential organisational barriers of implementing RFID on packaging have one exception, in returnable transport packaging systems. This meant that it was interesting to start by studying these kinds of RFID implementations in order to investigate the practical benefits and cost of implementation RFID technology in packaging. Subsequently, two case studies were conducted to study the use of RFID technology in managing and controlling returnable transport packaging. The case study research method was chosen, not only due to the novelty of using RFID technology in logistics, but also to obtain insight into how and why organisations implement and assess RFID technology (Eisenhardt 1989; Ellram 1996; Yin 2003). One case study focused on an RFID trial conducted by IKEA, while the other focused on an RFID implementation conducted by Arla Foods. Just as in the previous case studies, accessibility was an important aspect to consider when selecting these cases. The companies were very open and supportive and showed great interest in taking part in the study. The findings of these research studies are reported in appended paper III. In the Arla Foods case study an opportunity for future research presented itself, i.e. to conduct a simulation study to analyse the rotation of returnable transport packaging. This potential empirical path (see the future research discussion in chapter seven) is influenced by paper IV which presents the concept of combining case study and simulation. Conducting a simulation study based on the Arla Foods case study could further increase insights into the weaknesses and strengths of combining case study and simulation.

A potential weakness of conducting explorative and inductive research, in the same manner as I have done, is that when the researcher has analysed and reflected on the collected empirical data, she/he might identify an area, problem or phenomenon that would have been more interesting to investigate. This potential weakness was evident in the research process. For example, in paper II the consequences of introducing an innovative unit load were investigated. In addition to analysing the consequences I realised that it would be interesting to investigate the implementation process in more detail. So in paper III, the process of implementing RFID technology was investigated and the consequences of the technology were merely a secondary objective. When analysing the implementation process of RFID technology, I saw that organisational issues proved to be just as important as technological issues. This in turn has led me to be interested in investigating the role of organisations when implementing technology or introducing innovations (see the discussion about future research in chapter seven). However, this change of research attention is not entirely a weakness when conducting explorative and inductive research. It seems that its weakness is also its strength since it is this learning process which creates understanding and highlights new paths to be explored. It is also this learning process which makes the research process an endless journey. Figure 5-3 illustrates how empirical studies have generated and contributed to the research results.

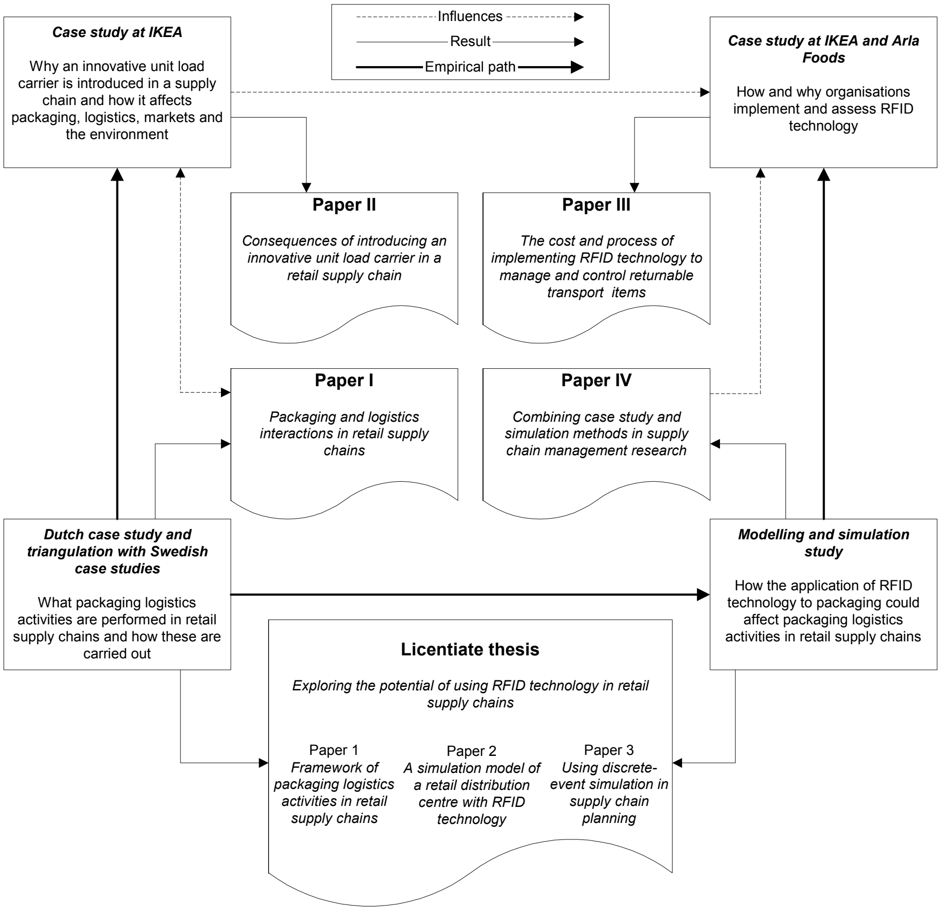

Figure 5-3. Outline of interconnections between the empirical studies.

Besides studies presented in figure 5-3, other small-scale studies have been carried out during the research process. For example, two studies, one at Volvo Car Body Components in Olofström and one at Scania in Södertälje, have been carried out where different concepts and designs of Auto-ID systems were developed to manage and control returnable transport packaging. The empirical data or the results from these studies are not presented in this thesis. However, the insights of these studies have contributed to the research by broadening the empirical context.

Some parts of this thesis are based on research carried out in a VINNOVA[12]-financed research project; E-log II. The purpose of this project was to describe, evaluate and explain how new, innovative logistics solutions can be developed through a more offensive use of information technology and the effects these new solutions have on profitability and sustainability. The project was performed in collaboration with the Institute of Technology at Linköping University and Chalmers University of Technology. The role of Lund University Faculty of Engineering was to have a packaging perspective, i.e. to establish how packaging systems can be designed as information and feature carriers to provide new logistics solutions and more efficient, effective transport. My participation in the E-log II project was a reason to why the empirical path towards investigating the consequences of the innovative unit load was pursued, which reinforced the research focus on interactions between packaging and logistics. The research conducted in appended papers II-IV represents deliverables to the E-log II project.

5.3 Research design discussion

The research design is the chain of logic which links the initial research questions to the empirical and theoretical data collected, to the analysis results and, ultimately, to the final research conclusions. As described in the research journey section, this research has been a dynamic and iterative process. Empirical and theoretical insights have been gained during the process, resulting in continuous changes to the research design first contemplated. The final research design resulted in three studies using the case study research method and one study combining the use of case study and simulation research. These methods are extensively discussed in the appended papers

[12] The Swedish Governmental Agency for Innovation Systems

along with descriptions of data collection and analysis procedures. However, scientific papers are restricted in the amount of words they may contain, forcing authors to sometimes limit data collection and analysis discussion. Consequently, some data collection issues and a qualitative data analysis discussion are provided as a complement below. Furthermore, a discussion concerning why I have not continued to combine case study and simulation in my research after my licentiate thesis is provided.

5.3.1 Why not continued to combine case study and simulation

Appended paper IV presents the concept of combining case study and simulation methods in research. Numerous possible benefits and strengths of combining case study and simulation are presented and discussed in the paper. However, in my post-licentiate research no combinations of the methods are carried out. The reasons for this were threefold. The first reason was that combing case study and simulation would not help me solve or clarify the purpose/problem addressed in papers II and III. Each method has its strengths and weaknesses and the issue is not that one method is better than the other. The choice of method depends on how well the chosen method helps the researcher solve or clarify her/his purpose or problem. Even so, an opportunity to combine the Arla Foods case study with a simulation study in order to analyse the rotation of returnable transport packaging presented itself in the research process. The reason for not pursuing this opportunity was the problem of time constraints. As discussed in paper IV, the need for additional resources is one weakness of combining case study and simulation. Thus, conducting a simulation study based on the Arla Foods case study was left as a future research activity (see the future research discussion in chapter seven). A third reason was that in my pursuit of further developing the concept of combining case study and simulation methods I not only have to combine the methods but I also need to conduct separate case studies and separate simulation studies to further learn *how* and *why* they could be combined.

5.3.2 Data collection issues

Yin (2003) argues that there are six important sources of data: documentation, interviews, archival records, direct observation, participant observation and physical artefact. Table 5-1 indicates that all these data sources have been used in this research. The table also indicates that interviews have been a data source in all studies. There are different types of interviews depending on the structure of the interview, i.e. open, open but focused, semi-structured, and structured interviews (Lantz 1993). The open interview can be characterised as a guided conversation, while the structured interview is in the form of a formal survey. In the Dutch case study open interviews were used, while in the other case studies semi-structured interviews were used. In the Arla Foods and IKEA case study semi-structured interviews were the primary sources of data (see appendix C for the interview guide used). Since it was "only" possible to conduct four interviews in this case study a complementary and further discussion about the conducted pilot interview is offered below. Moreover, the use of master's thesis students in collecting data is discussed.

Table 5-1. The sources of data used in the studies conducted.

	Dutch case study	Modelling and simulation study	IKEA case study	Arla Foods and IKEA case study
Documentation	X		X	X
Interviews	X	X	X	X
Archival records		X		X
Direct observation		X	X	X
Participant observation	X			
Physical artefact			X	

As a preparation for the interviews in the Arla Foods and IKEA case study a pilot interview was carried out. The pilot interview helped to refine and expand the questions in the interview guide. It also helped to structure the interview by grouping questions together; narrowing the interview focus within a group of question, while at the same time widening the whole interview focus. Conducting the pilot interview also indicated how much time was needed for an interview. The pilot interview was conducted with a respondent working at a supplier for the automotive industry. The supplier had conducted several RFID pilots and had plans to implement RFID technology. The respondent was selected due to his participation in the RFID pilots but also due to his interest in the study. Geographical convenience and accessibility were also factors in choosing a respondent for the pilot interview.

In the IKEA case study, where I investigate the consequences of introducing an innovative unit load, two master's thesis students were involved in collecting data (see Jonsson & Mathiasen 2004). For a period of four months these two students were used to gather data on site using semi-structured interviews, direct observation, internal documentation and a questionnaire. As supervisor I obtained a wealth of information about the company, how it perceives the issue of packaging and logistics, and most of all, how it has approached the issue of implementing the innovative unit load carrier. Reports were sent in and discussions were performed on a weekly basis. However, as described in paper II, the empirical data collected by the two master's thesis students was supplemented with follow-up interviews, observations and review of internal documentations.

Using master's thesis students to collect data in a case study is a win–win situation. The researcher saves time and the students are given high-quality supervision. With my preunderstanding and planning of the case study it is possible for the student to reduce the start-up time, thus enabling them to move further forward in their master's thesis. Using master's thesis students in research is not something new, see Knudsen (2003) and Nilsson (2005).

5.3.3 Qualitative data analysis

During the research process extensive amounts of qualitative data have been collected and analysed. Qualitative data are usually prepared for analysis by the raw experience and material (e.g., documents, notes, recordings, photos) being converted into partially processed data (e.g., transcripts), which are then coded and subjected to a analysis scheme (Huberman & Miles 1998). However, the qualitative data collected in the case studies have been analysed differently depending on case study aim and design. My practical understanding and experience of analysing narrative data have also contributed to the use of different analytical procedures.

In the Dutch case study, where packaging logistics activities were mapped and explored, the aim was merely to understand what was going on and how things were proceeding. The data were gradually processed and analysis was done as the data were collected. The data processing and analysis consisted of categorising data into the different activities, relationships and processes which formed the Dutch case description (see chapter 4 in my licentiate thesis). The Dutch case description was then compared and triangulated with three Swedish case studies (see Saghir 2002) resulting first in a narrative framework of packaging logistics activities in retail supply chains (see appended paper one in my licentiate thesis), and later in appended paper I.

In the IKEA single-case study, I used semi-structured interviews for the first time. These interviews were recorded and transcribed within days after the interview. The transcriptions were reviewed and commented on by the respondents. All data collected were categorised, in a manner similar to Strauss and Corbin's (1998) open coding, to identify the consequences of introducing the innovative unit load carrier and their properties. During the coding process, which involved breaking data down into different sets of information, sentence by sentence, sometimes word by word, I began to write paper II. With the notion of writing a partially descriptive paper I assumed that writing a case description would be redundant. However, as a scientific paper is limited to a certain amount of words some details and explanations had to be left out. Removing these details (e.g. background to the unit load carrier introduction) partially go against single-case study research, which according to Merriam (1994) and Stake (2000) is to gain a deep understanding of phenomena by providing a rich description based on a holistic view. Thus, I regret that I did not do a case description in this study.

In the Arla Foods and IKEA case study the raw material, mostly composed of interview recordings and documents, was coded in a manner similar to Strauss and Corbin's (1998) open and axial coding. The different events and steps in IKEA's RFID trial and Arla Foods implementation were categorised. The categorised events and steps, and their relationships, were then linked to form IKEA's trial and Arla Foods' implementation process, resulting in two case study descriptions; one for each case study (see appendix A and appendix B). This within-case analysis allowed the patterns of each case to emerge before patterns between the two cases were identified in the cross-case analysis. It was in the cross-case analysis that the proposed RFID implementation model was developed. The tactics for developing the model were noting patterns, themes and making comparisons and contrasts between the two cases.

5.4 Judging research quality

Yin (2003) presents four tests to assess the quality of case study research. The first test is c*onstruct validity;* the extent to which collected data are free from bias. The second test is *internal validity*; the degree to which findings correctly map the phenomenon in question. The third test is *external validity*; the degree to which findings can be generalised to other settings similar to the one in which the study was conducted. The fourth and last test is *reliability;* the extent to which findings can be replicated or reproduced by another researcher. In each test Yin describes different case study tactics, which are made up of activities during different phases of research, to make it more likely that valid and reliable results are produced (see table 5-2). During my research process, Yin's four tests have been used to ensure case study research quality. When collecting data, multiple sources of evidence have been used, converging the evidence into the same set of findings. Case study protocols and case study databases have also been used during data collection. Case study protocols and databases make it possible to establish a chain of evidence in the case studies. In the case studies key informants have reviewed the case study reports, i.e. case study descriptions. Moreover, in the data analysis raw material has been coded and categorised in order for patterns to be identified.

Table 5-2. Four tests for judging the quality of case study research (Yin 2003 p.34)

Tests	Case study tactic	Phase of research in which tactic occurs
Construct validity	Use multiple sources of evidence	Data collection
	Establish chain of evidence	Data collection
	Have key informants review draft case study report	Composition
Internal validity	Do pattern matching	Data analysis
	Do explanation building	Data analysis
	Address rival explanations	Data analysis
	Use logic models	Data analysis
External validity	Use theory in single-case studies	Research design
	Use replication logic in multiple-case studies	Research design
Reliability	Use case study protocol	Data collection
	Develop case study database	Data collection

However, how one judges research quality depends on one's own assumptions about the nature of science (Halldorsson & Aastrup 2003). Quality criteria defined from one perspective may not be appropriate for judging actions taken from another perspective. Yin's four tests are based on a positivistic belief that a single objective reality exists and that it should be studied using "objective" methods. Thus, my recognition of subjectivity does not fit very well with testing the validity and reliability of case study research. An alternative approach to assessing qualitative research is Lincoln and Guba's (1985) trustworthiness. This trustworthiness approach has four major components which correspond to the conventional view of research quality, i.e. internal validity, external validity, reliability and objectivity. They are respectively: credibility, transferability, dependability and conformability.

5.4.1 Credibility

Credibility is the most important component in establishing trustworthiness of results. Credibility addresses the match between the research subject's (e.g., respondent's) constructs and the researcher's representations and descriptions of these. Activities carried out in this research in order to increase the probability that credible findings are produced were triangulation, prolonged engagement and member checks. Triangulation of data sources (e.g. document, interview, and observation), methods (simulation and case study) and investigators (i.e. my co-authors) provided different perspectives on the same phenomena, thereby enhancing the credibility of the findings. The prolonged engagement in the Dutch case study, where I invested more than one month's on-site study to identify and map the activities related to the physical flow of packaging throughout a retail supply chain, provided a thorough understanding of the interaction between packaging and logistics systems. This prolonged engagement improved the probability that the findings and interpretations of the physical interactions between packaging and logistics are to be found credible.

Member checking is the most crucial activity for establishing credibility (Lincoln & Guba 1985), so this has been carried out continuously throughout the research process. Transcripts of interviews were audited by respondents to ensure no part was missing, taken out of context or misinterpreted. Changes were made if a respondent had any corrections or additional viewpoints. When collected data was condensed into case descriptions, key informants and respondents reviewed the descriptions to ensure they matched the view of the sources form which they came. This direct test of findings and interpretations improved the credibility of the research.

5.4.2 Transferability

Transferability concerns the ability of the findings to be applied more broadly and to additional empirical contexts. Lincoln and Guba (1985 p.297) describe transferability as "*the degree of similarity between sending and receiving contexts*". Thus, transferability is in the eyes of the beholder. Lincoln and Guba (1985) argue that the researcher can only provide a description of the time and context in which the findings are found to hold in order to enable someone interested in making a transfer. The research in paper I addresses the physical interactions between logistics and packaging related to ambient Fast-Moving Consumer Goods (FMCG)[13] in retail supply chains. The findings of this research are therefore directed at retailing companies within the ambient FMCG sector. However, the mapped and described interactions between packaging and logistics are quite universal, indicating that the findings must not be limited to this retail sector or industry. The same argument concerns the research findings in paper II, which identifies and describes the consequences of introducing an innovative unit load carrier throughout a supply chain. The findings are limited to the supply chain context studied, but, the knowledge acquired in the case study context, e.g. the need for, and potential of, a holistic packaging approach in order to evaluate the total impact of packaging on supply chains, is relevant to other contexts. The research in paper III suggests practical implementation guidelines in order to improve and accelerate the implementation of RFID technology applications in logistics systems. The focus of the paper is on two case studies where the cost and process of implementing RFID technology to manage and control the rotation of returnable transport packaging were investigated. Even though returnable transport packaging has increasingly been introduced in various industries the research findings are limited to the particular context of the case studies. The guidelines are not intended to be directly applied in other contexts involving other applications, technology and individuals. This does not mean, however, that knowledge acquired in the case studies contexts is of no relevance to other contexts.

5.4.3 Dependability

Dependability concerns the temporal stability of data (Erlandson, Skipper, & Harris 1993). The context in which qualitative research is conducted is constantly changing. Time is one aspect which will change both the context and the individuals (who are) in it. In other words, replicating a case study in order to achieve reliability is thus not only meaningless, but also impossible. However, dependability addresses the stability of data over time and is

[13] Ambient FMCG represent commodities such as crackers, chips, coffee, cereals, nappies, washing powder, shampoo, toilet paper, pet food, beer, soft drinks, water, ketchup and tinned food.

achieved by documenting the process of inquiry. Observed data instability does not have to be an error; it can be a result of a reality shift and better insights.

5.4.4 Conformability

Conformability addresses the ability of the findings to be confirmed through the data itself (Erlandson, Skipper, & Harris 1993). In other words, the integrity of the findings is to be traced back to the sources. The case studies produced a number of traceable data records to support conformability. Transcribed interviews, documents etc in case study databases make it possible to trace findings back to their origin.

6 CONTRIBUTIONS

The contributions of this research are separated into academic, management-related/industrial and methodological contributions. A majority of the contributions are to do with management since the research is applied. However, this does not mean that the academic and methodological contributions are of less significance.

6.1 Contributions to industry

A management-related contribution of this research is that of the detailed descriptions of packaging logistics activities (see figures 4 to 11 in appended paper I) which provide decision-makers with a comprehensive overview of the physical interactions between packaging systems and logistic systems in retail supply chains. The comprehensive overview of the interactions between packaging systems and the logistics systems can be used to bridge the gap between logisticians and packaging professionals by enabling them to engage in a dialogue, and understand where and how packaging decisions and logistics decisions can impact on the performance of packaging and logistics systems. This research also provides meaningful reference points for logisticians and packaging professionals, by describing and highlighting packaging logistics activities (see table 4-2) and interacting packaging aspects (see table 4-1). These reference points, along with the description of physical interactions between packaging and logistics (see table 3-2), can be used as a tool/model to extend the traditional and limited packaging perspective from a firm-based view to a supply chain level. They may also serve to identify where there are opportunities for packaging-related improvements and to encourage a packaging focus on logistics-related value addition.

A contribution of this research to industry is also the presented cause-and-affect model (see figures 3-1 and 4-6). The model encourages an integrated approach to packaging by showing the impacts of packaging and logistics decisions. The model can also support decision-makers in their integration efforts, i.e. facilitate bridging the gap between packaging and logistics professionals. An integrated approach to packaging and logistics requires an extension of the scope of the traditional logistician and packaging engineer. As might be expected, logisticians focus on the logistics system while packaging engineers focus on the packaging system. This often results in a mismatch in the interaction between the two systems, causing adverse effects on the total cost and performance. The cause-and-affect model may extends the scope of the traditional logistician and packaging engineer and enables them to understand how packaging and logistics decisions can impact on packaging and logistics systems. With such understanding, it is possible to take decisions such as changing the packaging system or the logistics system, or both, based on a holistic packaging perspective which enables increased overall supply chain efficiency. Understanding the impact of packaging and logistics decisions is also a prerequisite for managers to be able to systematically improve and develop packaging and logistics systems enabling them to enhance their own supply chain considerations.

In order for packaging decision-makers to avoid sub-optimisations, they need not only to carefully consider the impact, but also the trade-offs of packaging along supply chains. This research contributes to the understanding of potential trade-offs between standardised and differentiated packaging solutions, thereby providing practitioners with a better basis for making decisions on logistics and packaging design and development. The study investigating why an innovative unit load carrier is introduced throughout a supply chain and how the innovative unit load carrier affects packaging, logistics, marketing and the environment was used to elaborate on potential trade-offs between standardised and differentiated packaging solutions. In the same study, multiple consequences of introducing the innovative unit load carrier were identified, contributing to the notion that packaging should not be considered as a sub-system to logistics or marketing, but a strategically important area which contributes to the overall supply chain performance. As the study illustrates innovative practices it will hopefully trigger and contribute to new ideas and concepts among managers, promoting packaging and logistics innovations and technological developments.

A contribution to industry is also the description of how packaging logistics activities can be affected when RFID technology is applied to packaging. RFID technology in packaging is gaining acceptance throughout the retail industry and to be able to introduce the technology, practitioners need to understanding its impact on retail supply chains. A conceptual model and a simulation model are developed to explore the impact of RFID. The models provide insights into how logistics activities can be affected by RFID technology and illustrate potential benefits of introducing the technology in packaging throughout retail supply chains.

A final contribution to industry is the general understanding of the cost and the process of implementing RFID technology to track returnable transport packaging. This research provides insights into some technological and organisational issues which are involved in the process of implementing RFID. These technological and organisational issues indicate that managing organisational interactions in RFID implementations is as important to implementation success as ensuring technology integrity. A model of implementing RFID technology is suggested where different implementation stages and practical steps are presented (see table 3-3). Based on the different implementation stages suggested in the model, implications for management are identified to guide managers in the process of implementing RFID technology. This research also provides some general reflections on implementation costs and presents cost-benefit analyses (see tables in appended paper III) which may help managers to understand the cost of implementing RFID technology to track returnable transport packaging. Moreover, this research highlights significant savings and benefits, as well as the potential benefits and risks of implementing RFID to track returnable transport packaging.

6.2 Contributions to academia

The main academic contribution of this research is to the field of packaging logistics. This research builds on previous packaging logistics research by providing a comprehensive overview of the physical interactions between packaging systems and logistics systems in retail supply chains. The influence of the packaging system on logistics is often implicitly and fragmentally recognised, but seldom directly shown and discussed in a comprehensive way. From a systems-oriented perspective this research emphasises the importance of considering the interactions between packaging and logistics in order for the "whole" system to be understood. This is instead of dividing packaging and logistics into separate systems which are analysed on their own, and assuming that the "whole" is the sum of the systems. Thus, this research implies that understanding interactions between packaging and logistic systems is an elementary step towards understanding the role of packaging in logistics and the role of logistics in packaging. This in turn implies that recognising interactions between packaging and logistic is not only central to the concept of packaging logistics but also central to the logistics and the packaging discipline.

This research also serves as a fundamental step towards adopting a holistic packaging approach. It implies that understanding packaging interactions makes it possible to make decisions such as changing the packaging system or logistics system, or both, based on a holistic packaging approach. The research illustrates adoption barriers and potentials of a holistic packaging approach and is an aid in showing how packaging-related decisions might impact on supply chains. The research explicitly shows that there are extensive physical interactions between packaging systems and logistics systems. However, as interactions and the nature of packaging change via innovations and technology, case studies on implications of RFID technology on packaging and on implications of introduction an innovative unit load carrier provide insights into how these technological developments impact on packaging systems, logistics systems and on the interactions between the two.

A contribution to the field of packaging logistics is also represented by the empirical data and the various conceptual models, tools and framework proposed in this thesis. For example, the framework developed in this research provides an overall description of packaging logistics activities in the retail supply chain and can be used as a platform from which to communicate and discuss packaging logistics issues. The purposed conceptual models, tools and framework add to and shed some new light on the concept of packaging logistics by addressing physical interactions between packaging system logistic systems in retail supply chains and the impact of technological developments on these systems and interactions. A contribution to academia is also represented by the purposed further research areas and investigations to be pursued by both academic researchers and practitioners.

6.3 Methodological contribution

A methodological contribution of this thesis is the further development of research practices by presenting and discussing the concept of combining case study and simulation methods. This research shows that combining case study and simulation methods into a multi-method study allows the researcher to gain synergies, harmonise the weaknesses and assess the relative strengths of each individual method. For example, combining the methods enables the researcher to identify and measure relevant characteristics of the system studied and at the same time be able to gain greater insights into the behaviour and performance of the system than if a single method had been employed. This facilitates handling of complexity in real-life settings and strengthens the theorising process by enabling the research to generate a theory, test it, further develop it, and experiment with it. Moreover, adopting two methodological perspectives may provide an extended view of a phenomenon, for example, incorporating soft aspects such as individual subjective interpretations and understanding, and hard aspects which are measured or quantified. Thus, combining case study and simulation enables researchers to go beyond the methodological limitations researchers place on themselves by strictly adhering to only doing case or simulation research. Even though, to some extent, there are paradigmatic differences between case study and simulation, this research shows that the methods can be successfully combined. A model of combining the methods is provided in this research, providing guidance and insights into the process of combining the methods (see figure 3-2).

7 FURTHER RESEARCH AREAS

Even if this thesis has explored interactions between packaging and logistics systems, thereby contributing to packaging and logistics research and practice, there are several areas within the integral field of packaging and logistics which would be interesting to explore further. First it must be stated that this research provides by no means a complete description of all packaging and logistics interactions. This research has primarily focused on the physical interactions between packaging systems and logistics systems in retail supply chains contexts and should therefore be complemented with investigations of other interactions and other supply chains contexts. Conducting additional case studies will lead to increased insights into interactions between packaging and logistics and will improve our understanding of the relations between packaging system and logistics activities. Additional case studies would also shed more light on inefficient activities along the retail supply chain, providing opportunities for tangible improvements. Packaging systems physically interact with end-consumers as well as with logistics. Accordingly, the physical interaction between packaging system and end-consumers is an area for further research. Making packaging decisions based on all the packaging system interactions is a prerequisite in a holistic packaging approach, where the multiple functions of packaging are carefully considered to avoid negative trade-offs.

Second, research is needed on how a person or people could manage the packaging system and its interactions across multiple firms. How could these people be organised within the firm and supply chain? It is generally recognised that a packaging department will interact with many areas of the firm in the course of its activities (McGinnis & Hollon 1978). Furthermore, it is common that people in the organisation take responsibility for parts of the packaging system. My research stresses that packaging and logistics decisions are interrelated and sometimes inseparable. Thus, there is a need for firms and supply chains to manage the packaging and logistics systems and the interactions between the two, rather than managing the packaging and logistics systems separately. Moreover, there is a need to define new roles needed in organisations for managing packaging systems and their interactions. This research provides a basis from which to perform research in this area since managers and decision-makers need to be familiar with how packaging and logistics systems interact. Inspired by Nilsson (2006), an interesting future study would be to explore packaging management in practice; what do packaging managers perceive as being difficult and challenging; how do they handle problems, uncertainties and trends in their everyday work? This may increase our understanding of packaging decision processes potentially related to supply chain performance.

A third area in need of further research is the strategic impact of packaging on supply chains. Packaging strategies are needed to ensure that packaging decisions support the overall goals of an organisation and its supply chain. In addition to being an important cost driver/reducer, packaging must also be considered as a tool for achieving competitive advantage and a source of profit. The contribution of the packaging system (and its interactions) to satisfying needs and adding value to supply chain members, as well as end-consumers, is a key factor in gaining competitive advantage, profit and overall supply chain efficiency and effectiveness. Thus, different packaging strategies need to be identified. This research has provided insights into the packaging trade-offs between standardisation and differentiation. However, more in-depth studies are needed in order for packaging, logistics and supply chain mangers to understand the strategic impact of packaging solutions on supply chains.

Fourth, there is a need for more research covering the adoption and impact of advanced Auto-ID technology (especially RFID) in logistics, and supply chain management. Potential adoption benefits and barriers, such as technology immaturity and performance, privacy issues, costs and organisational issues need to be investigated. This research has used a case study approach to shed light upon these problems and provides insight into how and why organisations implement and assess RFID technology. However, the case study research only deals with how RFID was used to manage and control returnable transport packaging, so that there is a great need for research covering other applications. Moreover, the case study research proposed an RFID implementation model which needs to be tested, and this is also an opportunity for further research. A suggestion for future research is to use diffusion or technology transfer theories. Applying these theories to RFID adoption in organisations can provide valuable insights into RFID implementations decisions. Furthermore, an interesting supply chain management concept to use in future studies covering RFID technology implementations and deployments is “risk and gain sharing” (see Norrman

2006 for a detailed discussion of the concept). How are risks and gains from RFID technology shared among supply chain organisations? How do the mindset and power conditions among supply chain organisations influence the applications of RFID technology? Another suggestion for further research is to explore how advanced Auto-ID technology can drive business process reorganisation towards concepts such as supply chain visibility (see Småros et al. 2003), sense and respond (see Bradley & Nolan 1998), real world awareness (see Heinrich 2005) and adaptive logistics (see Nilsson 2005).

Finally, the concept of combining case study and simulation research is an area which needs to be further developed. This research shows that combining the methods allows the researcher to harmonise the weaknesses of the methods and assess their relative strengths. Nevertheless, research within the discipline of supply chain management and logistics can be enriched through the application of this combination of research methods. A suggestion for further research is to develop a procedure to combine case study and simulation. A systematic procedure is needed and is a further step in the development of combining case study and simulation. My approach to further develop the concept of combining case study and simulation research is to gain more insights and experience in conducting both case and simulation studies. More experience of using the methods in single settings, facilitates greater understanding of the relative weaknesses and strengths of the various methods. Obviously, combining the methods in practise is also an opportunity to gain insights into and experience of combining the methods. In future research I plan to extend the already conducted Arla Foods case study and combine it with an empirical simulation study, using Johansson's (2006) hybrid simulation approach, to analyse the rotation of returnable transport packaging. This will not only contribute to the further development of combining case study and simulation but will also demonstrate how data collected from advanced Auto-ID systems can be used in daily operations to improve supply chain performance.

References

Abrahamsson, M. & Brege, S. 2004, "Dynamic Effectiveness: Improved Industrial Distribution from Interaction Between Marketing and Logistics Strategies", *Journal of Marketing Channels*, vol. 12, no. 2, pp. 83-112.

Agarwal, V. 2001, *Assessing the benefits of Auto-ID Technology in the Consumer Goods Industry*, Auto-ID Center, Massachusetts Institute of Technology.

Alderson, W. 1951, "A Systematics for Problems of Action", *Philosophy of Science*, vol. 18, no. 1, pp. 16-25.

Alexander, K., Gilliam, T., Gramling, K., Kindy, M., Moogimane, D., Schultz, M., & Woods, M. 2002, *Focus on the Supply Chain: Applying Auto-ID within the Distribution Center*, Auto-ID Center, Massachusetts Institute of Technology.

Alvesson, M. & Sköldberg, K. 1994, *Tolkning och reflektion - Vetenskapsfilosofi och kvalitativ metod*, First Edn, Studentlitteratur, Lund.

Arbnor, I. & Bjerke, B. 1997, *Methodology for Creating Business Knowledge*, Second Edn, Sage Publications, Thousand Oaks CA.

Arlbjørn, J. S. & Halldorsson, A. 2002, "Logistics knowledge creation: reflections on content, context and processes", *International Journal of Physical Distribution & Logistics Management*, vol. 32, no. 1, pp. 22-40.

Arthur, W. B. 1989, "Competing Technologies, Increasing Returns, and Lock-In by Historical Events", *The Economic Journal*, vol. 99, no. 394, pp. 116-131.

Ballou, R. H. 2004, *Business Logistics/Supply Chain Management: Planning, Organizing, and Controlling the Supply Chain*, Fifth Edn, Pearson Prentice Hall, New Jersey.

Bjärnemo, R., Jönson, G., & Johnsson, M. 2000, "Packaging Logistics in Product Development", Proc. International Conference on Computer Integrated Manufacturing (ICCIM), Singapore, pp. 135-146, 28-30 March 2000.

Bowersox, D. J. & Closs, D. J. 1996, *Logistical Management, The integrated supply chain process*, International Edn, McGraw-Hill, New York.

Bowersox, D. J., Closs, D. J., & Cooper, M. B. 2002, *Supply Chain Logistics Management*, First International Edn, McGraw - Hill / Irwin, New York.

Bowersox, D. J. & Daugherty, P. J. 1995, "Logistics Paradigms: The Impact of Information Technology", *Journal of Business Logistics*, vol. 16, no. 1, pp. 65-80.

Bradley, S. P. & Nolan, R. L. 1998, *Sense & Respond: Capturing Value in the Network Era*, First Edn, Harvard Business School Press, Boston, Massachusetts.

Bramklev, C. 2004, *Concurrent Development of Product and Packaging - Towards an Integrated Development Procedure*, Licentiate thesis, Department of Design Sciences, Division of Packaging Logistics, Lund University, Sweden.

Brunsson, N. & Jacobsson, B. 2002, *A World of Standards*, First Edn, Oxford University Press, Oxford.

Burrel, G. & Morgan, G. 1979, *Sociological Paradigms and Organizational Analysis; Elements of the Sociology of Corporate Life*, First Edn, Heinemann Educational Books, London.

Chalmers, A. F. 2002, *What is this thing called Science?*, Third Edn, Open University Press, Buckingham.

Chang, K. 2000, *RF and Microwave Wireless Systems,* John Wiley & sons – Interscience.

Chappell, G., Durdan, D., Gilbert, G., Ginsburg, L., Smith, J., & Tobolski, J. 2003, *Auto-ID on Delivery: The Value of Auto-ID Technology in the Retail Supply Chain*, Auto-ID Center, Massachusetts Institute of Technology.

Checkland, P. 1999, *Systems Thinking, Systems Practice - includes a 30-year retrospective*, John Wiley & Sons, Chichester.

Christopher, M. 1998, *Logistics and Supply Chain Management*, Second Edn, Financial Times, Prentice Hall, London.

Churchman, C. W. 1968, *The systems Approach*, Dell Publishing, New York.

Coles, R. C. & Beharrell, B. 1990, "Packaging Innovation in the Food Industry", *British Food Journal*, vol. 92, no. 9, pp. 21-31.

Cooper, R. B. & Zmud, R. W. 1990, "Information Technology Implementation Research: A Technological Diffusion Approach", *Management Science*, vol. 36, no. 2, pp. 123-139.

Corbin, J. & Strauss, A. 1996, "Analytic ordering for theoretical purposes", *Qualitative Inquiry*, vol. 2, no. 2, pp. 139-151.

Coyle, J. J., Bardi, E. J., & Langley, C. J. Jr. 2003, *The Management of Business Logistics: A Supply Chain Perspective*, Seventh Edn, South-Western, Ohio.

Creswell, J. W. 1994, *Research Design - Qualitative & Quantitative Approaches*, First Edn, Sage Publications, Thousand Oaks CA.

David, P. A. & Greenstein, S. 1990, "The economics of compatibility standards: An introduction to recent research", *Economics of Innovation and New Technology*, vol. 1, no. 1, pp. 3-41.

Denzin, N. K. & Lincoln, Y. S. 1998, *The Landscape of Qualitative Research: Theories and Issues*, Sage Publications, London.

Dicken, P. 1998, *Global shift - transforming the world economy*, Third Edn, Paul Chapman Publishing, London.

Dominic, C., Johansson, K., Lorentzon, A., Olsmats, C., Tiliander, L., & Weström, P. 2000, *Förpackningslogistik*, Second Edn, Packforsk, Kista.

Dubois, A. & Gadde, L.-E. 2002, "Systematic combining: an abductive approach to case research", *Journal of Business Research*, vol. 55, no. 7, pp. 553-560.

DULOG 1997, *Handling Costs in The Swedish Grocery Retail Industry*, Dagligvaruhandlarnas Utvecklings och Logistikgrupp (DULOG), Stockholm.

Ebeling, C. W. 1990, *Integrated packaging systems for transportation and distribution*, Marcel Dekker, New York.

Eisenhardt, K. M. 1989, "Building Theories from Case Study Research", *Academy of Management Review*, vol. 14, no. 4, pp. 532-550.

Ellram, L. M. 1996, "The use of case study method in logistics research", *Journal of Business Logistics*, vol. 17, no. 2, pp. 93-138.

Erlandson, D. A., Skipper, B. L., & Harris, E. L. 1993, *Doing Naturalistic Inquiry: A Guide to Methods*, Sage Publications, Newbury Park.

Esse, R. L. 1989, "Package Development, Manufacturing, and Distribution Strategy Considerations," in *Packaging strategy - meeting the challange of changing times*, A. W. Harckham, ed., Technomic Publishing AG, Lancaster, Pennsylvania, pp. 107-116.

Fabbe-Costes, N., Jahre, M., & Rouquet, A. 2006, "Interacting standards: a basic element in logistics networks", *International Journal of Physical Distribution & Logistics Management*, vol. 36, no. 2, pp. 93-111.

Finkenzeller, K. 2003, *RFID Handbook: Fundamentals and Applications in Contactless Smart Cards and Identification*, Second Edn, John Wiley & Sons, Chichester.

Fleisch, E. & Tellkamp, C. 2005, "Inventory inaccuracy and supply chain performance: a simulation study of a retail supply chain", *International Journal of Production Economics* no. 95, pp. 373-385.

Gammelgaard, B. 1997, "The Systems Approach in Logistics", Proc. 8th NOFOMA Conference, pp. 9-20, June 1996, Institute for Logistics and Transport, Copenhagen Business School.

Gammelgaard, B. 2004, "Schools in logistics research? A methodological framework for analysis of the discipline", *International Journal of Physical Distribution & Logistics Management*, vol. 34, no. 6, pp. 479-491.

Grant, D. B., Lambert, D. M., Stock, J. R., & Ellram, L. M. 2006, *Fundamentals of logistics management*, European Edn McGraw-Hill Education, London.

Griffin, R. C. Jr., Sacharow, S., & Brody, A. L. 1985, *Principles of Package Development*, Second Edn, Van Nostrand Reinhold Company, New York, USA.

Gummesson, E. 2000, *Qualitative Methods in Management Research*, Second Edn, Sage Publications, Thousand Oaks CA.

Halldorsson, A. & Aastrup, J. 2003, "Quality criteria for qualitative inquiries in logistics", *European Journal of Operational Research*, vol. 144, no. 2, pp. 321-332.

Heinrich, C. 2005, *RFID and Beyond: Growing your business through real world awareness*, Wiley Publishing, Indianapolis, Indiana.

Henriksson, L. 1998, *Packaging requirements in the Swedish retail trade, Licentiate*, The Lund Institute of Technology, Department of Engineering Logistics, Lund University.

Huberman, A. M. & Miles, M. B. 1998, "Data Management and Analysis Methods," in *Collecting and Interpreting Qualitative Materials*, N. K. Denzin & Y. S. Lincoln, eds., Sage Publications, London, pp. 179-210.

Jacka, J. M. & Keller, P. J. 2002, *Business Process Mapping - Improving customer satisfaction*, John Wiley & Sons, New York.

Jahre, M. & Hatteland, C. J. 2004, "Packages and physical distribution: Implications for integration and standardisation", *International Journal of Physical Distribution & Logistics Management*, vol. 34, no. 2, pp. 123-139.

Jick, T. D. 1979, "Mixing Qualitative and Quantitative Methods: Triangulation in Action", *Administrative Science Quarterly*, vol. 24, no. December, pp. 602-611.

Johansson, K., Lorentzon, A., Olsmats, C., & Tiliander, L. 1996, *Förpackningslogistik*, First Edn, Packforsk, Kista.

Johansson, O. 2006, *Towards a model for managing uncertainty in logistics operations - A simulation modeling perspective*, Licentiate in Engineering, Division of Packaging Logistics, Lund University, Lund.

Johnsson, M. 1998, *Packaging Logistics - a value added approach*, Doctoral thesis, Department of Engineering Logistics, Lund Institute of Technology, Lund University, Lund, Sweden.

Jones, P., Clark-Hill, C., Shears, P., Comfort, D., & Hillier, D. 2004, "Radio frequency identification in the UK: opportunities and challenges", *International Journal of Retail & Distribution Management*, vol. 32, no. 3, pp. 164-171.

Jönson, G. 2000, *Packaging Technology for the Logistician*, Second Edn, Department of Design Sciences, Division of Packaging Logistics, Lund University, Lund.

Jönson, G. 2001, *Packaging Development - Update 2001*, Department of Design Sciences, Division of Packaging Logistics, Lund University, Lund.

Jönson, G. & Berglund, A. 1995, *Packaging Development*, Department of Engineering Logistics, Lund University, Lund.

Jonsson, A. & Mathiasen, B. 2004, *Consequences of the loading ledge implementation*, Master Thesis, Department of Design Sciences, Division of Packaging Logistics, Lund University, Lund, Sweden.

Kambil, A. & Brooks, J. 2002, *Auto-ID Across the Value Chain: From Dramatic Potential to Greater Efficiency and Profit*, Auto-ID Center, Massachusetts Institute of Technology.

Kanter, R. M. 1983, *The Change Masters – Innovation and Entrepreneurship in the American Corporation*, Simon & Schuster, New York.

Kärkkäinen, M. 2003, "Increasing efficiency in the supply chain for short shelf life goods using RFID tagging", *International Journal of Retail & Distribution Management*, vol. 31, no. 10, pp. 529-536.

Kärkkäinen, M. & Holmström, J. 2002, "Wireless product identification: enabler for handling efficiency, customisation and information sharing", *Supply Chain Management: An International Journal*, vol. 7, no. 4, pp. 242-253.

Kirkeby, O. F. 1994, "Abduktion," in *Vetenskapsteori och metodlära - Introduktion*, Heine Andersen, ed., Studentlitteratur, Lund, pp. 143-180.

Klevås, J. 2005a, *On opportunities of integrating packaging, logistics and product development - Experiences from a case study at IKEA*, Licentiate thesis, Department of Design Sciences, Division of Packaging Logistics, Lund University, Sweden.

Klevås, J. 2005b, "Organization of packaging resources at a product-developing company", *International Journal of Physical Distribution & Logistics Management*, vol. 35, no. 2, pp. 116-131.

Knudsen, D. 2003, *Improving Procurement Performance with E-business Mechanisms*, Doctoral thesis, Department of Industrial Management and Logistics, Lund Institute of Technology, Lund University, Lund.

Koehorst, H., De Vries, H., & Wubben, E. 1999, "Standardisation of crates: lessons from the Versfust (Freshcrate) project", *Supply Chain Management: An International Journal*, vol. 4, no. 2, pp. 95-101.

Kovács, G. & Spens, K. M. 2005, "Abductive reasoning in logistics research", *International Journal of Physical Distribution & Logistics Management*, vol. 35, no. 2, pp. 132-144.

Kuhn, T. S. 1996, *The Scientific Revolution*, Third Edn, The University of Chicago Press, Chicago.

Lambert, D. M., Stock, J. R., & Ellram, L. M. 1998, *Fundamentals of Logistics Management*, International Edn, McGraw-Hill Higher Education, London.

Lambert, D. M., Cooper, M. C., & Pagh, J. D. 1998, "Supply Chain Management: Implementation Issues and Research Opportunities", *The International Journal of Logistics Management*, vol. 9, no. 2, pp. 1-18.

Lantz, A. 1993, *Intervjumetodik*, Studentlitteratur, Lund.

Larsson, E. & Ljungberg, A. 2006, "Process Orientation," in *Handbook of Global Supply Chain Management*, J. T. Mentzer, M. B. Meyer, & T. B. Stank, eds., Sage Publications, London.

Larsson, R. 1993, "Case Survey Methodology: Quantitative Analysis of Patterns across Case Studies", *Academy of Management Journal*, vol. 36, no. 6, pp. 1515-1546.

Lincoln, Y. S. & Guba, E. G. 1985, *Naturalistic inquiry*, Sage Publications, Beverly Hills CA.

Livingstone, S. & Sparks, L. 1994, "The New German Packaging Laws: Effects on Firms Exporting to Germany", *International Journal of Physical Distribution & Logistics Management*, vol. 24, no. 7, pp. 15-25.

Lockamy III, A. 1995, "A conceptual Framework for assessing strategic packaging decisions", *The International Journal of Logistics Management*, vol. 6, no. 1, pp. 51-60.

Longman 1995, *Longman Dictionary of Contemporary English: The complete guide to written and spoken English*. Third Edn, Longman Group, Harlow.

Lumsden, K. & Acharjee, P. 2005, "Business value of improved identification in the spare part consignment chain", Proc. 17th NOFOMA Conference, Copenhagen, pp. 433-448, 9-10 June 2005.

Maloney, D. 2001, "Returnable savings", *Modern Materials Handling*, vol. 56, no. 9, pp. 37-38.

Mangan, J., Lalwani, C., & Gardner, B. 2004, "Combining quantitative and qualitative methodologies in logistics research", *International Journal of Physical Distribution & Logistics Management*, vol. 34, no. 7, pp. 565-578.

McFarlane, D. & Sheffi, Y. 2003, "The Impact of Automatic Identification on Supply Chain Operations", *The International Journal of Logistics Management*, vol. 14, no. 1, pp. 1-17.

McGinnis, M. A. & Hollon, C. H. 1978, "Packaging: Organization, Objectives and Interactions", *Journal of Business Logistics*, vol. 1, no. 1, pp. 45-62.

McKerrow, D. 1996, "What makes reusable packaging systems work", *Logistics Information Management*, vol. 9, no. 4, pp. 39-42.

Mentzer, J. T. & Kahn, K. B. 1995, "A framework of logistics research", *Journal of Business Logistics*, vol. 16, no. 1, pp. 231-250.

Meredith, J. 1998, "Building operations management theory through case and field research", *Journal of Operations Management*, vol. 16, pp. 441-454.

Merriam, S. B. 1994, *Fallstudien som forskningsmetod*, Studentlitteratur, Lund.

Näslund, D. 1999, *Towards Bridging the Gap Between Strategy and Operations - A Process Based Framework*, Doctor, Lund Institute of Technology, Department of Design Sciences, Lund University.

Nickels, W. G. & Jolson, M. A. 1976, "Packaging - the fifth 'P' in the marketing mix", *S.A.M. Advanced Management Journal*, vol. 41, no. 4, pp. 13-21.

Nilsson, F. 2005, *Adaptive logistics - using complexity theory to facilitate increased effectiveness in logistics*, Doctoral thesis, Division of Packaging Logistics, Lund University, Lund.

Nilsson, F. 2006, "Logistics management in practice - towards theories of complex logistics", *International Journal of Logistics Management*, vol. 17, no. 1, pp. 38-57.

Norrman, A. 2006 "Supply chain risk sharing contracts from buyes' perspective: content and experiences", Proc. 18th NOFOMA Conference, Oslo, 8-9 June 2006.

Öjmertz, B. 1998, *Materials Handling from a Value-Adding Perspective*, Doctoral thesis, Department of Transportation and Logistics, Chalmers University of Technology, Gothenburg, Sweden.

Olsmats, C. & Dominic, C. 2003, "Packaging scorecard - a packaging performance evaluation method", *Packaging Technology and Science*, vol. 16, no. 1, pp. 9-14.

Olsson, A. 2006, *The change from feature focus to customer focus in packaging development*, Doctoral thesis, department of Design Sciences, Division of Packaging logistics, Lund University, Lund, Sweden .

Olsson, A. & Györei, M. 2002, "Packaging throughout the Value Chain in the Customer Perspective Marketing Mix", *Packaging Technology and Science*, vol. 15, pp. 231-239.

Paine, F. A. 1981, *Fundamentals of Packaging*, First Revised Edn, Brookside Press, Leicester.

Pålsson, H. 2005, "Implications of interorganizational RFID implementation - a case study", Proc. ELA Conference 2005, pp. 85-100, Paris, 2005.

Parkhe, A. 1991, "Interfirm Diversity, Organizational Learning, and Longevity", *Journal of International Business Studies*, vol. 22, no. 4, pp. 579-602.

Persson, G. 1982, "Materialadministrativ metod - Några synpunkter", *Scandinavian Journal of Materials Administration*, vol. 8, no. 3, pp. 72-96.

Persson, P.-O. & Stefansson, G. 2006, "The state of a hype - A survey on Radio Frequency Identification", Proc. 18th NOFOMA Conference, Oslo, 8-9 June 2006.

Prendergast , G. 1995, "The EC directive on packaging and packaging waste: current status and logistical implications", *Logistics Information Management*, vol. 8, no. 3, pp. 10-17.

Prendergast, G. & Pitt, L. 1996, "Packaging, marketing, logistics and the environment: are there trade-offs?", *International Journal of Physical Distribution & Logistics Management*, vol. 26, no. 6, pp. 60-72.

Robertson, G. L. 1990, "Good and Bad Packaging: Who Decides?", *International Journal of Physical Distribution & Logistics Management*, vol. 20, no. 8, pp. 37-41.

Rod, S. 1990, "Packaging as a Retail Marketing Tool", *International Journal of Physical Distribution and Logistics Management*, vol. 20, no. 8, pp. 29-30.

Rogers, E. M. 2003, *Diffusion of Innovations*, Fifth Edn, Free Press, New York, NY.

Russell, D. M. & Hoag, A. M. 2004, "People and information technology in the supply chain: Social and organizational influences on adoption", *International Journal of Physical Distribution & Logistics Management*, vol. 34, no. 2, pp. 102-122.

Rutner, S. M., Waller, M. A., & Mentzer, J. T. 2004, "A practical look at RFID", *Supply Chain Management Review*, vol. 8, no. 1, pp. 36-41.

Saghir, M. 2002, *Packaging Logistics Evaluation in the Swedish Retail Supply Chain*, Licentiate thesis, Department of Design Sciences, Division of Packaging Logistics, Lund University, Lund.

Saghir, M. 2004a, *A platform for Packaging Logistics Development - a systems approach*, Doctoral thesis, Department of Design Sciences, Division of Packaging Logistics, Lund University, Lund.

Saghir, M. 2004b, "The concept of Packaging Logistics", Proc. 2nd World Conference on POM and 15th Annual POM Conference, Cancun, 30 April – 3 May 2004.

Saghir, M. & Jönson, G. 2001, "Packaging Handling Evaluation Methods in the Grocery Retail Industry", *Packaging Technology and Science*, vol. 14, no. 1, pp. 21-29.

Schermerhorn Jr, J. R. 1975, "Determinants of Interorganizational Cooperation", *Academy of Management Journal*, vol. 18, no. 4, pp. 846-856.

Senge, P. M. 1990, *The fifth discipline: the art and practice of the learning organization*, First Edn, Doubleday, New York.

Shapiro, C. & Varian, H. R. 1999, "The art of standards war", *California Management Review*, vol. 42, no. 2, pp. 8-32.

Småros, J. & Holmström, J. 2000, "Viewpoint: reaching the consumer through e-grocery VMI", *International Journal of Retail & Distribution Management*, vol. 28, no. 2, pp. 55-61.

Småros, J., Lehtonen, J. M., Appelqvist, P., & Holmström, J. 2003, "The impact of increasing demand visibility on production and inventory control efficiency", *International Journal of Physical Distribution and Materials Management*, vol. 33, no. 4, pp. 336-354.

Smith, A. D. 2005, "Exploring radio frequency identification and its impact on business systems", *Information Management & Computer Security*, vol. 13, no. 1, pp. 16-28.

Solem, O. 2003, "Epistemology and Logistics: A Critical Overview", *Systemic Practice and Action Research*, vol. 16, no. 6, pp. 437-454.

Stahre, F. 1996, *Små returlastbärare i logistikkedjor - införande och effekter*, Licentiate thesis, Department of Management and Economics, Linköping University, Linköping, Sweden.

Stake, R. E. 2000, "Case Studies," in *Handbook of Qualitative Research*, Second Edn, N. K. Denzin & Y. S. Lincoln, eds., Sage Publications, London, pp. 435-453.

Stock, G. N., Greis, N. P., & Kasarda, J. D. 1999, "Logistics, strategy, and structure - A conceptual framework", *International Journal of Physical Distribution & Logistics Management*, vol. 29, no. 4, pp. 224-239.

Stock, G. N. & Tatikonda, M. V. 2000, "A typology of project-level technology transfer processes", *Journal of Operations Management*, vol. 18, pp. 719-737.

Stock, J. R. 1997, "Applying theories from other disciplines to logistics", *International Journal of Physical Distribution and Logistics Management*, vol. 27, no. 9/10, pp. 515-539.

Stock, J. R. 2001, "Doctorial research in logistics and logistics-related areas: 1992-1998", *Journal of Business Logistics*, vol. 22, no. 1, pp. 125-257.

Stock, J. R. & Lambert, D. M. 2001, *Strategic Logistics Management*, Fourth Edn, McGraw-Hill Higher Education.

Strauss, A. & Corbin, J. 1998, *Basics of qualitative research*, Second Edn, Sage Publications, Thousand Oaks CA.

Sundin, E. 2001, "Människan Tekniken och Organisationen: omedveten teori men genderiserad praktik," in *Användarperspektivet - Strategier för att förstärka samspelet mellan användare och utvecklare*, B. Olsson, ed., The Swedish agency of innovation system, Stockholm, pp. 121-127.

Tashakkori, A. & Teddlie, C. 1998, *Mixed methodology - Combining qualitative and quantitative approaches*, Sage Publications, Thousand Oaks CA.

Twede, D. 1992, "The process of logistical packaging innovation", *Journal of Business Logistics*, vol. 13, no. 1, pp. 69-95.

Twede, D. 1999, "Can you justify returnables?", *Transportation & Distribution*, vol. 40, no. 4, pp. 85-88.

Twede, D. & Clarke, R. 2004, "Supply Chain Issues in Reusable Packaging", *Journal of Marketing Channels*, vol. 12, no. 1, pp. 7-26.

Twede, D. & Parsons, B. 1997, *Distribution packaging for logistical systems - A literature review*, First Edn, Pira International, Surrey, UK.

Von Bertalanffy, L. 1969, *General Systems Theory - Foundations, Development and Applications*, First Revised Edn, George Braziller, New York.

Wallén, G. 1996, *Vetenskapsteori och forskningsmetodik*, Second Edn, Studentlitteratur, Lund, Sweden.

Wills, G. 1975, "Packaging as a Source of Profit", *International Journal of Physical Distribution and Materials Management*, vol. 5, pp. 305-334.

Wilson, R. C. 1965, "A packaging problem", *Management Science*, vol. 12, no. 4, pp. 135-145.

Witt, C. E. 1999, "Transport Packaging: Neat and clean or down and dirty", *Material Handling Engineering*, vol. 54, no. 9, pp. 71-73.

Witt, C. E. 2000, "Are reusable containers worth the cost?", *Transportation & Distribution*, vol. 41, no. 9, pp. 105-108.

Yin, R. K. 2003, *Case Study Research: Design and Methods*, Third Edn, Sage Publications CA.

PAPER I

Packaging and logistics interactions in retail supply chains

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Packaging and Logistics Interactions in Retail Supply Chains

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The impact of the packaging system on logistics processes along the supply chain is often implicitly and fragmentally recognized. In order to increase understanding of the impact of packaging on logistics, this paper provides a comprehensive overview of the interactions between the packaging system and logistics processes in the retail supply chain. Four case studies involving Swedish and Dutch retail supply chains were conducted to identify, describe and understand in depth the logistics activities related to packaging within these retail supply chains. The comprehensive overview provided in this paper serves as an elementary step towards understanding the role of packaging systems in logistics, which is a prerequisite for taking packaging and logistics decisions based on a supply chain perspective. Moreover, the paper provides a process-orientated description of what a packaging system must fulfil and perform along the retail supply chain. It also provides a means for evaluating packaging systems, with emphasis on logistics aspects. The interactions between the packaging system and the logistics processes identified in this research can be used to bridge the gap between logisticians and packaging engineers/designers/technicians/managers by enabling them to engage in a dialogue and understand where and how packaging and logistics decisions can impact the performance of packaging system and logistics processes in the retail supply chain. Copyright © 2006 John Wiley & Sons, Ltd.

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KEY WORDS: packaging; logistics; retail; supply chain; case studies

INTRODUCTION

The retail industry is a major consumer of different types of packaging. In Sweden alone, it handles more than 1000 million retail packages annually. The potential savings achieved by improvements in packaging handling in the Swedish retail supply chain, from the retail distribution centre (DC) to the retail outlet, are estimated at €5 million for every reduced second in the handling process for consumers and retail packaging.[1] This constitutes an excellent reason to investigate and discuss packaging, efficiency and logistics activities in the retail supply chain.

There is a need for methods and tools which show the impact of packaging along the retail supply chain in order to avoid sub-optimizations and a need to embrace a systems-orientated approach towards the evaluation of packaging concepts. Historically, packaging has mainly been evaluated by consideration of its basic functions, e.g. from chemical, mechanical and biological

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points of view.[2] Literature reviews reveal the lack of evaluation methods for packaging concepts from a logistics point of view.[3,4] Therefore, methods and tools for evaluating packaging concepts are needed in both industry and academia. Our intent is to provide such means, with an emphasis on logistics aspects.

The purpose of this paper is to provide a comprehensive overview of the interactions between the packaging system and logistics processes in the retail supply chain. The paper demonstrates how mapping the logistics processes connected to the physical packaging flow can facilitate awareness of the value-adding of packaging and thus help to improve the efficiency and effectiveness of retail supply chains. The research presented in this paper strives to focus attention on the increased need for a better basis for packaging decision-making and to provide tools for extending the traditional and limited packaging perspectives to a supply chain level.

The paper is organized as follows: the first section offers a brief overview of packaging; the concept of packaging as a system and its role in logistics are explained. The next section explains the methodology used. The third section presents a detailed description of logistics activities related to packaging in the retail supply chains studied. The fourth section discusses the identified interactions between packaging and logistics in retail supply chains. This is followed by a discussion about the impact of packaging and logistics decisions and the complexity of the packaging decision. Finally, concluding remarks and suggestions for further research are made.

PACKAGING

The functions that packaging must perform are manifold and complex. Paine[5] stresses the fundamental functions of protecting, containing, preserving and communicating the product. Packaging not only protects the product from external influences but can also protect the surrounding environment from the product. Obviously, all products must be contained in order to provide easy handling, warehousing and transport. For most food products, preservation is a vital function of packaging which ensures that the product is sold fresh. The communication function of packaging is threefold: communication of information (e.g. content, destination, means of handling), promoting the product, and maximizing communication with consumers. The importance of the communication function as a marketing tool is especially eminent in market channels with considerable competition at the retail point of sale. Further important functions of packaging that perhaps might not be so obvious are unitization and apportionment of products to desirable amounts.[6]

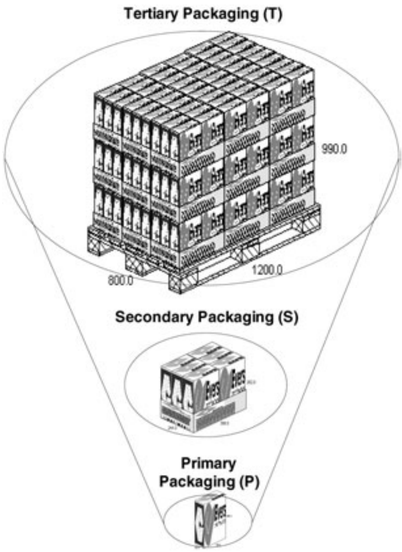

Figure 1. Packaging system levels.

The packaging system and terminology

Packaging can be classified to reflect its different levels as primary, secondary or tertiary[7] (see Figure 1). Primary packaging is that in direct contact with the product, while secondary packaging is designed to contain several primary packages. An assembly of a number of primary or secondary packages on a pallet or a roll container is defined as tertiary packaging. These definitions should be

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used with the recognition of packaging as a *system*, with hierarchical levels. The systems approach highlights the natural interaction between the different levels of packaging and facilitates an understanding of their interdependence. Packaging system performance is thus affected by the performance of each level and by the interactions between these levels.

Packaging is multidisciplinary and the challenge lies in fulfilling the logistics, marketing and environmental functions of the packaging system. According to Saghir,[4] packaging is 'a coordinated system of preparing goods for safe, secure, efficient and effective handling, transport, distribution, storage, retailing, consumption and recovery, reuse or disposal combined with maximizing consumer value, sales and hence profit'. This definition stresses the main packaging functions, i.e. logistics, marketing, environmental and fulfilling needs along a product life cycle, from the very first point of packaging use until the product is consumed and the packaging material is disposed of. Packaging fulfils logistics needs by enabling handling and distribution and providing/carrying information about products, conditions and locations. Packaging is also governed by legislative and marketing demands, affecting elements such as its graphical design and format. It must both fulfil customers' requirements along the supply chain and provide the end consumer with convenience and value. According to Rod,[8] it is also a vital tool in the marketing mix, too often ignored by companies, since twice as much is spent annually on packaging as on above-the-line advertising and promotions. In conclusion, packaging affects supply chain effectiveness because it represents an interface between the supply chain and its main customer, the end user. It enables the chain's primary task, that of serving end consumers, by fulfilling consumers' needs and expectations and enhancing product consumption.

A number of other definitions and terms are used by both industry and academics when discussing packaging. Several terms are often used to describe the same type of packaging when it is viewed from different aspects/standpoints, or treated with emphasis on a certain area, such as logistics or marketing. This complicates the general perception of the packaging system and hinders effective communication across functional and disciplinary borders. Primary packaging is often referred to as 'consumer' or 'sales packaging', and secondary packaging may be called 'group packaging', 'transport packaging', 'industrial packaging' or 'distribution packaging', depending on the main function or application being considered. Other terms that are used are display packaging, retail packaging and used packaging. The Swedish retail industry (from both the producer side and the retail side) has, for example, recognized the implications of using these different terms and has therefore agreed to work actively toward using only three main dual definitions for packaging, i.e. primary or consumer packaging, secondary or outer packaging and tertiary or group packaging.

PACKAGING IN LOGISTICS

Although packaging is recognized as having a significant impact on the efficiency of logistics systems[9–11] and activities such as manufacturing, distribution, storage and handling throughout the supply chain, many packaging-dependent costs in the logistics system are frequently overlooked by packaging engineers.[12] Packaging specifications directly influence the time required for completion of packaging operations,[13] which ultimately affects product lead time and due date performance (delivery) to the customer.[11] Packaging affects main logistics activities, i.e. transport, inventory, warehousing and communication. Packaging-related actions generating increased costs can be motivated by substantial improvement in logistics performance. Examples of such packaging cost trade-offs with logistics activities were described by Lambert *et al*.[14] in Table 1. Other packaging-related trade-offs among logistics, marketing and environmental issues are also present, but are complex to comprehend and explain.[15]

In logistics, the most common way to approach packaging is to concentrate on packaging development that benefits packaging-related logistics activities. However, the packaging system has to satisfy demands from a number of logistics processes along supply chains, which makes it hard to isolate relationships and functions in a 'cause-and-effect' manner. In order to gain insight

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Table 1. Packaging cost trade-offs with other logistics activities (Lambert *et al*., 1998)

Logistics activity	Trade-offs
Transportation	
Increased package information	Decreases shipment delays; increased package information decreases tracking of lost shipments
Increased package protection	Decreases damage and theft in transit, but increases package weight and transport costs
Increased standardization	Decreases handling costs, vehicle waiting time for loading and unloading; increased standardization; increases modal choices for shipper and decreases need for specialized transport equipment
Inventory	
Increased product protection	Decreased theft, damage, insurance; increases product availability (sales); increases product value and carrying costs
Warehousing	
Increased package information	Decreases order filling time, labour costs
Increased product protection	Increases cube utilization (stacking) but decreases cube utilization by increasing the size of the product dimensions
Increased standardization	Decreases material handling equipment costs
Communications	
Increased package information	Decreases other communications about the product, such as telephone calls to track down lost shipments

into the influence of the packaging system on the supply chain, it is necessary to explore and analyse packaging-related activities on an operational level. Packaging engineers cannot make accurate decisions without identifying the processes the packaging will be put through. Lockamy[10] stresses the strategic impact of packaging and stipulates the examination of all packaging-related processes, in order to provide a competitive advantage for the firm. This requires identifying all business processes that are associated with packaging.

From a system perspective, there are three areas where packaging-related improvements in the supply chain can be made: (a) in the logistics process; (b) in the packaging system; and (c) in interactions between the two. The third area constitutes the interface between different packaging levels and various logistics processes along supply chains (Figure 2). As might be expected, logisticians often focus on the logistics process, while traditional packaging engineers often focus on the packaging system. This results in a mismatch in the interaction between the two, since the majority of hidden and indirect costs, profit improvement potential and value-adding attributes are to be found in this interaction. This research, as well as previous research such as that by Johnsson[3], Saghir[4], Twede and Parsons[9] and Twede,[12] shows and implicitly supports this. Consequently, there is a need to focus on the interactions and not on the packaging system or the logistics processes separately. Recognizing the importance of these interactions stipulates the extension of the traditional firm-based view to include processes and activities along the supply chain. Furthermore, this enforces the extension of the scope of the traditional logistician and packaging engineer and enables her/him to understand where and how logistics and packaging decisions can impact the supply chain.

METHODOLOGY

The first step towards adopting a holistic view of packaging and its interrelationship with logistics is to identify and understand the nature of the interaction between the two. To accomplish this, the logistics activities related to packaging in the retail supply chain with a focus on the physical flow of products and packaging material were mapped

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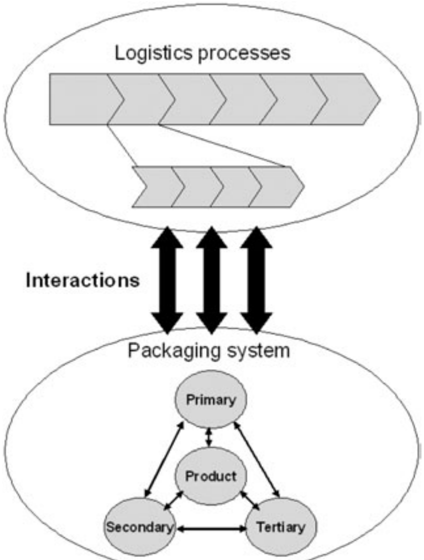

Figure 2. Interactions between packaging and logistics.

and explored, using four case studies. This resulted in detailed process maps illustrating the physical path of packaging and logistics interfaces from the filling point at the manufacturers, via the DC, and eventually to the point of sale at the retail outlets.

The main objective of using case studies was to gain and enhance a deep understanding of phenomena by providing a rich description based on a holistic view.[16,17] The four case studies were used to identify, describe and gain in-depth understanding of the logistics activities related to packaging in retail supply chains. According to Yin,[18] the use of a case study is a relevant methodology in order to answer 'how' questions. The focus of the case studies was not only on identifying and describing which logistics activities are related to packaging, but on understanding how these activities are carried out and how they can affect the efficiency and effectiveness of retail supply chains.

Three of the case studies involved two Swedish retail supply chains and one involved a Dutch retail supply chain. The Swedish/Dutch context of the studies was used due to data availability and the rare opportunity to encompass a retail supply chain. Using more than one national context strengthens the quality of the research, but the packaging/logistics interfaces mapped and described are quite universal. The case studies were primarily chosen because they represented different retail supply chains with different retail concepts. Triangulation was used to compare the different case studies. This enabled the verification of results and in the process, identifying and eliminating methodological shortcomings, data or investigator bias, thus strengthening the validity of the research.[19] Throughout the triangulation process, multiple perceptions were used to compare the case studies. The comparison enhanced the understanding of the conditions of the logistics activities that are related to packaging in retail supply chains. The synthesis of the triangulation was achieved by comparing the four case studies with the same unit of analysis, resulting in generic process maps.

By focusing on the physical flow in the retail supply chain, it was possible to address the logistics activities related to packaging in the cases, since packaging is strongly connected to the product itself. The case studies focused on ambient fast-moving consumer goods (FMCG), since these products constitute the majority of the total material flow of retail supply chains. Mapping the physical flow and analysing the activities along the retail supply chain enhanced the comprehension of the conditions of the logistics activities connected to packaging and their potential impact on the overall efficiency of the retail supply chain (see Figure 3 for an illustration of the system boundaries of the case studies).

The case studies provided a holistic and in-depth view of the physical flow by focusing on both product-specific and non-product-specific aspects. In the Swedish case studies three grocery products (fruit syrup in a 1.5 litre PET bottle, candy in a 250 gram plastic bag and juice in a 1 litre aseptic carton packaging) were the subjects of thorough investigation and mapping throughout their extended supply chain, from the packing point in the producing company to the point of sale at the store. The products were used to demonstrate typical packaging-related logistics problems and identify critical areas throughout the retail supply

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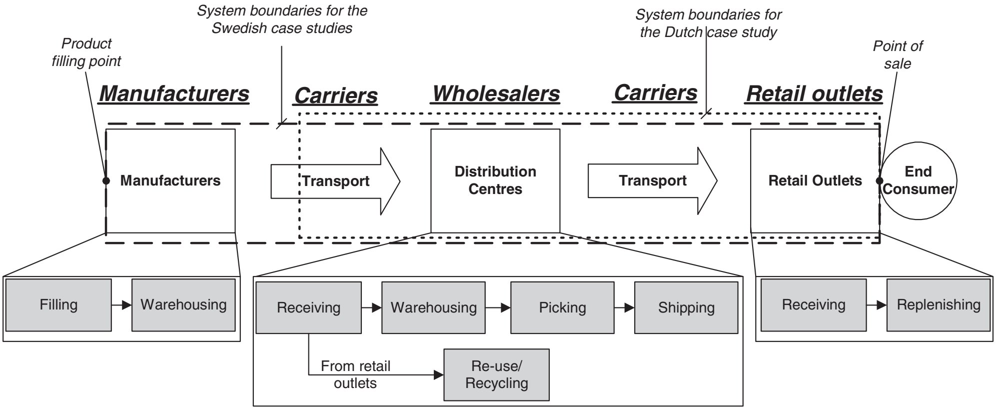

Figure 3. The context and demarcations of the case studies.

chain. These product-specific studies provided an opportunity to understand in-depth and to follow the logical processes involved as well as to understand how the participating companies treated packaging and logistics-related issues. In the Dutch case study there was a focus on mapping the flow of the FMCG in general throughout the retail supply chain, from distribution centres to end consumers, including the reverse flow of products and packages. The purpose of studying FMCG in general was to generate a holistic view of the total flow and how logistics activities related to packaging were treated in the retail chain, as well as including non-product-dependent activities.

Observations and unstructured and semi-structured interviews were used to gather data. Observations of activities at manufacturers, distribution centres, carriers and retail outlets provided necessary understanding of the conditions of the activities. Unstructured interviews were performed with employees carrying out the activities, while approximately 20 semi-structured interviews were conducted with packaging, logistics, distribution, marketing, product and retail outlet managers and other key personnel responsible for packaging and logistics development. The semi-structured interviews were recorded and manually analysed by the authors. The process-mapping tool facilitated an analysis of the relations among the observed activities and made it possible to compare the similarities and differences in the processes of the supply chains involved.

The Swedish retail supply chains

Five companies were involved in the Swedish case studies, representing two food manufacturers (Procordia Foods and CloettaFazer), a transport company (Schenker) and two of Sweden's largest retail chains (ICA and Coop Sweden). The companies are among the market leaders in their business fields and provide a reliable representation of their respective business sectors. Procordia Food is Sweden's tenth-largest food company and produces a wide range of packaged and ready-to-eat food. CloettaFazer is Sweden's largest producer of confectionery and the eleventh-largest food company.

ICA is the main retail chain in Sweden, with a market share of 37.3% (2003), and operates approximately 1800 outlets all over Sweden. Coop is the second-largest retail chain in Sweden, with a market share of 18.3% (2003) and operates approximately 880 outlets. The Swedish grocery retail market has been dominated by these two major retail chains for a long time but is experiencing an increased level of competition and price pressure.

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The market has been consolidating with fewer retail outlets, increased concentration on fewer marketing segments and retail concepts and more centralized logistics operations with fewer central distribution centres. Traditionally, the Swedish market has been dominated by national retail chains. This trend is now changing due to the entry of international actors on the market, such as the German Lidl and the Danish Netto, although they have a relatively small market share.

The Dutch retail supply chain

The Dutch retail supply chain consists of a wholesaler, its carriers and retail outlets. The wholesaler company is a family-owned business which deals mainly with three retail chains; these constitute a total of approximately 150 retail outlets. One of the retail chains is the wholesaler's own chain of retail outlets, Jumbo supermarket, which currently consists of more than 60 retail outlets, among which 18 are run on a franchise basis. These retail outlets operate over a retail surface of an average of 900 m^2, offer 26500 stock-keeping units (SKU) and their retail model is categorized as 'cheaper supermarkets which focus on quality'. Jumbo supermarket is the fastest-growing retailer in The Netherlands; in December 2001 they had a market share of 1.7% of the Dutch market, which had grown to 2.9% by December 2003. They are relatively small food retailers compared to the two largest food retailers in The Netherlands, Albert Heijn and Laurus, which combined account for almost 50% of the Dutch market.

LOGISTICS ACTIVITIES RELATED TO PACKAGING

This section describes in detail the logistics activities related to packaging within retail supply chain processes. The aim of the description is not to evaluate different packaging trade-offs but instead to demonstrate the interface between the packaging system and the logistics processes. Process maps are used to illustrate the processes describing packaging material input, output and the physical flow of products from the filling point at the manufacturer, via the DC and down to the point of sale at the retail outlet.

Manufacturer

Manufacturing conditions are relatively rigid and revolve around high product volume and tied capital investments in packaging machinery, process equipment, etc. The high degree of automation makes it difficult to change or adjust current activities. The first step of the packaging journey through the retail supply chain begins in the filling process, at the packaging and filling machine. It is here that the product meets the primary packaging (see Figure 4). From this moment on, the product and the primary packaging are considered as a unified and inseparable single unit. They will not be separated until they reach the point of consumption.

The manufacturer's key operational issues are packing line efficiency and flexibility; these are governed by the type of product, primary packaging, filling and sealing technology. Label application is also dependent on the type and design of the packaging; important issues include label application time, label placement, amount of information carried by the label and label type. The labels also have to comply with readability and traceability requirements. The information on the labels depends on the level of packaging. Primary packaging information is directed towards the consumer, while secondary and tertiary packaging information is used inside the retail supply chain. The pallet label serves as a location or destination label and is used to identify and verify products along the supply chain.

The purpose of the control activity (see Figure 4) is to ensure product safety, quality and quantity (volume and weight). The activity of filling/placing products into secondary packaging is adapted to quantity, speed and stability of the primary packaging. The choice of secondary packaging is a driver of customization and differentiation further down the retail supply chain. The size of the secondary packaging and the number of products it carries affect handling, transportation, warehousing, picking and retailing. By enabling

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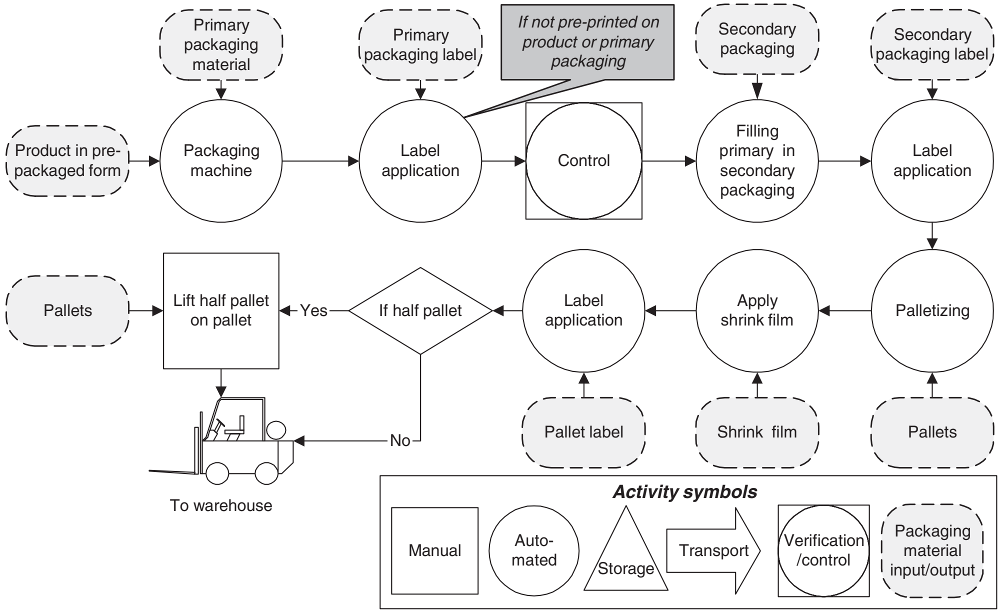

Figure 4. Packaging logistics activities in the filling process at the manufacturers.

variations in secondary packaging size, it is possible to adapt to conditions and customer demands further down the supply chain. This also applies to palletizing, where the possibility of choosing full pallet or half pallet makes it possible to customize the order size according to the demands and conditions of the DC and retail outlets. Furthermore, the ability to deliver half pallets with display packaging enables the half pallets to be directly placed at the retail outlet. This reduces handling at both the DC and retail outlets and adds marketing value. Palletizing should facilitate efficient handling, which includes stability and stacking. The level of stacking depends on the material and shape of the packaging. When palletizing, stability is gained by using lock pattern stacking. Shrink film is also used to increase the stability and to protect the products.

Pallets are the main transport unit of the manufacturer. Half pallets are normally stacked on a regular pallet, to enable efficient handling. The manufacturer's warehouse is either located on-site or at a remote central warehouse (see Figure 5). The warehousing process, which includes storage, picking and shipping, is similar in both cases but extra activities, such as transport, unloading and verification, are required when, for instance, a remote central warehouse is used.

Transport

Transport activities interact mainly with tertiary packaging, i.e. pallets and roll cages. Transport unit adaptability is considered the most important factor from an efficiency point of view. Stackability is also an important factor that directly affects transport costs. Weight and height of tertiary packaging are two limiting factors with constraints which directly affect transport efficiency and cost. Pallet adaptability has a direct effect on volume and area efficiency in the transport vehicle.

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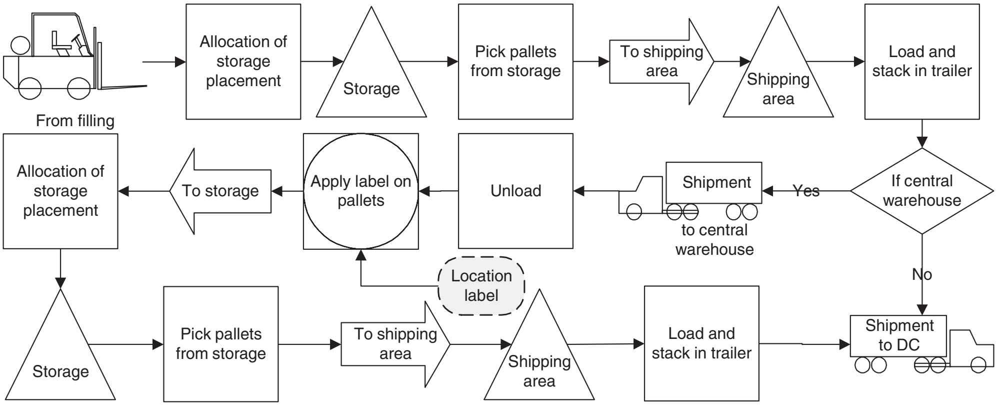

Figure 5. Packaging logistics activities in the warehouse process at the manufacturers.

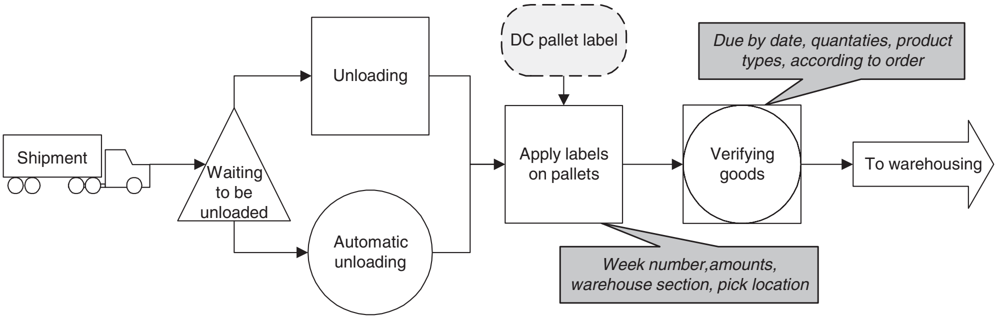

Figure 6. Packaging logistics activities in the receiving process at DC.

Distribution centre

Secondary and tertiary packaging is handled at the DC. The logistics processes related to packaging at the DC are receiving, storing, picking, shipping and handling of used packaging materials. Most activities performed in these processes are packaging-dependent. Labour generally represents the greatest cost in a DC, as there is an extensive amount of manual handling.

The activities in the receiving process are unloading, application of labels and controlling the received products (see Figure 6). Unloading is often carried out by the truck driver, using a pallet stacker, or automatically, using automated unloading equipment. Once the shipment has been unloaded, the pallets are labelled and verified. The labelling activity is also used as a means of verifying the number of pallets received.

In the storing process (see Figure 7), the allocation of storage placement is fundamental. In the DC studied this was done in one of three ways: employing a warehouse management system, using the T-method, or using a pick location badge. The T-method is based on manually choosing a storage placement for incoming pallets as near the pick location as possible, preferably above or on the right or left of it. The pick location badge was

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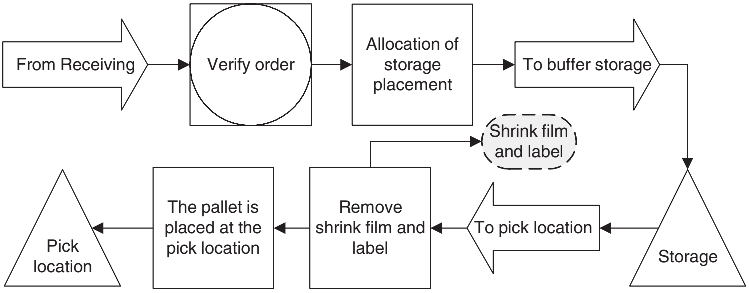

Figure 7. Packaging logistics activities in the storing process at DC.

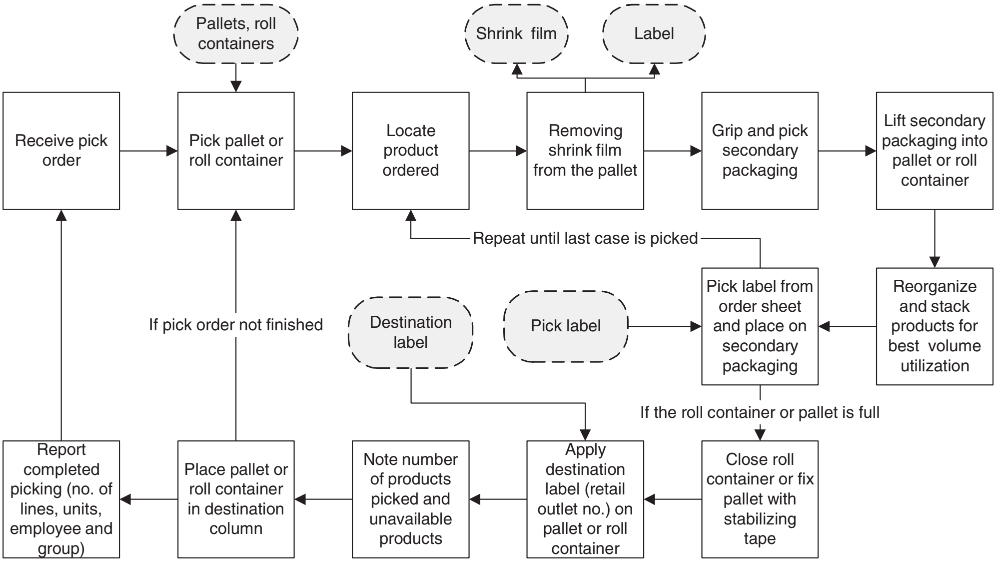

Figure 8. Packaging logistics activities in the picking process at DC.

placed at the pick location and used as a direction marker for incoming pallets bearing the same products.

Assigning pick orders is the first step in the picking process (see Figure 8). In two cases the picking assignment was achieved randomly. In one case, the pick orders were assigned individually on the basis of individual employee skills, e.g. speed, strength and experience. A strong picker is assigned to pick heavy products, such as crates of soda or beer, while a fast picker is assigned to pick orders made up of many products. Order picking represents the core activity of the DC and is the most labour-intensive. Packaging aspects which influence the efficiency of the order picking activities are quantity, weight, volume and stackability. The main function of the pick label applied to the secondary packaging is to verify that all products have been picked. Picking efficiency is closely linked to considerations such as human factors,

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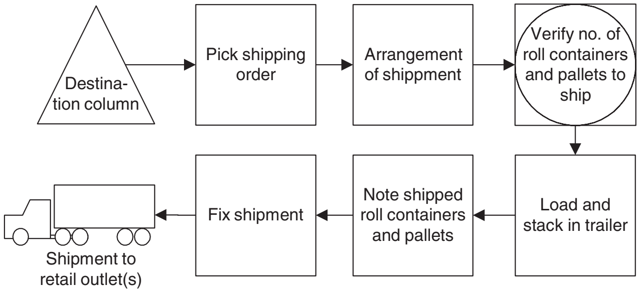

Figure 9. Packaging logistics activities in the shipping process at DC.

reward systems, order structure, warehouse layout, picking equipment, type of products picked and the shape and type of packaging. The main packaging-related problems that occur in the DC are: pallet overhang due to stacking products outside the limits of the pallet; difficulty in stacking products in the roll container; ergonomic aspects (weight of picked packages, slippery packages, risk of cutting injuries on the edge of corrugated board and difficulties in getting a grip); missing handling aids, e.g. grip handles; too-strong adhesive between packaging layers on the pallet; and too-fragile packages that open up or break when handled.

The shipping process is often organized using numbered destination columns (see Figure 9). In two of the cases, the arrangement and verification of the shipment were done by the truck driver. In one case these activities were done by DC employees, with extensive verification of shipped products. Checks were made at the secondary packaging level in order to guarantee the accuracy of the order picking process. The controllers also arranged the roll containers in lanes and sequences to match delivery routes.

The last process at the DC is related to the handling of used packaging material, which was handled at the retail outlet or in the DC, depending on the structure and ownership of the retail chain. In two cases this was carried out at the DC (see Figure 10). In one case the crates and bottles had to be sorted at the DC according to product. This detailed sorting was not required in the other two cases, as a centralized third party carried out this process.

Retail outlet

The activities at the retail outlet include all levels of the packaging system and are dominated by handling and marketing properties; 63% of the handling time in the retail outlet is packaging-related and only 37% is method-orientated (working procedures and routines).[1] Manual handling, product information and sales promotion are important primary packaging factors. The activities in the retail outlet vary depending on the ownership, location, size and retailing concept of the retail outlet. In the case studies where the outlets were franchised, the shipment was verified when it was at the retail outlet (see receiving and shipping processes in Figure 11). Only random checks were made when the DC and retail outlet had the same owner. The location, whether or not it was located in central urban areas, and the size of the retail outlet influenced the size of storage (backroom inventory), shelf capacity and the capability to handle used packaging material. The replenishment process depended on the retailing concept; the alternatives considered were: single products on shelf; secondary packaging on shelf; or whole pallets on the floor. Retail outlets which focused on shopper experience and perception of the outlet preferred to replenish in the evenings or at night when the outlet was closed. In two cases, the used packaging material was sent to the DC, while in the third case the retail outlet handled recyclable corrugated board on site. At the retail outlet, packaging has to accommodate shelf adaptation, sales promotion requirements, the facilitation of product identification and communication,

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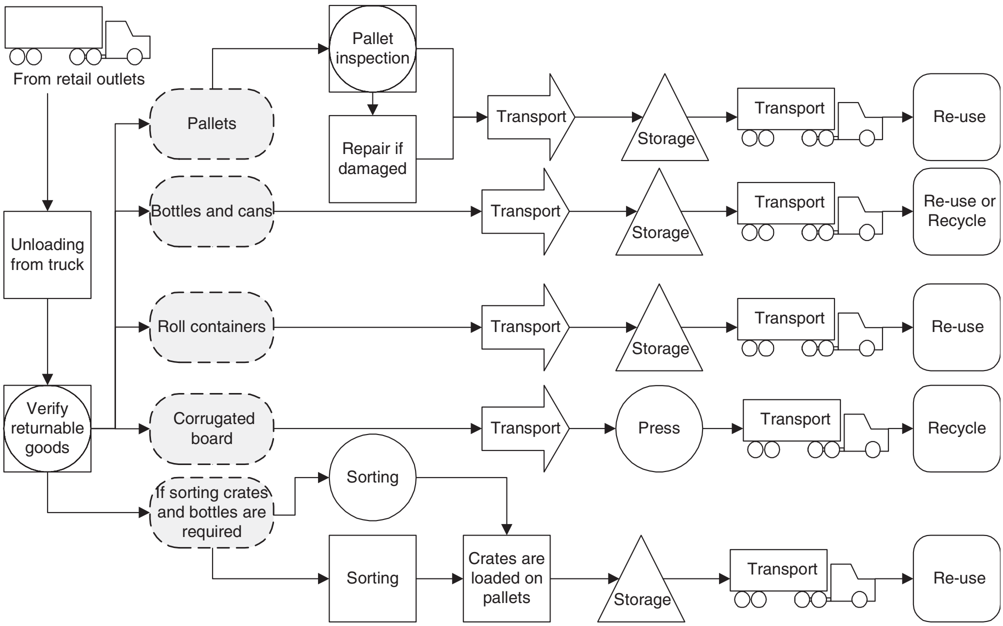

Figure 10. Used packaging material activities at DC.

handling efficiency and ergonomic requirements. The main packaging-related problems which occur in the retail outlet are: deciding on the placement on shelf; ergonomic aspects in the replenishment process, e.g. difficulty in opening, picking and gripping the package, weak packaging structure and packages that are too heavy; difficulty in stacking packages on the shelf; damaged packaging shape and design (both secondary and primary); packaging appearance; and excessive disposal packaging material.

THE INTERACTION BETWEEN PACKAGING AND LOGISTICS

The detailed mapping of logistics activities related to packaging gives a comprehensive overview of the physical environment for the overall packaging system in the retail supply chain. Understanding the packaging environment is a prerequisite for taking packaging decisions based on a supply chain perspective. More importantly, howevert, the detailed mapping shows the interactions between packaging and logistics. Table 2 summarizes where the interactions (marked with X) between the packaging system and logistic processes are located along the retail supply chain. This table of interactions (Table 2) could be used to bridge the gap between logisticians and packaging engineers by helping them to identify the connections between packaging and logistics decisions. To provide meaningful reference points for these two groups of professionals, the interacting logistics activities and the interacting packaging aspects are described and highlighted in the following subsections. These reference points enable packaging engineers and logisticians to engage in a dialogue, and understand where and how packaging and logistics decisions can impact the packaging system and logistics processes. More importantly, in light of that impact, the reference points show

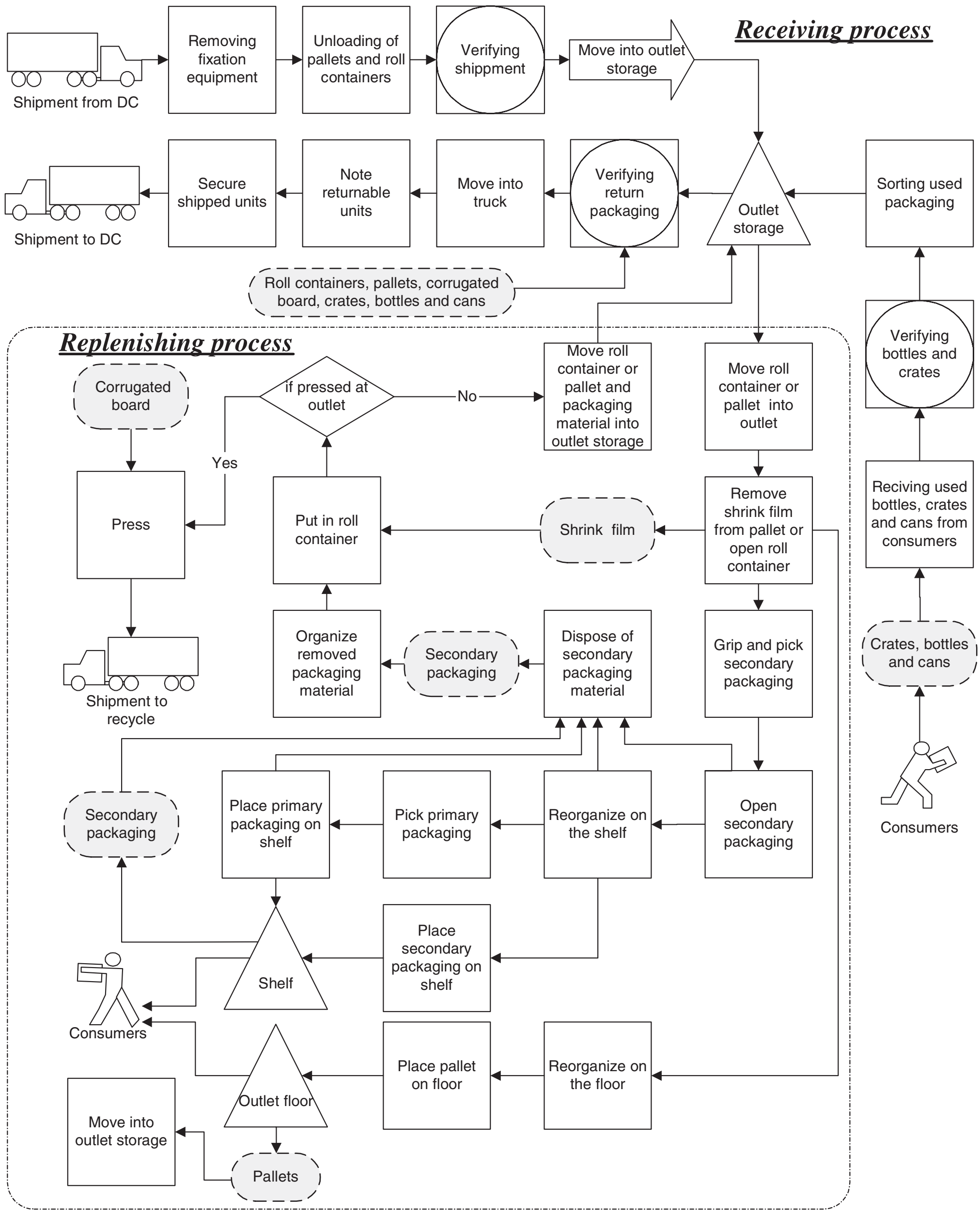

Figure 11. Packaging logistical activities at retail outlet.

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Table 2. The interactions between the packaging system and the logistics processes

Supply chain members	Manutacuturer			Distribution centre					Retail outlet		
Logistics Processes	Filling process	Warehousing process	Transport	Receiving process	Storing process	Picking process	Shipping process	Transport	Receiving and shipping	Replenishing process	Re-use and recycle
Packaging system											
Primary	X									X	X
Secondary	X					X			X	X	X
Tertiary	X	X	X	X	X	X	X	X	X	X	X

how packaging-related decisions can impact the supply chain.

The interacting logistics activities

The detailed description of logistics activities related to packaging can be used as a platform to analyse and discuss tangible logistics issues along the retail supply chain. The description provides the necessary means to evaluate the logistics activities related to packaging from a value-adding perspective by showing how activities are performed and for what reason. The detailed description also identifies unnecessary and excessive activities along the supply chain. Ultimately, it can serve as an aid in identifying inefficiencies and encouraging a logistics focus on packaging-related value addition. Table 3 summarizes the distributions of the main logistics activities interacting with the packaging system throughout the retail supply chain and shows key areas with a potential for efficiency improvement. When discussing the distribution of activities in Table 3, one should bear in mind that a single DC often serves a large number of retail outlets.

Table 3 shows that nearly all automated handling activities are carried out at the manufacturers, while manual handling activities are most prominent at the DC and retail outlets. The most labour-intensive part of the retail supply chain is at the retail outlets. The replenishment process at retail outlets constitutes the most labour-intensive process related to packaging in the retail supply chain. At the DC, the picking process is the most labour-intensive. However, as Table 3 also indicates, there is no extensive integration between supply chain members. Barcode-based labelling is a recurring activity in the retail supply chain. If a standardized label was used throughout the supply chain, there would be no need to relabel items: this would reduce labour and errors. As Table 3 shows, seven different labelling activities occurred in the retail supply chains studied. Furthermore, numerous control and verification activities are manually carried out today, and are in the best of worlds of no value if earlier activities have been performed correctly. The need for relabelling, control and verification was extensive in the cases studied and this indicates a lack of integration throughout the retail supply chain. One way to eliminate and improve relabelling, control and verification activities is to introduce more advanced automated identification technology than barcode technology, such as radio frequency identification, which represent a major opportunity to overhaul and improve the shortcomings of these activities.[20–22]

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Table 3. The distribution of logistics activities related to packaging in the retail supply chains

Supply chain members	Manutacturer			Distribution centre					Retail outlet		
Logistics Processes	Filling process	Warehousing process	Transport	Receiving process	Storing process	Picking process	Shipping process	Transport	Receiving and shipping	Replenishing process	Re-use and recycle
Activities											
Control and verifying	1	1	–	1	1	0	1	–	3	0	2
Labelling	3	1	–	1	0	2	0	–	0	0	0
Automated handling	4	0	–	1	0	0	0	–	0	0	2
Manual handling	1	7	–	1	3	11	5	–	6	16	4
Transport	0	4	–	0	2	0	0	–	0	0	4
Storage or waiting	0	4	–	1	2	0	1	–	1	2	4
Packaging material											
Input	6	0	–	0	0	1	0	–	1	0	0
Output	0	0	–	0	1	1	0	–	0	3	0

The interacting packaging aspects

The detailed mapping of logistics activities related to packaging can also be used as a platform to analyse and discuss tangible packaging issues along the retail supply chain. It provides the necessary means to evaluate the packaging aspects related to logistics processes from a value-adding perspective and shows what packaging aspects are important in the various processes along the supply chain. Ultimately, it may serve as an aid in identifying where there are opportunities for packaging-related improvements and for encouraging a packaging focus on logistics-related value addition. Table 4 summarizes the packaging aspects that interact with the logistics system throughout the retail supply chain; one should bear in mind that the packaging aspects identified here are those that directly relate to a certain packaging level that interacts with the logistics processes. Table 4 demonstrates that tertiary packaging interacts with all the logistics processes and in several processes, such as transport and storing, is the only packaging interaction. Secondary packaging affects the core retail logistics processes, i.e. picking and replenishment. Primary packaging is most influential in the production process at the manufacturer and in some of the replenishment activities in the retail outlet. However, the primary packaging level is of most importance from a marketing point of view. The perception of the product and its sales packaging in the retail outlet is the single most influential packaging factor from a marketing standpoint.

THE IMPACT OF PACKAGING AND LOGISTICS DECISIONS

Understanding where and how logistics and packaging decisions impact the processes along the supply chain is central for identifying the potentials for efficiency improvements. There has been a tendency to consider packaging as mainly a cost for most companies, where the focus is put on min-

Table 4. The interacting packaging aspects in the retail supply chain processes

Supply chain members	Manutacturer			Distribution centre					Retail outlet		
Logistics Processes	Filling process	Warehousing process	Transport	Receiving process	Storing process	Picking process	Shipping process	Transport	Receiving and shipping	Replenishing process	Re-use and recycle
Packaging system											
Primary	Packing line efficiency Filling speed Label application Closing and scaling technology Flexibility									Mandling efficiency Promoting sale Shelf adaptation Product identification	Handling efficiency Material
Secondary	Handling efficiency Packing line efficiency					Handling efficiency Identification Ergonomics Protection Stability			Handling efficiency Identification	Handling efficiency Identification Protection shelf adaptation Ergonomics	Handling efficiency Material
Tertiary	Handling efficiency Stackability	Handling efficiency Btackability Protection Stability	Cube utilization Stackability Weight and height Stability	Stability Identification	Cube utilization Weight and height	Handling efficiency Material	Handling efficiency Weight and height Stability	Cube utilization Weight and height Stability Stackability	Handling efficiency material Stability	Handling efficiency Store concept adaptation Product identification Promoting sale	Handling efficiency Material

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imizing the cost of packaging material. The contribution of packaging to improving profit and not merely reducing costs has, however, gained increased attention. The focus so far has been on the impact on the single company and there are rare examples of examining impacts and opportunities along the supply chain. Moreover, when making decisions, logisticians often focus on the impact on the logistics process, while traditional packaging engineers often focus on the function of the packaging system. However, the majority of the hidden and indirect costs, value-adding attributes and profit improvement potentials are represented in the interaction between the packaging system and the logistics process. Hence, there is a need to focus on the interactions and not on the packaging system or the logistics processes separately. Recognizing the importance of these interactions stipulates the extension of the traditional firm-based view to include processes and activities along the supply chain. This would extend the scope of the traditional logistics and packaging engineer and enables her/him to understand where and how logistics and packaging decisions might impact the packaging system and logistics processes.

Packaging and logistics decisions are interrelated and sometimes inseparable, which stresses the necessity for an integrated decision process. However, an integrated approach is difficult to adopt and implement if causes and effects cannot be shown in a manageable manner. Here the identification of the interactions between the packaging system and logistics processes could help in adopting and implementing such an approach. It is in these interactions that packaging and logistics decisions make an impact on the overall supply chain. This means that the tables of interactions (Tables 2–4) can be used to bridge the gap between logisticians and packaging engineers since they represents the link between packaging and logistics decisions. Figure 12 illustrates the interdependability of packaging and logistics decisions as well as how these affect the performance of the packaging system and logistics processes. A packaging decision affects not only the packaging system (product, primary, secondary and tertiary packaging) but also the interacting logistics processes and, as shown in Figure 12, a logistics decision affects not only logistics processes but also the interacting packaging levels in those processes.

A packaging decision, for example, to improve the openability of secondary packaging in order to ease the replenishment process at retail outlets illustrates the impact of decisions on the packaging system and logistics processes. The improvement is accomplished at the secondary packaging level without the need to change the other packaging levels. However, the secondary packaging level does not only interact with the replenishment process at retail outlets. According to the table of interactions (Table 2), it also interacts with the filling process at the manufacturer, the picking process at the DC, the receiving and shipping process at retail outlets and the re-use and recycle process. Hence, these interactions need also to be considered. A secondary packaging that is easily opened at the retail outlet could be less robust and accidentally opened when it is picked at DC, causing a less efficient picking process. Furthermore, it may require changes in the filling process, which in turn interacts with primary and tertiary packaging levels. Accordingly, efforts must also be made to adapt interacting logistics processes to the packaging system. Figure 12 reflects the need for awareness of this complex 'loop' of effects initiated by packaging and logistics decisions.

With the understanding of how logistics and packaging decisions impact the packaging system and logistics processes, it is possible to take decisions, such as changing the packaging system or the logistics activities, or both, based on a holistic packaging perspective that enables increased overall supply chain efficiency. Any packaging decision must take into consideration the impact of the chosen packaging solution or feature on the identified interface processes. Accordingly, efforts must also be made to adapt the operations and features of the logistics interface processes to the packaging system used. Combined, these interrelated considerations can make it possible to achieve considerable performance improvements in both the packaging system and logistics processes. Despite being an important cost driver/reducer for logistics activities along the retail supply chain, packaging must also be considered as a tool for achieving competitive advantage and a source of profit. The contribution of the packaging system to satisfying needs and adding

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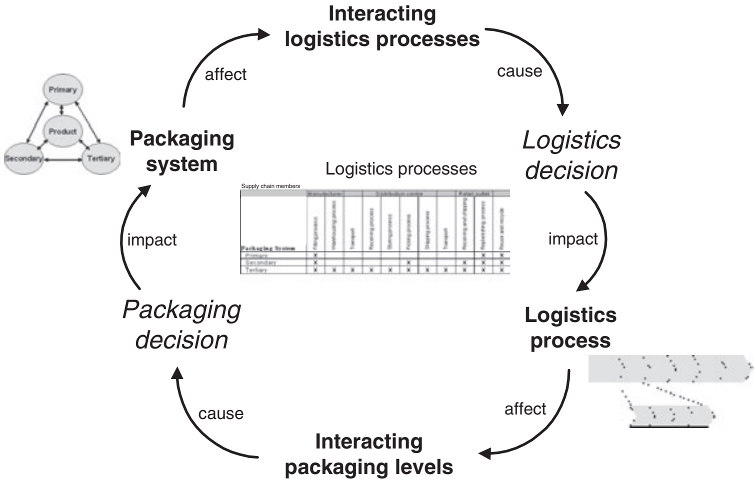

Figure 12. The cause–affect loop of packaging and logistics decisions.

value for the supply chain members, as well as for the end consumers, is a key factor in gaining competitive advantage, profit and overall supply chain effectiveness. As the development of packaging and logistics evolve over time and competition increases, the importance of marginal incremental improvements increases and provides a decisive competitive advantage.

The packaging decision dilemma

A packaging decision is a complex process involving different actors to consider, many functions to serve, different requirements to satisfy and conditions to pay attention to. Hence, a packaging decision requires a holistic approach that provides means to manage these complexities. The narrow functional mind set and power conditions prevailing in the retail supply chain and its various organizations influence (and sometimes inhibit) the applicability of a holistic packaging decision. The success of a holistic packaging approach considering the total impact of packaging along retail supply chains is likely to depend on the ability of retail organizations to agree upon how they can share the costs and benefits of such an approach.

A holistic approach to packaging in the retail supply chain shows that marketing and logistics aspects often conflict and that trade-offs are applied in packaging decisions.[15] Primary packaging, for example, has to fulfil efficiency requirements in the filling and replenishment processes as well as marketing requirements in the retail outlet. Packaging designers and engineers need to find means for fulfilling different and conflicting packaging requirements, but must often prioritize whether to provide a unique differentiated selling packaging or a standardized and logistically efficient packaging. Often the prioritization of the most important aspect (marketing or logistics) is up to the brand owner, but the reality of the retail supply chain structure imposes different rules. Today's retail organizations have considerably increased their power and put their most important requirements of store and picking efficiency on the packaging decision agenda. Concurrently, retail organizations have increasingly chosen to integrate vertically in the supply chain by introducing private-label-products that compete with their suppliers' products. This development has increased the influence from structural and organizational aspects in the supply chain on the already complex packaging decision. Awareness of

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the impact of a poorly designed packaging system on the supply chain is fundamental to providing a better decision support, but must today be combined with awareness of the priorities of the main system owner. Beside the fundamental packaging requirements, whose main priorities must a packaging engineer heed? The manufacturer and sometimes the brand owner or the retail organization? There is no doubt that the dilemma of the packaging decision is increasing in its complexity and we therefore need better insight, but mostly more developed and advanced decision support and tools.

CONCLUDING REMARKS

The influence of the packaging system on logistics processes along the supply chain is often implicitly and fragmentally recognized, but seldom directly shown and discussed in a comprehensive way. This may depend on the general consideration of packaging as a minor subsystem of logistics, with limited influences on the overall performance of the supply chain. The awareness of the logistics activities along the supply chain and their interactions with the packaging system is a fundamental step in changing this limited perception. We argue that the logistics processes described in detail and the identified and highlighted interactions between the packaging system and logistics processes illustrated in this research contribute to increasing such awareness. Optimally, this research strives to put attention on the increased need for a better basis for packaging decision-making and to provide tools for accomplishing this. It also extends traditional packaging perspectives.

The detailed mapping of logistics activities related to packaging gives a comprehensive overview of the physical environment for the overall packaging system in the retail supply chain. It serves as an elementary step towards understanding the role of packaging systems in logistics, which is a prerequisite for making packaging decisions based on a supply chain perspective. Moreover, the detailed mapping describes the interactions between the packaging system and the logistics processes along the retail supply chain and these are highlighted and discussed. These interactions can be used to bridge the gap between logisticians and packaging engineers by enabling them to engage in a dialogue and to understand where and how packaging and logistics decisions might impact the packaging system and logistics processes. Recognizing the importance of these interactions stipulates the extension of the traditional firm-based view to include processes and activities along the supply chain. Ultimately, it may then serve as an aid in showing how packaging-related decisions might impact the supply chain.

FURTHER RESEARCH

This research provides a by no means complete description of all retail supply chains and should therefore be expanded and multiplied by incorporating consumer activities and investigating the conditions of other retail supply chains. Tools of analysis, such as simulation and the DSM matrix,[23] can be used to further explore and analyse the interactions between packaging and logistics in tangible and specific packaging cases. This would increase the understanding of the relations between the packaging system and logistics activities and would shed more light on inefficient activities along the retail supply chain, giving opportunities for tangible improvements.

Besides the logistics function, the packaging system has, among other things, a marketing function to fulfil. A more holistic packaging approach requires a careful consideration of the multifunction of packaging to avoid negative trade-offs. Hence, it is crucial to make packaging decisions based on the packaging system interactions with logistics processes and including the processes of end consumers. Accordingly, the interactions between the packaging system and end consumers need to be explored to further extend the scope of the traditional packaging engineer.

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REFERENCES

1. Development and Logistics Group of the Wholesale and Retail Trade in Sweden (DULOG). *Handling Costs in the Swedish Grocery Retail Industry*. DULOG: Stockholm, Sweden, 1997.
2. Saghir M, Jönson G. Packaging handling evaluation methods in the grocery retail industry. *Packag. Technol. Sci.* 2001; **14**(1): 21–29.
3. Johnsson M. Packaging logistics – a value-added approach. Doctoral thesis, Department of Engineering Logistics, Lund University, Sweden, 1998.
4. Saghir M. A platform for packaging logistics development – a systems approach. Doctoral thesis, Division of Packaging Logistics, Lund University, Sweden, 2004.
5. Paine F. *Fundamentals of Packaging.* Brookside Press: Leicester, UK, 1981.
6. Livingstone S, Sparks L. The new German packaging laws: effects on firms exporting to Germany. *Int. J. Phys. Distrib Logist. Manag.* 1994; **24**(7): 15–25.
7. Jönson G. *Packaging Technology for the Logistician.* Lund University: Lund, Sweden, 2000.
8. Rod S. Packaging as a retail marketing tool. *Int. J. Phys. Distrib. Logist. Manag.* 1990; **20**(8): 29–31.
9. Twede D, Parsons B. *Distribution Packaging for Logistical Systems: A Literature Review.* Pira International: Leatherhead, UK, 1997.
10. Ebeling CW. *Integrated Packaging Systems for Transportation and Distribution.* Marcel Dekker: New York, 1990.
11. Lockamy A. A conceptual framework for assessing strategic packaging decisions. *Int. J. Logist. Manag.* 1995; **6**(1): 51–60.
12. Twede D. The process of logistical packaging innovation. *J. Business Logist.* 1992; **13**(1): 69–94.
13. Lee SG, Lye SW. Design for manual packaging. *Int. J. Phys. Distrib. Logist. Manag.* 2003; **33**(2): 163–189.
14. Lambert DM, Stock JR, Ellram LM. *Fundamentals of Logistics Management.* McGraw-Hill: Singapore, 1998.
15. Prendergast G, Pitt L. Packaging, marketing, logistics and the environment: are there trade-offs? *Int. J. Phys. Distrib. Logist. Manag.* 1996; **26**(6): 60–72.
16. Stake RE. Case studies. In *Handbook of Qualitative Research*, Denzin NK, Lincoln YS (eds). Sage: Thousand Oaks, CA, 2000; 435–453.
17. Merriam SB. *Fallstudien som Forskningsmetod.* Studentlitteratur: Lund, Sweden, 1998.
18. Yin RK. *Case Study Research: Design and Methods*. Sage: Thousand Oaks, CA, 2003.
19. Oppermann M. Triangulation – a methodological discussion. *Int. J. Tourism Res.* 2000; **2**(2): 141–146.
20. Kärkkäinen M, Holmström J. Wireless product identification: enabler for handling efficiency, customization and information sharing. *Supply Chain Manag. Int. J.* 2002; **7**(4): 242–253.
21. Kärkkäinen M. Increasing efficiency in the supply chain for short shelf life goods using RFID tagging. *Int. J. Retail Distrib. Manag.* 2003; **31**(10): 529–536.
22. McFarlane D, Sheffi Y. The impact of automatic identification on supply chain operations. *Int. J. Logist. Manag.* 2003; **14**(1): 1–17.
23. Ulrich KT, Eppinger SD. *Product Design and Development.* Irwin McGraw-Hill: Boston, U.S., 2000.

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PAPER II

Consequences of introducing an innovative unit load carrier in a retail supply chain

By Daniel Hellström

Under review in

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Consequences of introducing an innovative unit load carrier in a retail supply chain

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Abstract

Purpose – To explore the logistics, market, packaging and environmental consequences of introducing an innovative unit load carrier in a retail supply chain.

Design/methodology/approach – A case study was conducted at a large global retailer and at its supply chain. The case study reveals a previously inaccessible phenomenon, since the innovative unit load carrier has only been implemented on a large scale at the studied retailer's supply chain. In order to explore the consequences the study draws on a longitudinal research approach.

Findings – The case study demonstrates the opportunity and potential of logistics-driven packaging innovation in retail supply chains. It provides detailed insights into the impact of introducing an innovative unit load carrier on different supply chain echelons. These insights emphasise the need for an integrated logistics, market, packaging and environmental perspective in order to understand the total impact of packaging innovations on supply chains.

Research limitations/implications – This is a case study of the consequences of a particular innovation on a particular supply chain. Even though the consequences in other supply chains may be different, this study provides detailed explanations and illustrative examples which generate insights relevant to other firms and supply chains.

Practical implications – This paper provides an understanding of potential trade-offs between standardised and differentiated packaging, providing practitioners with a better basis for making decisions on packaging design and development.

Originality/value – The paper illustrates the need to consider packaging as a strategic component which contributes to overall supply chain performance. To support strategic packaging decision-making a framework for assessing packaging in retail supply chains is proposed.

Keywords Packaging, Logistics, Distribution management, Supply chain, Innovation

Paper type Case study

Introduction

Standardised unit load carriers such as EUR pallets, are fundamental components in packaging and logistics systems. Standardised unit load carriers have indisputably played a central role in shaping logistics systems and have provided firms with handling and transport efficiency. A study undertaken by ECR Europe (1997) claimed that a more efficient size and shape standardisation of

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The author acknowledges and thanks IKEA of Sweden and in particular Allan Dickner, André Jonsson and Björn Mathiasen for their assistance in this research project.

pallets in European grocery supply chains could cut logistics costs by the equivalent of 1.2 per cent of sales revenue. These savings would accrue from improved utilisation of vehicle cube, better space utilisation and more efficient handling of materials in warehouses and stores, and reduction in the use of packaging material. The strength of standardised packaging is that it makes it easier to develop efficient logistics systems because it enables similar demands on transport and material-handling equipment (Stock and Lambert, 2001). However, standardisation may also lead to less flexibility (adaptability) with regard to change (Jahre and Hatteland, 2004). Thus, when setting standard specifications for packaging, it is important to try to predict future changes of the packaging "environment" as well as the stability of these variables (Koehorst *et al.*, 1999).

In an ever-changing marketplace, new emphasis and requirements are placed on packaging and logistics systems, questioning the efficiency of using standardised unit load carriers. Globalisation is an unmistakable paradigm shift which has increased supply chain distances, since raw material supplies, material conversion, assembly and end-consumers can all be located in different parts of the world (Dicken, 2003; Schary and Skjoett-Larsen, 2001). Due to this shift, some unit load carrier functions have become increasingly important to logistics systems, namely: enabling efficient transport, ensuring product quality by protecting goods under global transport conditions, and product security (Forcinio, 2005; Sonneveld, 2000; Starkey, 1994; Torstensson, 1999). Differences in infrastructure, logistical structures and transport and material-handling equipment between markets place additional emphasis and requirements on unit load carriers and logistics systems. For example, in industrialised countries, the majority of the material flow is based upon different standardised unit load carriers. However, in recently industrialised countries, such as those in East and Southeast Asia and Latin America, unit load carrier standards are rare. International regulations also place additional emphasis and requirements on unit load carriers. One example of a regulatory requirement is compliance with the International Standard for Phytosanitary Measures in order to reduce the risk of introducing and/or spreading quarantine pests associated with wood packaging material. However, this shift of emphasis in globally oriented requirements has not decreased the significance of traditional unit load carrier requirements, e.g. enabling efficient warehousing and handling, providing information and branding, and being environmentally friendly. To meet both new and traditional unit load carrier requirements, packaging and logistics managers need to re-evaluate their unit load carrier options. Should standardised or differentiated unit load carriers be used? Should reusable or recyclable unit load carriers be used? What unit load carrier innovations would enable firms to stay ahead of competition? These are only a few of the unit load carrier options which managers are presented with.

The objective of this paper is to explore the impact of introducing an innovative unit load carrier on different echelons across a retail supply chain. It will also explore the logistics, market, packaging and environmental consequences of introducing an innovative unit load carrier. Moreover, this paper will discuss packaging from a systems perspective, proposing a framework for assessing packaging in retail supply chains. Furthermore, the potential trade-offs between standardised and differentiated packaging solutions will be discussed from a logistics perspective, providing practitioners with a better basis on which to make decisions relating to logistics and to packaging design and development.

As indicated in the objectives, the context of this research is a retail supply chain. The retail industry is probably the largest packaging material consumer in the world, where enormous amounts of packages are procured and handled throughout retail supply chains. The impact of packaging-related decisions can be extremely important in the retail supply chain where the value of goods can be quite low, goods are handled by many parties, there are many products and many levels of packaging, and efficient utilisation of warehouse-, transport-, and shelf-space is vital. These issues constitute excellent reasons for investigating the impact and consequences of introducing an innovative unit load carrier in a retail supply chain.

In the following section, a frame of reference is presented to position the case study in existing literature. This is followed by a presentation of the research method, accompanied by a brief description of the research process. After that follows a description of the innovative unit load carrier and the unit load carriers traditionally used by the case company. The subsequent section describes the impact of introducing the innovative unit load carrier across supply chain echelons, followed by the logistics, market, packaging and environmental consequences. This is followed by a discussion which considers packaging from a systems perspective and a discussion of potential trade-offs between standardised and differentiated packaging from a logistics point of view. In the last section, conclusions are drawn and suggested areas of further research are presented.

Frame of reference

Packaging

Paine (1981) provides a broad and well-established definition of packaging in the three following statements:

(1) Packaging is a co-ordinated system of preparing goods for transport, distribution, storage, retailing, and end use.
(2) Packaging is the means of ensuring safe delivery to the ultimate consumer in sound condition at minimum cost.
(3) Packaging is a techno-economic function aimed at minimising costs of delivery while maximizing sales (and hence profits).

The definition indicates that the fundamental functions packaging must perform are manifold. Paine (1981), Robertson (1990), and Livingstone and Sparks (1994) stress the fundamental functions of packaging: protection, containment, preservation, apportionment, unitisation, convenience, and communication of the product. However, the various functions packaging perform depend on the type of packaging. Johansson *et al.* (1996) and Jönson (2000) classify different types of packaging as primary (consumer and sales packaging), secondary (distribution and multi-unit packaging) or tertiary (transport packaging). Primary packaging is in direct contact with the product, while secondary packaging contains several primary packages. Tertiary packaging, e.g. pallets and roll containers, is an assembly of a number of primary or secondary packages. This classification is used when considering packaging as a system, and illustrates the components and levels of hierarchy in the packaging system (see Figure 1). A systems approach to packaging highlights the interactions and the interdependence between the packaging levels. Thus, the performance of the packaging system is not only affected by the performance of each packaging level, but also by the interactions between the packaging levels.

Packaging influences a number of business and management-related areas. In logistics, packaging is recognised as having a significant impact on the costs and performance of the logistics system (Ebeling, 1990; Fernie and Sparks, 2004; Lancioni and Chandran, 1990). Packaging affects the cost of every logistical activity (Bowersox *et al.*, 2002). Moreover, packaging affects the efficiency of many logistics activities such as transport and warehousing (Ballou, 2004; Fernie and McKinnon, 2003; Lambert *et al.*, 1998). In marketing, packaging is not only a vital tool in the marketing mix (Burt and Davis, 1999; Rod, 1990); Nickels and Jolson (1976) have introduced packaging as a fifth "P" along with the four P's (price, place, product, promotion) in the marketing mix, stressing the importance of packaging in marketing. Environmental aspects, such as the consumption of materials, are also of great importance for packaging (Livingstone and Sparks, 1994). Furthermore, packaging influences product development and design, and production (Bjärnemo *et al.*, 2000; Esse, 1989; Griffin *et al.*, 1985).

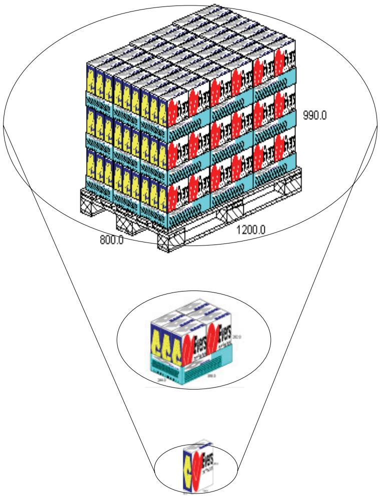

Figure 1. Packaging systems levels.

Due to the diversity of aspects which need to be considered in packaging, trade-offs among the different areas of interest are unavoidable (Bowersox and Closs, 1996; Jahre and Hatteland, 2004; Johnsson, 1998; Livingstone and Sparks, 1994; Prendergast and Pitt, 1996; Robertson 1990). This has made many researchers call for a systems approach to packaging, e.g. Prendergast and Pitt (1996), Saghir and Jönson (2001), Wills (1990). According to Lambert et al., (1998), packaging decisions require the use of a systems approach in order for the "total cost" picture to be understood. However, few firms manage their packaging through a systems approach (Bowersox and Closs, 1996). Coles and Beharrell (1990) state that the problem of meeting the demand for pack innovation and marrying that with a systemic approach to combining distribution requirements along with product requirements needs to be solved. Johnsson (1998) suggests a value-added approach through the integration of packaging and logistics, which can be used to increase the value of the product. A similar approach is proposed by Twede and Parsons (1997) who emphasise that an integrated logistics approach to packaging can yield significant logistics value. However, Johnsson (1998), and Twede and Parsons (1997) conclude that a more holistic view to packaging must be taken. Packaging decision-makers need an approach which carefully considers the total impact and trade-offs of packaging along supply chains in order to avoid sub-optimisations.

Despite the importance of packaging and its significant impact on logistics, research coverage of the area is fragmented (Öjmertz, 1998; Stahre, 1996). In a review of logistics and logistics-related doctorial dissertations Stock (2001) found that "packaging historically has been viewed as having a minor role within logistics, especially from a research standpoint". Saghir (2004) argues that this may depend on the general consideration of packaging as a minor sub-system of logistics, with limited influences on the overall performance of the supply chain. In logistics practice, packaging is often regarded as an unavoidable non-value-added cost containing little to or strategic value (Lockamy III, 1995), resulting in packaging-dependent costs in the logistics system and innovation opportunities frequently being overlooked by packaging and logistics professionals (McGinnis and Hollon, 1978; Twede, 1992).

Packaging innovation

Packaging developments are heavily affected by different trends in today's society. According to Sonneveld (2000) the trends affecting packaging development and use can be divided into four areas: business dynamics of the packaging industry (e.g. mergers/acquisitions, chain integration and material developments), distribution trends (e.g. multinational retailers and market diversification), consumption trends (e.g. domestic/export, demographics and consumptions habits) and legislative frames (e.g. environment, health and safety). Packaging innovation is driven by these trends and firms who can anticipate these rapidly changing trends and who develop appropriate, perhaps very innovative, packaging will certainly obtain significant competitive advantage (Coles and Beharrell, 1990; Rundh, 2005).

Coles and Beharrell (1990) propose that the key factors determining the success of packaging innovation can be unified by being considered as consumer-driven, distribution/logistics-driven and technology-driven. A balance between the three factors is needed to ensure competitive advantage. In technological industries like the packaging manufacturing industry (e.g. packaging material producers and packaging converters), the development and innovation focus has traditionally been technology-oriented. This has led to a product and production orientation within the packaging manufacturing industry resulting in a focus on technical improvements and innovations, while consumer- and logistics-driven developments and innovations have unintentionally been neglected or not prioritised (Olsson, 2006; Paine, 2002). Consumer-driven innovations are less likely to be neglected since primary packaging contains the actual consumer products and provides a motive for a purchase. But as packaging is often regarded as an unavoidable non-value-added cost which has little or no influence on logistics performance, logistics-driven innovations are overlooked. This gap emphasises the need to investigate the opportunity and potential of logistics-driven packaging innovation.

Even though management-related focus on packaging has increased, a review of logistics literature reveals few theoretical contributions in the area of logistics-driven packaging innovations. Furthermore, there are few efforts in relation to its impact on supply chains. One of the contributions to the logistics-driven packaging innovation area is Twede's (1992). Twede explores the process of adopting logistics- driven packaging innovations and discusses the roles played by the supply chain members in the adopting firm. However, in order to introduce logistics-driven packaging innovation, managers need to understand its consequences. The question is not whether one packaging innovation is functionally better than another, but how the packaging in question is congruent with consumer and supply chain requirements and needs. Thus, there is a need to explore the final stage in the innovation-development process, i.e. the consequences. Rogers (2003: 436) states that: "Invention and diffusions are but means to an ultimate end: consequences that result from adoption of an innovation". Rogers argues that in spite of the importance of innovation consequences, they have received relatively little attention.

Innovation has a wide array of definitions. Whetten and Cameron (1998) distinguish between continuous improvement and innovation. In their view, continuous improvement refers to incremental steps, while innovation involves discontinuous changes and breakthroughs. Others, such as Abernathy (1985), would say that incremental steps are also innovation. In this paper, innovation is viewed as the successful exploitation of new ideas, which incorporates new technologies, design or methods. The unit load carrier addressed in this paper is perceived as a new idea and has been successfully introduced in the supply chain of a large global retailer. The carrier is thus referred to as an innovative unit load carrier.

Methodology

The case study research method was chosen in this inductive research, not only due to the novelty of using a innovative unit load carrier, but also to obtain insight into why an innovative unit load carrier is introduced in a supply chain and how it impacts on different echelons across supply chains (Eisenhardt, 1989; Ellram, 1996; Strauss and Corbin, 1998; Yin, 2003). According to Merriam (1994) and Stake (2000), the main reason for conducting case study research is to gain a deep understanding of phenomena by providing a rich description based on a holistic view. In this research, case study provided the opportunity to generate deep insight into the phenomena, producing rich explanations and illustrative examples.

Case selection

An in-depth single case study was conducted at a global retailer and its supply chain. The retailer has introduced a unit load carrier enabling varying unit load dimensions. Introducing a load carrier which enables varying unit load dimensions has had a profound effect on logistics activities since they are heavily influenced by standardised unit load carriers. It was thus of interest to investigate the supply chain impact and consequences of introducing this innovative unit load carrier.

According to Ellram (1996) and Yin (2003), a single case study can be particularly appropriate when the case is unique or extreme. This case is new and unique and reveals a previously inaccessible phenomenon, since the innovative unit load carrier has only been implemented on a large scale at the selected global retailer. In addition, no documented implementations of a similar load carrier have been found. Yin (2003) further stresses the vital importance of selecting cases which serve the specific purpose of the overall scope of the investigation. With an overall aim of exploring interactions between packaging and logistics systems, the supply chain impact and consequences of the innovative unit load carrier proved an interesting case to investigate.

The global retailer – IKEA of Sweden – has been identified as one of the world's best retailers in terms of its position, sales, number of stores, and longevity, and is well known for focusing on packaging issues (Arnold, 2002; Bowersox *et al.*, 2002; Klevås, 2005). The innovative unit load carrier has been used at IKEA since 2001. It is currently (2006) being used for approximately 10 % of the total inbound flow. These numbers, however, are continuously rising and the company expects that more than 50 % of its inbound flow will be on the innovative unit load carrier in the future. In addition to the innovative unit load carrier, IKEA mainly uses four different types of unit load carriers: EUR pallets, half pallets (600 x 800 mm), long pallets (2000 x 800 mm), and corrugated fibreboard pallets. The EUR pallets are managed in an open switch-pool system, while the half and the long pallets are only used and managed internally. These pallets are made of wood, are similarly constructed, and are generally used in European material flows, whereas corrugated fibreboard pallets are mostly used in non-European material flows.

Data collection

The data collection was carried out in two phases, a year apart, in order to achieve a longitudinal perspective on the consequences of introducing the innovative unit load carrier. According to Rogers (2003: 440), the study of innovation consequences requires that "a long-range research approach must be taken in which consequences are analysed as they unfold over a period of time". In the first phase, data were gathered by two investigators using semi-structured interviews, direct observation, and internal documentation over a period of four months at different European sites. A questionnaire was also administered at a distribution centre to obtain the material handlers' opinions on using the new load carrier. A total of fourteen semi-structured interviews were conducted with a broad selection of individuals, ranging from senior management to operational managers. The individuals were not only within the organisation of IKEA but also from a third-party logistics provider operating a distribution centre. This first data collection phase provided insights into the company, how it perceives the issue of packaging, and most importantly of all, information on how it has approached the issue of implementing the innovative unit load carrier. To achieve additional depth in the investigation, the empirical data collected by the two investigators were supplemented a year later with follow-up interviews, observations, and reviews of internal documentations in phase two. This additional data collection focused on further investigation of the consequences and progress of the introduction of the innovative unit load carrier. All data collected were reviewed by a key informant (a senior manager) involved in the implementation process of the new load carrier. The key informant was also helpful in identifying appropriate individuals to participate in the interviews.

The case study protocol is a way of increasing reliability of case study research (Yin, 2003). An outline of the research was developed to function as a case protocol. The outline contained the aim and focus of the research project, the data collection procedure (such as interview guidelines and observation protocols), frame of reference, suggestions for analysis tools, and a time plan. The outline functioned as a protocol, guiding investigators in the data collection process, at the same time keeping the focus on the unit of analysis, i.e. the consequences of introducing the innovative unit load carrier.

The innovative unit load carrier

The innovative unit load carrier consists of one component: a loading ledge, see Plate 1. Several loading ledges are used to construct a unit load carrier. Depending on how the unit load is shaped, loading ledges are placed in different positions beneath the products. Loading ledges are then strapped to the products and stretch film is applied to the unit load, in order to hold and stabilise it. Loading ledges are stackable and made of recyclable polypropylene plastic. They are produced using injection moulding and weigh about 400 g each. A loading ledge can handle up to 2500 kg of static pressure and functions at temperatures of up to 60º C and down to -20º C.

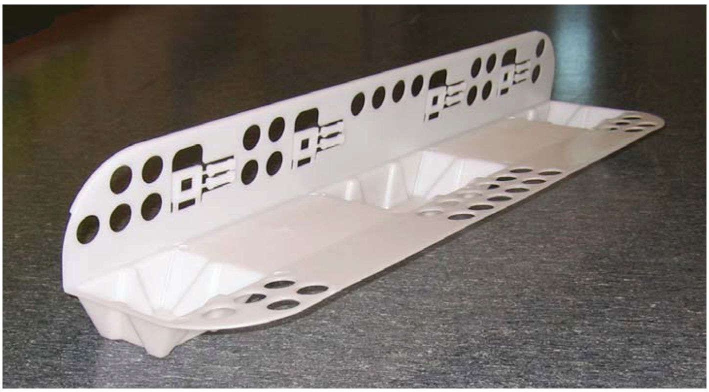

Plate 1. A loading ledge.

For products which are relatively small compared to their unit load dimensions, a supporting platform is needed when loading ledges are used. One way to achieve a supporting platform is to use a particle board as a base for the products, see Figure 2. Using a particle board as a base for the products creates a supporting platform which also increases the stability of the unit load and the protection it offers.

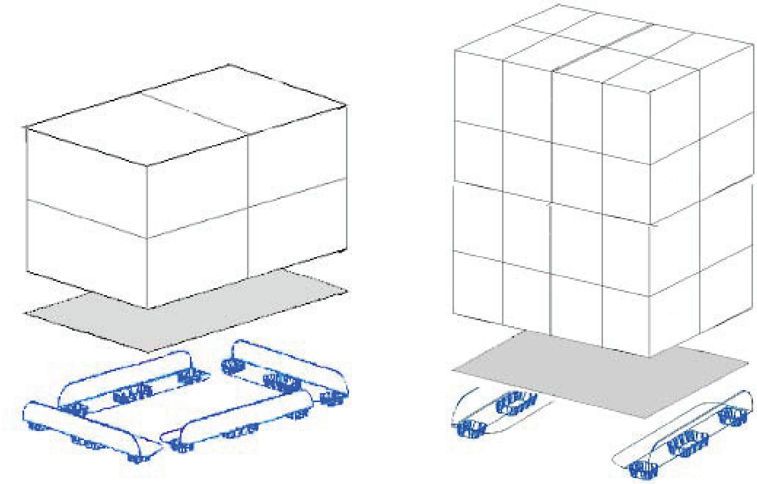

Figure 2. Illustration of how to use particle boards as supporting platforms.

Differences among unit load carriers

There are numerous designs and sizes of unit load carriers. In retail supply chains they are traditionally designed to meet specific performance requirements and are based on standard dimensions such as the EUR pallet (1200 x 800 mm) or the 48 x 40 inches (1219 x 1016 mm) pallet. Other common types of load carriers are slip-sheets and various non-standardised solutions such as corrugated fibreboard pallets.

The main differences between using loading ledges and a traditional pallet are that loading ledges allow for varying size and design. Traditional unit load carriers have fixed dimensions so that the products and the packaging are designed and made according to these. The use of loading ledges offers the opportunity to adjust the unit load dimensions to specific needs and requirements. For example, instead of the product dimensions being modified to fit the load carrier, the load carrier is adjusted to fit the products. Another difference is that loading ledges do not construct a self-supporting unit load carrier. The load-bearing support of the unit load comes from the products. For products which are non-supporting, it is essential that the packaging system provides the supporting platform. Moreover, loading ledges occupy a height of 45 mm on a unit load, while a wooden pallet occupies a height of 145 mm.

Material properties also generate differences in unit load carrier characteristics. Plastic is a relatively expensive material, but can be shipped all over the world without border restrictions or extra treatment considerations, which is the case with packaging material made of wood. Corrugated fibreboard is obtainable all over the world but is sensitive to humidity, which negatively influences the load-bearing qualities and stability of corrugated fibreboard pallets.

Case study findings

The in-depth case study offered significant insights into the supply chain impacts of introducing the innovative unit load carrier, allowing key consequences of the innovative unit load carrier to be identified. The impact on different echelons across the supply chain is presented in the next sections, followed by a description of the logistics, market, packaging, and environmental consequences of introducing the innovative unit load carrier.

Manufacturers

For manufacturers, the shift from traditional unit loads carrier to loading ledges has made them change existing palletising equipment or invest in new. Automated palletising machines have been implemented in the existing production line at some manufacturers. Given the low cost of labour, some manufacturers prefer manual palletising where a packaging fixture is used to strap loading ledges to the products. In automated production lines, a result of using loading ledges instead of wooden pallets is that of fewer stops in production. The wooden pallets are often rejected due to their poor quality and this halts production.

For some manufacturers, the introduction of loading ledges has enabled them to serve all markets with one type of unit load carrier. A manufacturer often serves different markets and each has its preferences for the unit load carrier. The European market prefers the EUR pallet, which is not an option for other markets, such as those of North America and Southeast Asia. Thus, the manufacturer needs to have different types of unit load carriers for different markets. Introducing loading ledges has made it possible for some manufacturers to serve all markets with one type of carrier, which simplifies their production and planning and reduces inventory.

Transport

Using loading ledges provides an opportunity to increase cube utilisation of transport units (railway wagon, container and trailer). Traditional unit load carriers sometimes limit the cube utilisation of transport units because they are not always compatible with the dimensions of the products, as they create empty spaces between unit loads in transport units. Loading ledges allow unit load dimensions to be adjusted to the products, eliminating empty spaces.

The increase in cube utilisation depends on the design of the product and on the mode of transport. For shipments where the regulated weight limit is reached, cube utilisation may increase by 3 % when wooden pallets are replaced by loading ledges, since loading ledges are lighter. Adjusting the unit load carrier to the dimensions of the product has also resulted in less damage to products. Fewer empty spaces between the unit loads have led to less movement within the transport unit, which in turn has decreased the risk of damaging goods. In order to illustrate the impact on transport when loading ledges are used, an example will be described and evaluated.

One group of high-volume products at IKEA is made up of the "600-millimetre products". These include products such as wardrobes, cabinets and bookcases which have a width of 600 millimetres and a length of up to 2.45 metres. The long pallet was traditionally used as the load carrier for these products. However, this left empty spaces between the unit loads in transport units, resulting in poor utilisation of the transport volume and risking product damage due to movement in transport units. With four loading ledges strapped to products forming the unit load, the empty spaces between the unit loads are eliminated. Figure 3 illustrates a total filling increase of 44 %. The average increase in cube utilisation, however, is about 26 % for the 600-millimetre products. The filling increase is due to both the elimination of empty spaces between units and the utilisation of the space previously taken up by pallets.

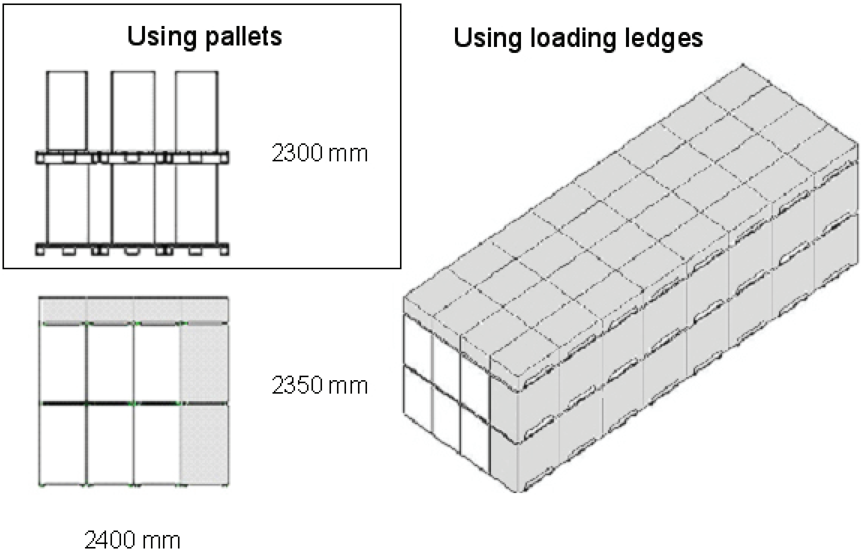

Figure 3. Illustration of a 44 % filling increase of a container.

IKEA currently has an annual volume of three million cubic metres of 600-millimetre products. If loading ledges were used on all these products, and assuming a 20 % average increase of cube utilisation, this would result in 600 thousand cubic metres less transport volume per year. This is equivalent to ten thousand 12-metre trailers.

Distribution centres
The introduction of loading ledges has had a detrimental effect on operations at distribution centres. Warehouse and material-handling systems, such as storage rack configurations, fork-lifts trucks and conveyors are designed for standardised wooden pallets and do not tolerate varying dimensions of unit loads enabled by loading ledges. Adjusting infrastructure (e.g. automated warehouse systems) at distribution centres to loading ledges is currently not economically possible. So in order to handle loading ledge units at distribution centres, IKEA currently has to strap these units to wooden pallets. Doing so is an additional, time-consuming activity. To reduce extra handling time, automated strapping equipment was introduced at distribution centres. Furthermore, loading ledge units on wooden pallets occupy more storage space and consequently this led to reduced utilisation of the warehouses. One instance where loading ledge units are not strapped to wooden pallets is when they are stored in block storage systems, where they increase storage space utilisation by eliminating empty spaces between units.

Strapping loading ledge units to wooden pallets is the same handling procedure as when dealing with corrugated fibreboard pallets, but requires less handling time. A majority of the non-European material flows use corrugated fibreboard pallets and are transported by sea. This frequently means that the corrugated fibreboard pallets collapse during transport due to humid transportation conditions. Loading ledges offer better protection from humidity and fork-lift handling, facilitating a more efficient unloading process at distribution centres.

Other types of material-handling equipment and policies are needed to ensure more efficient handling of loading ledge units than when wooden or corrugated fibreboard pallets are being handled. Fork-lift trucks have been equipped with spread shifters since loading ledge units have varying dimensions. The fork-lift trucks were also equipped with longer, thinner forks in order to get underneath loading ledges. Handling loading ledge units also requires other material-handling policies. For example, a wooden pallet is of robust construction and can therefore be handled carelessly. It is not possible to do this with loading ledge units without a high risk of causing damage to the products. It is thus vital that all material handlers are aware that loading ledge units need to be handled more gently. In the process of introducing loading ledges, ensuring acceptance from the material handlers was a critical and fraught process.

Retail stores

Introducing loading ledges has not yet had any significant impact on stores. This is because the stores receive loading ledge units placed on pallets from the distribution centre. IKEA stores are built and designed, just like distribution centres, to handle wooden pallets. Consequently, stores do not have the material-handling equipment for receiving or handling loading ledge units. In addition, the stores are limited in the time available to unload and replenish goods since this is restricted to closing hours. This results in stores not having the time to place loading ledge units on pallets, as distribution centres do. Consequently, handling loading ledge units is an activity stores currently do not have the capability to carry out.

However, IKEA plans to significantly increase the amount of direct deliveries to its stores. This means that the stores need to be able to handle an assortment of load carriers, such as loading ledges, and not just wooden pallets. To accommodate different unit load carriers at its stores, IKEA is working intensively with its material-handling equipment suppliers to modify and develop material-handling equipment which can be used to handle different unit load carriers.

A great potential in using loading ledges at stores is to improve the display function and the sales area scenery. A majority of the received goods are directly transported to the sales area in the stores. Currently, this results in a sales area with wooden pallet scenery. IKEA has developed various packaging sale solutions where loading ledges are integrated into trays and display packaging, improving the display function and the sales area scenery. However, this is a potential the company has not been able to take advantage of since its stores handle loading ledge units strapped to pallets.

Recycling/return system

Loading ledges are used once and are then ground down into plastic pellets. Instead of selling the pellets or using them as raw material for new loading ledges, IKEA produces consumer products from the pellets. The choice not to use the pellets to produce new loading ledges ensures that the physical properties and quality of loading ledges are maintained.

It is, however, technically possible to reuse loading ledges. This would require that the rotation of reused loading ledges would have to be administered and managed in a return system. Compared to the wooden pallet return system (which costs about 30-35 million Euros every year for IKEA), loading ledges would drastically reduce return transports and the need for storage space since they occupy much less space. An ordinary trailer has the capacity to carry approximately 50 unit loads or 500 EUR pallets or 34,000 loading ledges, i.e. one transport in every eleven is a return transport using EUR pallets compared to one in every two hundred when loading ledges are reused.

Logistics consequences

Introducing loading ledges has influenced logistics activities along the whole supply chain. Some parts of the supply chain have benefited at the expense of others. From a logistics perspective, the major benefit is the increase in cube utilisation of transport units, while the main drawback is additional time-consuming activities at distribution centres. However, a rough estimate indicates that the current annual decrease of transport costs (more than two million Euros) is more than ten times greater than the cost of additional handling at distribution centres. Using loading ledges has also cut costs associated with return handling and decreased the rate of damage to goods. However, policy, and process changes, and investments in material-handling equipment have been required throughout the supply chain in order to accommodate loading ledge units.

By introducing loading ledges, IKEA has decreased its dependence on standardised pallets. From a material-handling point of view the wooden pallets are outstanding since the logistics system – infrastructure, equipment and processes – is designed to handle these pallets. The integration of pallets in the logistics system involves a risk for companies in not being able to adapt to new situations and needs. For IKEA, globalisation is a central source of change which has led to longer transport distances. This has caused a need for more efficient transports where loading ledges provide an opportunity to increase cube utilisation of transport units.

Market consequences

An underlying reason to introduce loading ledges was to be able to meet new needs and requirements from different markets, which would assist IKEA in reaching and sourcing in new markets. For example, a third of its material flow originates from markets where the use of wooden pallets is not a viable choice. Here, loading ledges represent an alternative option to corrugated fibreboard pallets. Moreover, loading ledges are an additional option in the choice of load carriers, enabling the company to give more consideration to differences in infrastructure and equipment between markets. Using loading ledges instead of wooden pallets also avoids the regulatory requirement of the International Standard for Phytosanitary measures, which place requirements on wood packaging material to reduce the risk of introducing and/or spreading pests.

Having the capability to physically shape the unit load by using loading ledges has facilitated the introduction of new products. One example, partly due to loading ledges, is the introduction of bamboo flooring manufactured in Southeast Asia. The weight of the bamboo rules out the use of corrugated fibreboard pallets. The width of the bamboo floorboards is designed to fit with loading ledges in order to achieve a stable unit load and high cube utilisation of transport units. This has facilitated the introduction of bamboo flooring to the European market.

Packaging consequences

Introducing loading ledges has had far-reaching consequences on packaging systems. Using loading ledges has resulted in new requirements but also enables more freedom in product and packaging design. Traditionally, product development has been constrained by the fixed dimensions set by standardised unit load carriers. Using loading ledges places fewer restrictions on product development as less consideration is given to the dimensions of load carriers. In packaging design, loading ledges represent a new alternative in choosing a unit load carrier. Using loading ledges results in fewer restrictions in constructing unit loads, as it enables packaging engineers to construct unit loads adjusted to other needs, such as transport. Instead of being constrained by the dimensions of the load carrier, the creativity of product designers and packaging engineers who use loading ledges is guided by the product, the logistics processes, and the markets.

A fundamental requirement when using loading ledges is that the products and the packaging solutions have to form a self-supporting construction and function as bearing support for the unit load. It is thus important that the packaging does not contain empty spaces, as loading ledges make the products and the packaging together bear the weight of the unit load. Empty spaces in packaging do not only reduce load-bearing capacity, they also increase material, transport and storage costs. Furthermore, they involve a risk of packaging shifting and collapsing, which increases the risk of product damage. From a logistics point of view, empty spaces in packaging are something which should be eliminated, whether loading ledges are used or not. When using loading ledges for products which are non-supporting, it is essential that the packaging solution can carry the weight of the unit load. Due to this packaging requirement, a first step in introducing loading ledges might be on self-supporting products with poor utilisation of the existing transport unit.

For products which are relatively small compared to their unit load dimensions, a supporting platform is needed when loading ledges are used. IKEA uses particle board for this purpose. Generally, the company uses particle board or corrugated fibreboard as protection between unit load carriers and products. Consequently, the use of particle boards is not something new for IKEA.

Environmental consequences

The environmental impact of packaging is an increasingly important issue for businesses (Livingstone and Sparks, 1994). Using loading ledges instead of wooden pallets has the potential to reduce the environmental impact of transport. A life-cycle assessment comparing the environmental performance of using loading ledges and EUR pallets indicated that there are irrelevant differences in the environmental impact (Strömberg *et al.*, 2003). Even though the assessment referred to a situation where loading ledge units are strapped to pallets at distribution centres, it concluded that the mode of transport is a much more important aspect to consider than type of unit load carrier. However, the life-cycle assessment measured the environmental transport impact per tonne-kms. This does not include the capability to increase the cube utilisation of transport units, which reduces the amount of vehicle movement, i.e. vehicle-kms. Hence, loading ledges themselves do not make a smaller environmental footprint than the EUR pallet, but enable higher cube utilisation of transport units, which in turn reduces the environmental impact of transport. Prendergast and Pitt (1996) suggest that making packaging more environmentally friendly does not necessarily involve logistics or marketing trade-offs. The introduction of loading ledges demonstrates that the logistics consequences are of prime concern when the environmental impact of packaging is being assessed. A more environmentally friendly packaging system does not necessarily lead to reduced overall environmental impact, nor does a less environmentally friendly one necessarily lead to increased overall environmental impact. Understanding packaging interactions and consequences is therefore necessary when assessing the environmental impact of the packaging.

Packaging from a systems perspective

The multiple consequences of introducing the innovative unit load carrier illustrate and emphasise the need for a systems perspective in order to understand the total impact of packaging on supply chains. The case study findings indicate that a limited way to assess a unit load carrier, or any packaging for that matter, is to compare its basic functions (e.g. material cost, machinability, handleability, protection, volume and weight efficiency) with other load carriers. The question is not whether one unit load carrier is functionally better than another, however. It has to be assessed with respect to its impact along supply chains. Assessing a unit load carrier from a systems-oriented perspective aims to assess the overall system which consists of a set of sub-systems (packaging, logistics, marketing and environment) which are connected. The strength of a unit load carrier in one sub-system may be a weakness in another. This means that there are not only different “best” unit load solutions for different packaging systems but also different “best” solutions for different logistics systems, marketing systems and the environment. The "total value" a unit load carrier contributes to a supply chain therefore depends on how it interacts with the various sub-systems. Consequently, a fundamental aspect in assessing packaging is the careful consideration of its interacting systems and the consequences on these. However, this is a difficulty for decision-makers since there are extensive interactions to be considered.

A systems perspective to on logistics-driven packaging innovation emphasises the need to consider the interactions between packaging and logistics systems. Understanding these interactions facilitates decisions such as changing packaging system or logistics system, or both, to increase supply chain performance. However, decisions concerning logistics-driven innovations are often made in relation to the existing logistics system. Coles and Beharrell (1990) state "With high distribution costs, increased profitability from product and pack innovation can be wiped out immediately if new packaging units do not fit in easily with existing distribution systems". Since logistics systems are often based on handling standardised unit load carriers and altering this implies many other changes, packaging innovations which question standardised unit load carriers are often considered as unfeasible. The case study demonstrates the opportunity and potential of logistics-driven packaging innovation which does not fit in easily with existing logistics or packaging systems and therefore require changes in both systems. It was thanks to these changes being conducted that the innovative unit load carrier improved supply chain performance

To support packaging decision-making, the case study findings are used to propose a framework for assessing packaging in retail supply chains, see Figure 4. Packaging systems influence all retail supply chain echelons; from the product-filling point at the manufacturer's, where the product is merged with primary packaging, to distribution centres and retail stores, where the products are sold to the end consumer, and eventually to recycling or return handling. Horizontal packaging assessments identify the impact of packaging on different supply chain echelons. However, summarising these impacts would not generate an assessment of the total impact of packaging. The case study findings indicate that to assess the total impact of packaging the consequences on interacting sub-systems also need to be identified. To do this vertical assessments are needed. However, the interacting sub-systems must be considered as a "whole", rather than dividing packaging, logistics, marketing and the environment into separate systems which are assessed on their own, and assuming that the "whole" is the sum of the systems.

Sub-systems / Supply chain echelons	Packaging	Logistics	Marketing	Environmental
Manufacturer				
Transportation				
Distribution centre				
Retail store				
Consumer				
Recycle/return system				

Vertical assessment

Horizontal assessment

Figure 4. A framework for packaging assessments in retail supply chains.

The strength of vertical assessments is that they span the boundary of retail supply chain organisations. However, it seems that this strength is also a weakness. Organisational borders need to be considered if incentive alignments, e.g. risks and gains, among retail supply chain organisations are to be considered. An aspect which distinguishes the retail case company selected is that it has control over the supply chain – from the supplier to the consumer. For example, it does most of the product development and packaging design in house but does not generally have its own manufacturing facilities. This enabled the company to identify the opportunity to change its packaging and logistics systems to accommodate and introduce the innovative unit load carrier. This is in line with Twede's (1992) findings that vertically interacted companies seem to adopt logistics-driven packaging innovations more easily. Twede also found that the company which makes the packaging decisions tends to consider disposal costs less, the further downstream the disposal occurs. This means that the boundaries of retail supply chain organisations are vital aspects when logistics-driven packaging innovations are assessed and adopted. In conclusion, even though vertical and horizontal packaging assessments overlap, the combination of the assessments provides a comprehensive assessment of packaging in retail supply chains, taking into account the impact across supply chain echelons, organisational borders and the consequences on interacting sub-systems.

Trade-offs between standardised and differentiated packaging

Decision-makers need to find means for meeting different and conflicting packaging needs and requirements, but must often prioritise whether to provide a standardised or a differentiated packaging solution. The case study findings indicate that from a logistics perspective, this decision is a tough compromise between facilitating an integrated or a flexible system, and improving compatibility or performance of the packaging system.

Integration versus flexibility

From a packaging trade-off perspective, Jahre and Hatteland (2004) point out that standardisation of packaging facilitates integrated systems, which in turn facilitate co-ordination of activities and more efficient processes. However, a possible drawback of standards is the "lock-in" effect (David and Greenstein, 1990), which is the inflexibility in that once a dominant technology begins to emerge it becomes more "locked in" (Arthur, 1989) over time. This inflexibility may not only be caused by the standard itself, but by the interactions of the standard with other standards and resources (Fabbe-Costes *et al.*, 2006). The "lock-in" is also evident when firms have heavy and numerous investments in a particular standard, leaving them with little interest in abandoning it (Brunsson and Jacobsson, 2002). Standardisation facilitates integrated systems, but also leads to less flexibility with regard to change, thus hindering further development and innovations.

The trade-off between facilitating an integrated or a flexible system is particularly evident in the case of introducing the innovative unit load carrier. Standardised load carriers, such as the EUR pallet, are often seen as the obvious choice in order to achieve an efficient logistics system when the logistics system is based on handling these standardised unit load carriers. For IKEA, the introduction of the innovative unit load carrier is a step towards not becoming "locked in". The innovative unit load carrier increases the adaptability of IKEA's packaging system, making it more adaptable to different logistics activities and markets. Furthermore, the innovative unit load carrier offers more freedom in product and packaging design, since the product does not have to fit certain fixed dimensions set by traditional carriers. To attain this flexibility, investments have to be made. Manufacturers, carriers, distribution centres, and stores had to modify or change their material-handling equipment, processes and policies to some extent to accommodate different unit load carriers, at times resulting in great financial and organisational impacts.

Even though major investments had to be agreed upon throughout the supply chain, the difficulty of introducing the innovative unit load carrier was to ensure acceptance from end users, such as material handlers. For the majority of the users, standardised unit load carriers were often instinctively considered as the best and the given choice. Twede (1992) describes the same phenomenon regarding secondary packaging: “when people think of shipping containers, they think of corrugated fiberboard boxes”. This indicates that the “lock-in” effect not only applies to technology, but to the mindset of organisations.

Compatibility versus performance

A unit load carrier such as the EUR pallet, is a typical logistics and packaging standard. From a logistics point of view, standards are solutions for improving operational compatibility and facilitating co-ordination. However, Shapiro and Varian (1999) indicate that during the development of a standard, a trade-off between “compatibility” and “performance” often has to be made. An organisation can either choose to develop a new and better technology, in which users will have to change or replace existing equipment, or it can choose compatibility, i.e. a standard which fits the existing equipment, but which will probably not be the “best”. Thus, in deciding standardised or differentiated packaging, it is not only the packaging system that is of interest, but also how it interacts with logistics systems, markets and its impact on the environment.

The packaging trade-off between compatibility and performance is unambiguous in the introduction of the innovative unit load carrier. For packaging engineers, the new load carrier represents an alternative to the traditionally used unit load carriers. The aim of introducing the innovative unit load carrier is not to replace a specific unit load carrier, but to use the innovative unit load carrier in material flows where the total value (e.g. protection, cube utilisation, handling efficiency, machinability) exceeds that of other unit load carriers. Combining the use of different unit load carriers, IKEA is able to choose the one which offers the best total value. This means that even if a standardised and integrated unit load carrier system leads to efficient logistics activities, the flexibility of using alternative load carriers generates an opportunity to improve overall supply chain performance. It is not strictly a question of using a standardised or a differentiated packaging system, but the combination of both, which IKEA uses in order to improve supply chain performance.

Taking advantage of different unit load carriers to improve the performance of supply chains may involve combining the use of several carriers. For some products and material flows, a solution might be to use more than one type of load carrier. For example, one of the greatest gains of using the innovative unit load is in long-distance transports, while standardised wooden pallets are superior from a material-handling point of view since warehouses and stores are built to handle them. Combining these, as IKEA does, can result in greater improvements in supply chain performance than using the innovative unit load carrier or wooden pallet alone.

Conclusions and further research

New demands due to changes in consumptions and distribution trends require innovative packaging solutions in retail supply chains. This paper makes a modest, but important, contribution to the understanding of the opportunity and potential of logistics-driven packaging innovation in retail supply chains. The case study findings provide insights into the multiple logistics, market, packaging and environmental consequences of introducing an innovative unit load carrier. These insights will hopefully trigger new ideas and concepts among managers, promoting packaging and logistics innovation processes in retail supply chains.

This paper also contributes to the understanding of potential trade-offs between standardised and differentiated packaging solutions, providing practitioners with a better basis for making decisions on packaging design and development. The case study findings indicate that from a logistics perspective, the decision to provide a standardised or a differentiated packaging solution is a tough compromise between facilitating an integrated or a flexible system, and improving compatibility or performance of the packaging system. The findings also indicate that in order to improve supply chain performance it is not strictly a question of using a standardised or a differentiated packaging system, but the combination of both. However, in order to provide greater understanding of the packaging trade-offs between standardisation and differentiation, more in-depth studies on standardisation and differentiation of packaging solutions are needed.

This paper indicates that packaging should not be considered as a sub-system of logistics or marketing, but a strategically important area which contributes to overall supply chain performance. In addition to being an important cost driver/reducer, packaging must also be considered as a tool for achieving competitive advantage and a source of profit. The contribution of the packaging system to satisfying needs and adding value to supply chain members, as well as the end consumers, is a key factor in ensuring competitive advantage, profit, and overall supply chain efficiency and effectiveness. Even though the multiple consequences of introducing the innovative unit load carrier illustrate the need to consider packaging as a strategic supply chain component, further research into the strategic impact of packaging on supply chains is needed. A suggestion for further research is to identify and outline different packaging strategies in order to increase the understanding of the strategic impacts of packaging.

Since packaging decisions such as introducing a innovative unit load carrier can impact on several supply chain echelons and several functions within those echelons, it is necessary to use a supply chain and a cross-functional approach to make strategic packaging decisions. To support packaging decision-making, this paper proposes a framework for assessing packaging in retail supply chains. Horizontal packaging assessments identify the impact of packaging on different supply chain echelons, while vertical packaging assessments identify the logistics, marketing, packaging and environmental consequences of packaging. The case study indicates that the combination of the assessments provides a comprehensive assessment of packaging in retail supply chains, taking into account the impact across supply chain echelons, organisational borders and the logistics, marketing, packaging and environmental consequences.

References

Abernathy, W. J. (1985), "Innovation: Mapping the winds of creative destruction", *Research Policy*, Vol. 14 No. 2, pp. 3-22.

Arnold, S. J. (2002), "Lessons learned from the world's best retailers", *International Journal of Retail & Distribution Management*, Vol. 30 No. 11, pp. 562-570.

Arthur, W. B. (1989), "Competing Technologies, Increasing Returns, and Lock-In by Historical Events", *The Economic Journal*, Vol. 99 No. 394, pp. 116-131.

Ballou, R. H. (2004), *Business Logistics/Supply Chain Management: Planning, Organizing, and Controlling the Supply Chain*, 5th ed., Pearson Prentice Hall, New Jersey.

Bjärnemo, R., Jönson, G., and Johnsson, M. (2000), Packaging Logistics in Product Development. Proc, International Conference on Computer Integrated Manufacturing (ICCIM 2000) Singapore, pp. 135-146, 28-30 March 2000.

Bowersox, D. J. and Closs, D. J. (1996), *Logistical Management, The integrated supply chain process*, McGraw-Hill, New York.

Bowersox, D. J., Closs, D. J., and Cooper, M. B. (2002), *Supply Chain Logistics Management*, McGraw - Hill / Irwin, New York.

Brunsson, N. and Jacobsson, B. (2002), *A World of Standards*, Oxford University Press, London.

Burt, S. and Davis, S. (1999), "Follow my leader? Lookalike retailer brands in non-manufacturer-dominated product markets in the UK", *The International Review of Retail, Distribution and Consumer Research*, Vol. 9 No. 2, pp. 163-185.

Coles, R. C. and Beharrell, B. (1990), "Packaging Innovation in the Food Industry", *British Food Journal*, Vol. 92 No. 9, pp. 21-31.

David, P. A. and Greenstein, S. (1990), "The economics of compatibility standards: An introduction to recent research", *Economics of Innovation and New Technology*, Vol. 1 No.1, pp. 3-41.

Dicken, P. (2003), *Global Shift - Reshaping the global economic map in the 21st century*, 4th ed., Sage Publications Ltd, London.

Ebeling, C. W. (1990), *Integrated packaging systems for transportation and distribution*, Marcel Dekker, New York.

ECR Europe (1997), *The Efficient Unit Loads Report*, ECR Europe, Brussels.

Eisenhardt, K. M. (1989), "Building Theories from Case Study Research", *Academy of Management Review*, Vol. 14 No.4, pp. 532-550.

Ellram, L. M. (1996), "The use of case study method in logistics research", *Journal of Business Logistics*, Vol. 17 No. 2, pp. 93-138.

Esse, R. L. (1989), "Package Development, Manufacturing, and Distribution Strategy Considerations", in Harckham, A. W. (Ed.), *Packaging strategy - meeting the challenge of changing times*, Technomic Publishing AG, Lancaster, pp. 107-116.

Fabbe-Costes, N., Jahre, M., and Rouquet, A. (2006), "Interacting standards: a basic element in logistics networks", *International Journal of Physical Distribution & Logistics Management*, Vol. 36 No. 2, pp. 93-111.

Fernie, J. and McKinnon, A. C. (2003), "The grocery supply chain in the UK: improving efficiency in the logistics network", *The International Review of Retail, Distribution and Consumer Research*, Vol. 13 No. 2, pp. 161-174.

Fernie, J. and Sparks, L. (2004), "Retail Logistics: changes and challenges", in Fernie, J. and Sparks, L. (Eds.) *Logistics and Retail Management: Insights into Current Practice and Trends*, Kogan Page, London, pp. 1-25.

Forcinio, H. E. (2005), "New Systems for Counterfeit Protection and Quality Control", *Pharmaceutical Technology*, Vol. 29 No. 6, pp. 34-40.

Griffin, R. C. Jr., Sacharow, S., and Brody, A. L. (1985), *Principles of Package Development*, 2nd ed., Van Nostrand Reinhold Company, New York.

Jahre, M. and Hatteland, C. J. (2004), "Packages and physical distribution: Implications for integration and standardisation", *International Journal of Physical Distribution & Logistics Management*, Vol. 34 No. 2, pp. 123-139.

Johansson, K., Lorentzon, A., Olsmats, C., and Tiliander, L. (1996), *Förpackningslogistik*, Packforsk, Kista.

Johnsson, M. (1998), "Packaging Logistics - a value added approach", PhD thesis, Division of Packaging Logistics, Lund University, Lund.

Jönson, G. (2000), *Packaging Technology for the Logistician*, 2nd ed., Division of Packaging Logistics, Lund University, Lund.

Klevås, J. (2005), "Organization of packaging resources at a product-developing company", *International Journal of Physical Distribution & Logistics Management*, Vol. 35 No. 2, pp. 116-131.

Koehorst, H., De Vries, H., and Wubben, E. (1999), "Standardisation of crates: lessons from the Versfust (Freshcrate) project", *Supply Chain Management: An International Journal*, Vol. 4 No. 2, pp. 95-101.

Lambert, D. M., Stock, J. R., and Ellram, L. M. (1998), *Fundamentals of Logistics Management*, McGraw-Hill Higher Education, London.

Lancioni, R. A. and Chandran, R. (1990), "The Role of Packaging in International Logistics", *International Journal of Physical Distribution & Logistics Management*, Vol. 20 No. 8, pp. 41-43.

Livingstone, S. and Sparks, L. (1994), "The New German Packaging Laws: Effects on Firms Exporting to Germany", *International Journal of Physical Distribution & Logistics Management*, Vol. 24 No. 7, pp. 15-25.

Lockamy III, A. (1995), "A conceptual Framework for assessing strategic packaging decisions", *The International Journal of Logistics Management*, Vol. 6 No. 1, pp. 51-60.

McGinnis, M. A. and Hollon, C. H. (1978), "Packaging: Organization, Objectives and Interactions", *Journal of Business Logistics*, Vol. 1 No. 1, pp. 45-62.

Merriam, S. B. (1994), *Fallstudien som forskningsmetod*, Studentlitteratur, Lund.

Nickels, W. G. and Jolson, M. A. (1976), "Packaging - the fifth 'P' in the marketing mix", *S.A.M. Advanced Management Journal*, Vol. 41 No. 4, pp. 13-21.

Öjmertz, B. (1998), "Materials Handling from a Value-Adding Perspective", PhD thesis, Chalmers University of Technology, Gothenburg.

Olsson, A. (2006), "The change from feature focus to customer focus in packaging development", PhD thesis, Division of Packaging Logistics, Lund University, Lund.

Paine, F. (2002), "Packaging Reminiscences: Some thoughts on controversial matters", *Packaging Technology and Science*, Vol. 15 No. 4, pp. 167-179.

Paine, F. A. (1981), *Fundamentals of Packaging*, Brookside Press Ltd, Leicester.

Prendergast, G. and Pitt, L. (1996), "Packaging, marketing, logistics and the environment: are there trade-offs?", *International Journal of Physical Distribution & Logistics Management*, Vol. 26 No. 6, pp. 60-72.

Robertson, G. L. (1990), "Good and Bad Packaging: Who Decides?", *International Journal of Physical Distribution & Logistics Management*, Vol. 20 No. 8, pp. 37-41.

Rod, S. (1990), "Packaging as a Retail Marketing Tool", *International Journal of Physical Distribution and Logistics Management*, Vol. 20 No. 8, pp. 29-30.

Rogers, E. M. (2003), *Diffusion of Innovations*, 5th ed., Free Press, New York.

Rundh, B. (2005), "The multi-faceted dimension of packaging - Marketing logistic or marketing tool?", *British Food Journal*, Vol. 107 No. 9, pp. 670-684.

Saghir, M. (2004), "A platform for Packaging Logistics Development - a systems approach", PhD thesis, Division of Packaging Logistics, Lund University, Lund.

Saghir, M. and Jönson, G. (2001), "Packaging Handling Evaluation Methods in the Grocery Retail Industry", *Packaging Technology and Science*, Vol. 14 No. 1, pp. 21-29.

Schary, P. B. and Skjoett-Larsen, T. (2001), *Managing the Global Supply Chain*, 2nd ed., Copenhagen Business School Press, Copenhagen.

Shapiro, C. and Varian, H. R. (1999), "The art of standards war", *California Management Review*, Vol. 42 No. 2, pp. 8-32.

Sonneveld, K. (2000), "What drives (food) packaging innovation?", *Packaging Technology and Science*, Vol. 13 No. 1, pp. 29-35.
Stahre, F. 1996, "Små returlastbärare i logistikkedjor - införande och effekter", Licentiate thesis, Linköping University, Linköping.
Stake, R. E. (2000), "Case Studies", in Denzin, N. K. and Lincoln, Y. S. (Eds), *Handbook of Qualitative Research*, 2nd ed., Sage Publications, London, pp. 435-453.
Starkey, W. G. (1994), "Transit packaging - a global view", *Packaging Technology and Science*, Vol. 7 No. 1, pp. 3-10.
Stock, J. R. (2001), "Doctorial research in logistics and logistics-related areas: 1992-1998", *Journal of Business Logistics*, Vol. 22 No. 1, pp. 125-257.
Stock, J. R. and Lambert, D. M. (2001), *Strategic Logistics Management*, 4th ed., McGraw-Hill Higher Education, New York.
Strauss, A. and Corbin, J. (1998), *Basics of qualitative research*, 2nd ed., Sage Publications, Thousand Oaks CA.
Strömberg, K., Fröling, M., and Berg, H. (2003), *Comparative LCA of Loading Ledge and Wooden Pallet*, CIT Ekologik AB, Gothenburg.
Torstensson, H. (1999), "Damage analysis on transport packaging", *Technology, Law and Insurance*, Vol. 4 No. 3, pp. 181-190.
Twede, D. (1992), "The process of logistical packaging innovation", *Journal of Business Logistics*, Vol. 13 No. 1, pp. 69-95.
Twede, D. and Parsons, B. (1997), *Distribution packaging for logistical systems - A literature review*, Pira International, Surrey.
Whetten, D. A. and Cameron, K. S. (1998), *Developing Management Skills*, 4th ed., Addison-Wesley, Reading MA.
Wills, G. (1990), "Packaging as a Source of Profit", *International Journal of Physical Distribution and Logistics Management*, Vol. 20 No. 8, pp. 5-20.
Yin, R. K. (2003), *Case Study Research: Design and Methods*, 3rd ed., Sage Publications, Thousand Oaks CA.

PAPER III

The cost and process of implementing RFID technology to manage and control returnable transport items

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The cost and process of implementing RFID technology to manage and control returnable transport items

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The purpose of this paper is to explore and describe the costs and process of implementing RFID technology to manage and control the rotation of returnable transport items. Due to the novelty of using RFID in logistics and supply chain management, in-depth case studies were conducted at two global firms in the retail industry to investigate how and why organisations implement and assess RFID technology. These case studies provide insights into how RFID benefits have been attainable in practice, and indicate that the cost of introducing RFID technology is not generally a barrier. As a result, this paper proposes an inductively derived stage model of the RFID implementation process. In it, implications for management are identified and discussed to guide managers in the process of implementing RFID technology.

Keywords: Implementation; Radio Frequency Identification; Case study, Logistics, Packaging

1 Introduction

Logistics and supply chain management are heavily influenced by the rapid development of new technology, especially within the area of information technology (IT), as exemplified by the Internet and Electronic Data Interchange (Bowersox and Closs 1996; Coyle et al. 1996; Lambert et al. 1998). However, the development of technologies and systems for logistics information is ongoing, and the interest in advanced automated data capture and identification (Auto-ID) technologies, particularly radio frequency identification (RFID), has increased greatly. RFID technology has been a 'hot' topic during the last couple of years in the logistics and supply chain management community. RFID is the generic name for technologies which use radio waves to transfer data between a reader and a tag attached to an item to be identified. Compared to bar codes, the main strengths of RFID are that an RFID tag can be read through non-metallic obstructions not requiring line-of-sight, and that an RFID reader has the ability to read several tags simultaneously. Hence, RFID technology can potentially provide real-time information to manage operations and enable supply chain visibility. Sheffi (2004) provides a more detailed overview of the advantages of RFID technology over bar code systems, and Finkenzeller (2003) provides an introduction to the functionality of RFID technology and the physical principles involved.

The interest in RFID technology shown by industry and the scientific community partly originates from the mandates made by the US Department of Defense and large international retailers, such as Wal-Mart, Tesco and Metro. These retailers have announced that their suppliers need to apply RFID tags on tertiary (pallet) and secondary (case, tray) packaging levels in the near future. This has made researchers and practitioners believe that over the next few years, RFID will be widely and rapidly implemented throughout supply chains to the same extent as bar coding is used today. Research also claims that advanced Auto-ID technologies such as RFID, have the potential to improve supply chain efficiency and effectiveness as well as to restructure supply chains (Kambil and Brooks 2002; Kärkkäinen and Holmström 2002; Kärkkäinen 2003). Furthermore, it has

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been argued that introducing RFID represents an opportunity to improve inventory management, returns management, tracking and tracing systems, process control, security, sales, and enhance consumer experiences (McFarlane and Sheffi 2003; Jones et al. 2004; Fleisch and Tellkamp 2005; Lumsden and Acharjee 2005; Smith 2005; Wong and McFarlane 2007).

However, despite all the potential supply chain benefits and opportunities, some researchers and practitioners are not sure whether RFID will be widely and rapidly adopted; see for example the opinions expressed by respondents in Lieb and Bentz' (2005) survey. There are several adoption barriers to realizing supply chain benefits, including the cost and the performance of the technology, standards and privacy issues (Fusaro 2004; Lai et al. 2005). The main barrier to adoption, however, is probably not the technology but the mindset which still prevails in many organisations. A wide adoption of RFID technology along supply chains is likely to depend on the ability of organisations to share vital information with other members of the supply chain, and on their ability agree upon how they can share the costs and benefits of RFID technology. The scepticism towards RFID technology also highlights the fact that the descriptions of how benefits are attainable in practice are often unclear, and that the process and cost of implementing the technology have been omitted from the explanations. However, there are other logistics applications for RFID technology than the supply chain application pursued by retailers, i.e. applying disposable RFID tags on tertiary and secondary packaging. One example is closed-loop applications, which have different potential benefits and barriers to the application pursued by retailers.

RFID technology in closed-loop systems currently has fewer adoption barriers than supply chain applications. In closed-loop applications, organisations might avoid barriers such as sharing costs and benefits, the need for universally adopted standards, and sharing 'sensitive' information among supply chain members. Furthermore, these applications may currently have a greater payback potential, as the RFID tag is less of a cost issue when it is continuously used in a closed loop. This indicates that closed-loop applications are a feasible starting point for organisations during the process of getting started with RFID and trying to adopt the technology involved.

One general group of closed-loop applications is tracking returnable transport items, e.g. roll cages, pallets, totes, crates and dollies. Returnable transport items have increasingly been introduced in various industries. The operational benefits, such as providing better protection for products, improving working environments, enabling more efficient handling and cube utilisation, reducing packaging material, have made firms invest in returnable transport items (Witt 1999; Maloney 2001; Twede and Clarke 2004). Even though returnable transport items are often of high value, vulnerable to theft, and critical for production and distribution, they are often managed with limited visibility or control (McKerrow 1996; Twede 1999; Witt 2000). In a survey of 233 enterprises in consumer-oriented industries undertaken by Aberdeen Group (2004), one quarter of the respondents report that they lose more than 10 % of their returnable transport item fleet annually, with 10 % of the respondents losing more than 15 %. RFID technology might enable firms to manage and control the rotation of these returnable transport items more efficiently, and to reduce the loss by providing increased supply chain visibility.

Several firms have reported implementation of RFID technology in order to track returnable transport items. Marks & Spencer, for example, has announced that it uses RFID to track 3.5 million returnable food produce delivery trays throughout its supply and distribution network, thereby allowing the company to speed up its supply chain and reduce errors. Volkswagen uses RFID to track 10 000 containers in order to achieve visibility, and to improve container availability (Roberti 2005). Tesco has announced that it has revised its plan to tag trays of high-value goods, deciding instead to tag its returnable transport items delivered to retail outlets from distribution centres (Collins 2006). Moreover, an RFID benchmark study undertaken by LogicaCMG (2004) concluded that in European retail supply chains it is not a question of whether RFID will be adopted in returnable transport items; it is a question of when and how. However, empirical research covering implementations of RFID technology to track returnable transport items is surprisingly scarce. According to Angeles (2005) there is a need to carry out research on the actual achievement of the promises of RFID, and to understand effective implementation strategies.

The purpose of this paper is thus to explore and describe the costs and process of implementing RFID technology to manage and control the rotation of returnable transport items. This paper proposes an inductively derived stage model of the RFID implementation process and suggests practical implementation guidelines in order to promote the implementation of RFID technology in logistics applications. The focus of this paper is on an RFID trial conducted by IKEA and an RFID implementation conducted by Arla Foods. Consequently, it provides insights into how RFID benefits have been attainable in practice.

Following the logic of induction, the remainder of the paper is organised as follows. In the next section, the methodology used in this research is presented. The subsequent section contains a description of IKEA's RFID trial followed by a description of Arla Foods' RFID implementation. In section five, an empirically based stage model of the RFID implementation process is proposed and is accompanied by a discussion of implications for managers in the different stages of the implementation process. In section six, the estimated implementation costs for IKEA and the cost of Arla Foods' implementation are discussed. Concluding remarks and directions for further research are presented in the last section.

2 Methodology

A salient feature of this research is its inductive methodology inspired by grounded theory (Glaser and Strauss 1967; Strauss and Corbin 1998). Inductive research has its stating point in empirical data and tends to proceed from data to theory (i.e. method, data, findings, theory), while deductive research has its stating point in existing theory and literature and tends to proceed from theory to data (i.e. theory, method, data, findings). Deductive research primarily tests existing theory, whereas inductive research primarily generates new theory (Gummesson 2000). Inductive methodology was viewed as appropriate because the research purpose is a description of an emerging empirical topic, of which comparatively little is known, in order to provide preliminary explanations and descriptive inference (King et al. 1994).

2.1 Research method

The case study research method was chosen in this inductive research, not only due to the novelty of using RFID in logistics and supply chain management, but also to obtain insight into how and why organisations implement and assess RFID technology (Eisenhardt 1989; Ellram 1996; Strauss and Corbin 1998; Yin 2003). In-depth case studies were conducted at two global firms in the retail industry to study the use of RFID technology in managing and controlling returnable transport items. One case study focuses on an RFID trial conducted by IKEA, while the other focuses on an RFID implementation conducted by Arla Foods. From the results of these in-depth case studies this research is able to provide insights into the cost and process of implementing RFID technology and suggests guidelines for management in implementing the technology. Data access was the major reason why these two particular case studies were chosen. Both companies agreed to share and display the data necessary to study the phenomenon under investigation. Today, several companies are conducting trials and even implementing RFID, but, the insights are often confidential to some extent since the insights are considered as competitive advantages. Another reason for choosing these case studies was that unlike many companies conducting RFID projects in the retail industry, IKEA and Arla Foods RFID projects were not driven by mandates. The companies chose to carry out RFID projects based on the practical benefits and opportunities they saw RFID could provide. Even though this research explores a trial and an implementation of RFID technology in the retail industry, the problem of managing and controlling the rotation of returnable transport items is widespread within various industries. Brief descriptions of the case study firms can be found in the appendix.

2.2 Data collection

Multiple sources were used to gather data in the research, and included a series of semi-structured interviews, archival records and documentation. Furthermore, the two companies allowed the researcher to observe their operations which were related to their respective RFID applications. In total, four semi-structured interviews were conducted with key staff involved in IKEA's trial or Arla Foods' implementation. In the IKEA case, interviews were carried out with the project manager and the business developer who initiated and managed the trial. In the Arla Foods case, interviews were carried out with the logistics manager and the project manager responsible for the RFID implementation. The four respondents were the only ones who were highly involved in their respective RFID projects. More than 40 open-ended questions were used in the interviews. Each interview lasted four to five hours and was recorded. Within days of each interview it was transcribed. The transcription was reviewed and commented on by the respondent. To complement the interviews, the respondents were contacted via telephone or e-mail and asked questions which had been overlooked during the interview. A draft of the interview questions was used in a pilot interview; this was then refined as questions were added, deleted and modified.

2.3 Data analysis

The data based on organisations' actual experiences, were subjected to within-case and cross-case analysis, according to the guidelines set out by Huberman and Miles (1998) and Yin (2003). The within-case analysis resulted in two detailed case study descriptions; one for each case study. The written case descriptions helped the author to cope with the analysis of the large volume of data, and were central in generating insights into each case. The case study descriptions were also validated by the respondents to construct validity. The within-case analysis was the most inductive phase of the research. As much as possible, the author let the data speak for themselves and allowed the patterns of each case to emerge from the data before patterns between the two cases were identified in the cross-case analysis. The idea behind the cross-case analysis was to look beyond initial impressions and see the data through multiple lenses (Eisenhardt 1989). To do this thoroughly, and in accordance with Eisenhardt's (1989) recommendations, the author related emerging patterns to existing literature on technology implementation. During the investigation a case study research protocol was used to construct reliability (Yin 2003). Figure 1 is an attempt to illustrate the different steps taken during the research process.

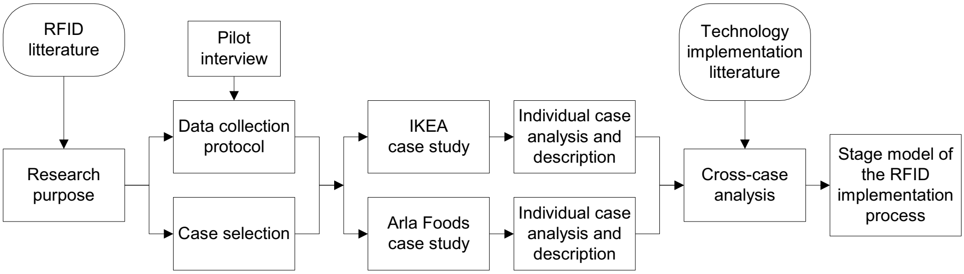

Figure 1. An overview of the research process.

2.4 Point of departure in technology implementation literature

The literature on implementation of technology is both voluminous and heterogeneous (see Meredith (1981), Ives and Olson (1984), and Tornatzky and Fleischer (1990) for reviews). Quite often, implementation literature focuses on how certain classes of technological, organisational and implementation factors affect implementation. For example, there are numerous studies which look at the effects of user participation (Franz and Robey 1986; Baronas and Louis 1988; Tait and Vessey 1988), technology complexity (Pelz 1983; Chen 2005), organisational receptivity towards change (Zmud 1984; Holahan et al. 2004) or top management support (Cheney et al. 1986; Reich and Benbasat 2000) in the implementation of some form of technology. Moreover, there is literature which focuses on how certain technology implementation is affected by different factors. For example, in the implementation of RFID software at four large US rail companies, Williams and Rao (1998) found that understanding software benefits, demand drivers, organisational openness, and positive evaluation of the software are important factors.

However, these kinds of factor studies provide little understanding of basic activities and structure underlying implementation processes, which is needed in order to create a more cumulative body of knowledge in the implementation area of a specific technology. Goodman and Griffith (1991) stress the need for researchers to apply a process perspective to a specific technology and context in order to obtain insights, and generate propositions and explanations about implementing new technology. Accordingly, a process perspective was applied in the cross-case analysis to the implementation of RFID technology in the context of managing and controlling returnable transport items.

The process perspective is found in some implementation research. Choi and Liker (1992) use a process perspective to examine the adoption of work-place ergonomics at an automobile manufacturing firm. Goodman and Griffith (1991) use a process perspective to understand the implementation of a vision system. Cooper and Zmud (1990) use a process perspective to chart the adoption and implementation of material requirements planning systems. They propose a comprehensive stage model of the IT implementation process founded on Kwon and Zmud's (1987) model of IT implementation activities which is organised around organisational change, innovation, and technology diffusion literatures. This stage model is presented as initiation, adoption, adaptation, acceptance, routinisation and infusion. Since Cooper and Zmud's stage model is comprehensive and concerns IT such as RFID, it was used as a framework for the cross-case analysis and as a foundation for the RFID implementation model to be proposed later on in the paper.

3 IKEA's RFID trial

The purpose of the trial was to gain insights into RFID technology and see if the technology could be used in tracking steel containers to improve the process of managing and controlling the rotation of steel containers. By conducting an RFID trial, IKEA also aimed to gain an understanding of how to set up an RFID implementation to track roll containers. The reason why IKEA wants to track steel containers is that it has difficulties managing and controlling the rotation of steel containers. Roughly 10 % of its steel containers are lost annually.

The steel containers are used in the distribution process of delivering products directly home to end-consumers, see figure 2. The steel containers are managed in a transfer system, where IKEA is responsible for administration, monitoring (accounts), cleaning, maintenance and storage. The drawback of the transfer system is the lack of consensus among the supply chain members (i.e. the logistics provider operating the customer distribution centre [DC] and transport providers) about how much is received and shipped. The RFID trial was restricted to the customer DC.

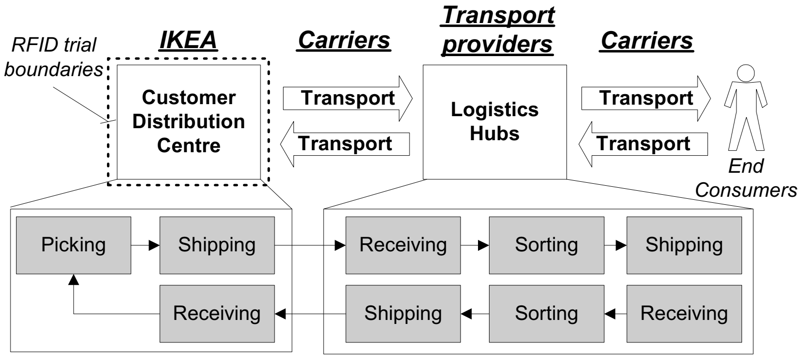

Figure 2. The rotation of steel containers.

3.1 *The trial process*

The RFID trial was conducted in two steps: (1) Choosing system integrator and RFID system components and (2) Trial design and set-up.

3.1.1 Choosing system integrator and RFID system. To select an RFID system for the trial IKEA invited a couple of system integrators to present their RFID equipment. IKEA had two major requirements; the system integrators had to be able to supply equipment according to a time schedule, and the RFID system had to be based on the Electronic Product Code^{TM} (EPC) standard. The latter requirement was based on the fact that IKEA considers the EPC standard to have the greatest potential of becoming a global standard, which is a prerequisite for the company in a wider implementation perspective where RFID is adopted throughout its supply chain. Only one system integrator was able to meet the requirements. This system integrator and IKEA jointly decided which RFID components (tags, readers and antennas) were to be used in the trial. The tags chosen to be used in the trial were EPC tags class 0. These tags contain a unique 96-bit identification number, are passive, read-only, and operate at Ultra High Frequency (UHF). Furthermore, the tags were embedded in rubber to protect and improve tag performance in metal environments. Availability and the design of the tag for metal environments were the reasons for selecting this type of tag. A stand-alone information system was used in processing the data collected from the tags, i.e. the data were not integrated with any Warehouse Management System (WMS) or Enterprise Resource Planning (ERP) systems.

3.1.2 Trial design and set-up. In order to track steel containers IKEA wanted to verify how many steel containers leave the customer DC and where they are going, and how many steel containers are received and from whom. Based on this, IKEA decided to test portal readers positioned at a shipping gate and at a receiving gate. A reader was also positioned at a wrapping machine in order to evaluate the scenario of only having RFID readers at the wrapping machines, instead of having readers at shipping gates.

In the trial approximately 300 steel container components were tagged. A steel container consists of two components; a platform and side bars. Depending on what products a steel container is supposed to contain and protect, different side bars are placed in different positions on a platform. With the tagged steel container components, different sets of handling units representing the units handled in each reading location were put together and tested. At the shipping gate and the wrapping machine steel containers containing products were tested. When steel containers are received, they are stacked into compact units. These units were tested at the receiving gate.

Moreover, in the trial numerous tag locations on the steel container components were tested. The four major aspects taken into consideration when decisions were taken on the location of the tags were; facilitate a high reading rate, protect the tag from being damaged, the tag should be replaceable, and cost of applying the tag.

3.2 Trial outcome

The trial indicated that the RFID system could be used to track steel containers. For the steel container platform, the reading rate at the three reading locations was about 100 %. The tag was attached underneath the platform on a supporting beam, protecting the tag. Four tag locations were tested on side bars. All four locations provided a reading rate of approximately 100 % at the shipping gate and at the wrapping machine. However, at the receiving gate there were difficulties obtaining readings from the tagged side bars since metal caused interference and blocked the radio waves. For readings to be obtained from the side bars at the receiving gate, the tags had to be attached to the outer surface of the side bars. However, tags positioned on the outer surface of the side bars would not last long, as the side bars are roughly handled. For readings to be obtained from the side bars at the receiving gate with tags attached on a protected position, the receiving process needs to be changed. Two different solutions were put forward; constructing an RFID tunnel, or manually using handheld portable RFID readers. However, neither of these suggestions was tested in the trial.

In order to obtain a high reading rate at the shipping gate, the portal reader had to have four antennas; two on each side. At the receiving gate a portal reader had to have five antennas in order to achieve a high reading rate; two on each side and one at the top. At the wrapping machine two antennas were sufficient for a high reading range to be obtained.

3.3 Estimated implementation costs

For the company to understand the magnitude and perhaps even justify an RFID investment at the customer DC, the payback period for such an investment was estimated. Payback calculations were estimated by IKEA in conjunction with the system integrator and were based on cost of investment (hardware, system integration, and trial cost), running cost (cost associated with replacing damaged hardware, system maintenance, and operating the system) and running profits. The running profit from an RFID investment was based on the assumption that it would eliminate the annual loss of steel container components, which is roughly 10 %. Implementing an RFID system would not itself eliminate the loss of steel containers components, but it would enable IKEA to invoice those who lose the steel container components. Table 1 presents the payback calculations for two investments scenarios. The calculations indicated that the payback period would be in the region of 15 to 23 months depending on the investment scenario. In a scenario where all steel container components are tagged and readers are installed at the four receiving gates and at the eight wrapping stations the payback period would approximately be 15 months. However, IKEA favours the idea of having readers at the shipping gates instead of at the wrapping stations since it is at the shipping gates that the responsibility for the steel containers is transferred to the transport providers. In such a scenario, i.e. readers are installed at all the 59 shipping gates instead of at eight wrapping stations, the payback period would approximately be 23 months.

Table 1. Payback period for the two investment scenarios at IKEA's customer DC.

	Readers at wrapping stations			Readers at shipping gates		
	Amount	Cost (€)		Amount	Cost (€)	
Hardware						
Tags for container platform	16 000	1.5	24 000	16 000	1.5	24 000
Tags for container side bars	64 000	1.5	96 000	64 000	1.5	96 000
Readers at receiving gates						
Process units	4	1 000	4 000	4	1 000	4 000
Antennas	20	500	10 000	20	500	10 000
Readers at wrapping machines						
Process units	8	1 000	8 000	-	-	-
Antennas	16	500	8 000	-	-	-
Readers at shipping gates						
Process units	-	-	-	59	1 000	59 000
Antennas	-	-	-	236	500	118 000
Servers	3	900	2 700	3	900	2 700
Cables		4 000	4 000		20 000	20 000
System integration						
Man-hours for hardware installation	1 500	20	30 000	2 500	20	50 000
Man-hours for software development	1 350	120	162 000	1 350	120	162 000
Man-hours for software installation	450	120	54 000	450	120	54 000
Trial			20 000			20 000
Cost of investment			422 700			619 700
Replacing hardware						
Tags for platform	400	1.5	600	400	1.5	600
Tags for side bars	1 000	1.5	1 500	1 000	1.5	1 500
Reader process units	1	1 000	1 000	4	1 000	4 000
Reader antennas	10	500	5 000	20	500	10 000
Man-hours for hardware replacement	20	40	800	100	40	4 000
System maintenance						
Software licence			20 000			20 000
Software development			10 000			10 000
Operating the system			15 000			20 000
Running costs			53 900			70 100
Decrease in container platform loss: 10%	1 600	170	272 000	1 600	170	272 000
Decrease in container side bar loss: 10 %	6 400	20	128 000	6 400	20	128 000
Running profit			400 000			400 000
Payback period (years)			1.2			1.9

4 Arla Foods' RFID implementation

The primary purpose of the RFID implementation was to track roll containers in order to improve the process of managing and controlling the rotation of the roll containers. The secondary purpose was to gain experience of, and insights into, RFID technology. The implementation involves tracking 6 000 roll containers circulating in a closed loop between a dairy DC and retail outlets, see figure 3. Tracking the 6 000 roll containers is the first phase of a larger implementation which aims to track 26 000 roll containers at four dairy DCs.

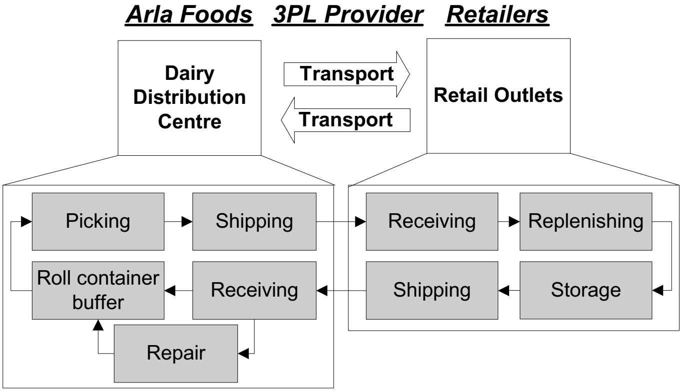

Figure 3. The rotation of the new roll containers.

4.1 The implementation process

Arla Foods' implementation process can be divided into six sequential and pragmatic steps: (1) Problem identification (2) Concept development and system design (3) Cost-benefit analysis (4) Trial (5) Choosing system integrator (6) Getting the system up and running.

4.1.1 Problem identification. Arla Foods has experienced difficulties in managing and controlling the rotation of roll containers. Arla Foods suspects that roughly 10 % of its 80 to 100 thousand traditional roll containers are lost annually due to theft and misplacement. The 6 000 new roll containers are specifically designed to be used in the distribution of low-volume dairy products and are more liable to be stolen since they are more useful than traditional roll containers. Based on its experience of using of the traditional roll container Arla Foods has estimated that twice as many new roll containers would be lost, compared to loss of the traditional roll container, i.e. 20 % annually. To decrease the predicted loss of the new roll containers, Arla Foods needed to improve the process of managing and controlling the rotation of the new roll containers. The question was then; how could this be done?

4.1.2 Concept development and system design. Different ways of managing and controlling the rotation of the new roll containers were explored. One proposal was to manage and control the roll container in a rental system. However, such a system would require additional administration, additional work for the lorry drivers, and would not be appreciated by the customers. Consequently, a rental system was rejected by Arla Foods.

A suggestion was put forward to track the roll containers by identifying them at two locations; in the receiving process at the dairy DC and in the picking process at the dairy DC. This solution appealed to Arla Foods since the roll container flows from the retail outlets converge into a single receiving location, i.e. all roll containers have to physically pass through a roll container washing machine when they are received. Furthermore, the roll container flow diverges after the picking process, i.e. all roll containers pass through a roll container station in order to be used in the distribution to retail outlets. As all roll containers have to pass through these two physical locations, Arla Foods would relatively easily be able to identify and link roll containers to specific customers/routes in the picking process, and identity and link the received roll containers to the dairy. This would in turn enable Arla Foods to obtain information about which roll container and how many roll containers are located at the dairy or at specific retail outlets. The data gathered would enable Arla Foods to identify where roll containers are lost and a discussion could be initiated with those who lose or misplace roll containers. In addition to the two identification locations, an identification location at the repair shop was suggested. At the repair shop the damaged roll containers would be identified and linked to the repair shop. The type of damage and repair to each roll container would be recorded in the system enabling Arla Foods to identify the underlying cause of damaged roll containers.

In order to track roll containers some kind of Auto-ID technology is needed. Using bar codes to identify the new roll containers would enable Arla Foods to track roll containers. However, scanning bar codes is a time-consuming activity which requires considerable human effort. Bar codes are also easily damaged due to rough handling of roll containers. According to Arla Foods, scanning bar codes is regarded by some workers as laborious. As a result, workers do not always scan the bar codes, which undermines the reliability of the system. These bar code drawbacks led to Arla Foods' interest in exploring alternative Auto-ID technologies.

4.1.3 Cost-benefit analysis. To find out if RFID was an economically viable choice of technology, a cost-benefit analysis was estimated based on the suggested system design. The analysis indicated a payback period of approximately 14 months (see table 2). The total cost of the investment was estimated at approximately 300 000 Euro. The investment costs included RFID hardware costs, attaching a tag to 26 000 roll containers, and installing three readers (a reader is composed of a process unit and an antenna) and a reader station (rails which antennas are mounted on) at each of the four dairy DCs which would use the roll container. The costs also included the development and installation cost of the software (middleware) which integrates the RFID system with Arla Foods' WMS and ERP systems. The cost of the trial and cost of training operational staff was also included in the RFID investment cost.

The total running profit of the investment was estimated at approximately 265 000 Euro annually. As mentioned earlier, Arla Foods expected that up to 20 % of its 26 000 roll containers would be lost annually. However, it was not assumed that an RFID system would eliminate the whole loss. Arla Foods made a moderate estimation that the loss would decrease by at least 7.5 %, which equals approximately 234 000 Euro annually. A decrease in tied-up capital was also included in the running profit. The RFID system enables Arla Foods to increase its control of the roll containers, resulting in the possibility of reducing the number of roll containers needed. An assumption was made that 20 % fewer roll containers will be needed and with an interest rate of 5 %, the decreased tied-up capital was estimated at approximately 30 000 Euro annually. In the payback analysis below, the cost of plastic plates is included. The need for the plastic plates is something that was discovered in the next implementation step; the RFID trial.

Table 2. Payback analysis for Arla Foods' RFID investment at the four dairy DCs.

	Amount/dairy	Total amount	Cost (€)	Total cost (€)
Hardware				
Tags		26 000	1.0	26 000
Plastic plate		26 000	0.8	20 800
Reader process units	3	12	2 000	24 000
Reader antennas	3	12	1 000	12 000
Reader stations	3	12	500	6 000
Servers	1	4	3 000	12 000
System integration				
Man-hours for tag installation		2 200	37.5	82 500
Man-hours for reader installation	25	100	40	4 000
Software development, installation		1	75 000	75 000
Trial				30 000
Training operational staff				10 000
Cost of investment				302 300
System maintenance and support				10 000
Running costs				10 000
Decrease in roll container loss: 7.5%		1 950	120	234 000
Decrease in tied-up capital: 20%		5 200	5% of 120	31 200
Running profit				265 200
Payback period (years)				1.2

4.1.4 RFID trial. Based on the short payback period and its interest in RFID technology, Arla Foods carried out an RFID trial in real conditions at a dairy to ensure that the technology could really be used to identify roll containers. Two different RFID systems, operating on 125 kHz and 13.56 MHz frequency, from two different system integrators, were evaluated in the trial. An RFID system operating on UHF was not evaluated in the trial because the performance of these systems was considered comparatively low in environments dominated by metals, liquids, shifting temperatures and rough handling, such as in Arla Foods' dairy. The trial indicated that the two different systems were essentially equivalent; both had a reading rate of approximately 100 % and a reading range which was sufficient for Arla Foods needs. Different tag locations and ways of attaching a tag to a roll container were also investigated in the trail. From a reading rate perspective the wheel house turned out to be the best location. An advantage of applying the tag to the wheel house is that the wheel (including the wheel house) is a standardised roll container component, also used by Arla Foods' traditional roll containers, which is easily replaced.

The 125 kHz RFID system was made up by passive read-only tags containing a unique 64-bit identification number. In ideal conditions these tags has a reading range of 250-300 mm. However, the tag is not specifically designed to be applied to metal, such as roll containers. So in order to use the tag, a plastic plate was constructed onto which the tag was fitted. On the roll container the plastic plate creates a distance between the tag and the metal, facilitating a reading range of approximately 100 mm from an antenna. With the relatively short reading range of approximately 100 mm, antennas were mounted on rails which the roll container is rolled through so that the tag attached to the roll container can be read.

4.1.5 Choosing system integrator. Based on the outcome of the trial and the short payback period, Arla Foods decided to implement an RFID system operating on 125 kHz frequency. This system was slightly more robust than the 13.56 MHz system and meant slightly lower costs. Four system integrators submitted an offer for supplying the RFID system. The system integrator chosen installed the hardware and fine-tuned the system in order to ensure high system performance. The RFID tag was applied to the roll containers during the production of the roll containers. The software which collects, processes and transfers the information from the RFID system to WMS and ERP systems was specifically developed for Arla Foods' needs.

4.1.6 Getting the system up and running. Problems were encountered when getting the RFID system up and running. However, the problems were not caused by the RFID system itself. The major problems were co-ordination and synchronisation with other projects. The RFID system was introduced at the same time as a new WMS was introduced. The RFID system components were installed, tested and ready to be used, but the start-up of the new WMS did not go as planned. This forced the dairy to prioritise on implementing and getting the WMS to function properly. This resulted in the RFID system being gradually introduced in different phases. Another problem in the implementation was gaining acceptance for the system from the dairy organisation, particularly from the pickers and their managers. In situations where the dairy had difficulties meeting deadlines, linking roll containers to customers/routes was neglected since it was seen as an unnecessary and time-consuming activity. This ruined the whole idea of the implemented system. Arla Foods tackled the lack of acceptance by informing the staff involved about the importance of linking roll containers to customers/routes and by providing them with training. Time studies were also performed to illustrate that linking roll containers does not take much more additional time.

4.2 Outcome of the implementation

Introducing the roll container involved a risk of losing one in five roll containers annually, and after having the RFID system running for more than a year hardly any roll containers have been lost. The elimination of the expected loss has mainly been due to people's awareness that the roll containers are tracked using RFID rather than as a result of actual action from Arla Foods. This awareness of the system has made the dairy organisation, lorry drivers and customers pay more attention to rules and procedures concerning the control of roll containers.

An outcome of the implementation is that there have not been any technology-oriented problems with the RFID system, even if it has been used in an environment dominated by metals, liquids and rough handling. The RFID system has almost a 100% reading rate and the RFID tag is more durable than the roll container. Another insight is how RFID and bar code technology complement each other. Apart from an RFID tag, all the roll containers have a bar code label which is used as a backup and for performing spot checks on customers who may have difficulties in returning roll containers.

However, in Arla Foods' view, the greatest value of the implementation has not yet been explored, i.e. the opportunity the system offers in improving the process of managing and controlling the rotation of roll containers. In order to do this Arla Foods needs to learn and gain understanding about the rotation of the roll containers by analysing and interpreting the data collected from the system implemented. Based on the accumulated data so far, Arla Foods has been able to learn the fundamentals of the rotation of the roll containers, for example, the distribution of the roll container cycle time. However, cycles and demand variations of roll containers related to weekends and holidays are still unexplored. It is these aspects which are important in order for the company to plan how many roll containers are needed in stock and to be able control the roll container flow between retail outlets and dairies. Other accumulated, as yet unexplored, data are the repair data.

5 A model of the RFID implementation process

In order to maximise the benefits of RFID investments, firms must understand and manage their implementation processes. It is important to improve our understanding of these processes since the strategic impact of RFID technology will be conditioned by its implementation. To do this, a stage model of the RFID implementation process is suggested in table 3 and it is one which can be used as a guide for managers implementing RFID technology to manage and control returnable transport items. The model is based on Cooper and Zmud's (1990) model of the IT implementation process, and on the grounded data from IKEA and Arla Foods' actual RFID trials and implementation experiences. The model summarises in stages the various insights which have been induced from the data. In the model the different stages involve practical activities, which may occur in parallel and in an iterative way. For example, if a cost-benefit analysis indicates too few benefits, one should go back to the initial stage involving concept development and system design step.

Table 3. Model of the RFID implementation process.

Stage	Activity description	Reason/motivation
Initiation	*Problem identification:* Identify the problem/opportunity and define an objective	Focuses efforts
	Concept development and system design: Develop different concepts of how to solve the problem. The concepts lead to different system designs which may have different information and technology needs	Find solutions and a match between business processes and technology
Adoption	*Cost-benefit analysis:* The result of the concept development and system design is assessed economically	Define and compare benefits and costs
	RFID trial: The technology is tested and put though its working environment in order to verify that it works as anticipated	Test and verify technology performance
Adaptation	*Choose system integrator:* Based upon software and hardware requirement, cost etc., system integrator(s) are chosen.	Purchase software and hardware
	Installation: Software is development and installed. Hardware is installed and adjusted. Business processes are changed and employees are trained in the new processes	Put the system in position ready to be used
Acceptance	*Education and training:* Inform, train and discuss with employees and end-users about the use and usefulness of the system	Gain organisational support
	Communication: Communicate with all involved organisations about the use and implication of the system	Gain organisational acceptance and awareness
Routinisation	*Improvements:* Perform installation changes to accommodate employee's needs and improve the level of automation and performance of the implemented system	Encourage the usage of the implemented system and increase performance and automation levels
	Process the collected data: Analyse and interpret the data accumulated from the system	Improve decision making
Infusion	*Expand the implementation:* Use the implemented system infrastructure for other applications	Gain benefits which were previously too expensive, risky and difficult
	Transfer the technology: Use the knowledge attained regarding the technology involved	Generate spin-offs in other applications/problem areas

Just like IT implementations in general, RFID implementations are expensive, risky and difficult due to their complexity, both technically and in the organisational issues they involve. IKEA's trial and Arla Foods' implementation shed light upon some technological and organisational issues which are involved in the process of implementing RFID. These technological and organisational issues indicate that managing organisational interactions in RFID implementations is as important to implementation success as ensuring technology integrity. In the subchapters below various insights and implications for management identified in the different stages are discussed. The author cites some of the available technology implementation literature relevant to the different implementation stages, recognising that he is just scratching the surface and apologises for omitting any notable papers in the process.

5.1 Initiation

RFID technology does not itself bring benefits; it is in the interaction with business processes that benefits are attained. One can too easily be blinded by the functionalities and the extensive opportunities offered by RFID technology, causing one to focus on the technology and overlook the business processes. Performing an RFID implementation for the sake of technology may end up in a business application with limited benefits. The role of IT such as RFID, in a business process should be considered in the early stages of process design (Venkatraman et al. 1993; Chan 2000). Davenport and Short (1990) postulates that IT should be view as more than an automation or mechanizing force, since it can fundamentally reshape the way business is done. So thinking about RFID should be in terms of how it supports new business processes, and business processes should be considered in terms of the capabilities RFID can provide. Thus, an important ingredient in performing an RFID implementation is obtaining a match between RFID technology and business processes.

IKEA conducted its trial with the overall purpose of gaining insights into RFID technology, which led to the trial being very technology oriented. The trial indicated that the technology could be used to track steel containers, and that the payback for such an investment would probably be less than two years. However, conducting the trial raised several questions concerning how RFID can support new business processes. For example, being able to track each individual steel container would enable IKEA to manage the rotation of steel containers differently, for example, by using a rental system or a switch pool system. Moreover, tagging every steel container component, i.e. all the platforms and side bars, might be unnecessary. The platform is a fundamental component of the steel container and without the platform the side bars are practically useless. Hence, preventing the loss of steel container platforms might indirectly mean that fewer side bars are also lost. Consequently, it might be enough to tag the steel container platforms in order to reduce the loss of steel containers. These questions concerning how RFID supports new business processes need to be addressed and considered before IKEA implements any Auto-ID technology.

Arla Foods performed its RFID implementation based on its business processes needs and on the capabilities RFID can provide. The overall purpose was to track the roll containers in order to improve the process of managing and controlling them. RFID was the Auto-ID technology chosen to do the job of identifying roll containers, resulting in the project becoming an RFID implementation project. For Arla Foods one implementation success factor was obtaining a match between RFID technology and the business processes, i.e. RFID technology facilitated and supported the new business processes.

5.2 *Adoption and adaptation*

Conducting a cost-benefit analysis and a trial are important activities when adopting RFID. According to Petroni (2002) the utilisation of a cost-benefit analysis is an important success factor in implementing information technology. A cost-benefit analysis helps to define and compare benefits and costs and serves as an aid to decision making (Zerbe and Dively 1994). Both IKEA and Arla Foods conducted a cost-benefit analysis to estimate the RFID investment payback time. For Arla Foods the cost-benefit analysis was an important activity in order to obtain top management support for continuing the implementation. For IKEA the analysis was primarily a way to understand the tangible benefits and costs associated with an RFID investment. However, one should bear in mind that there are intangible benefits, such as sociotechnical (staff satisfaction) and strategic (development of competencies) outcomes which are difficult to include in a cost-benefit analysis. IKEA and Arla Foods did not include any strategic benefits in their cost-benefit analyses, even though gaining competence concerning RFID technology was an important part of the RFID projects.

Conducting a trial is an activity which facilitates the adoption of innovations (Rogers 2003) such as RFID. A trial makes it possible to experiment on a limited basis and is one way for an individual to find out how it works under specific conditions (ibid. 2003). Performing an RFID trial plays an important role in helping those who want to adopt it reduce the perceived complexity of the technology. RFID is a novel and complicated technology with numerous internal and external interdependences. Both IKEA and Arla Food conducted an RFID trial to verify that RFID technology could be used to track their containers. Carrying out an RFID trial increased IKEA's and Arla Foods' proficiency in and understanding of the technology used by providing insights into RFID system components, functionalities, performance, standards and influential factors. Conducting a trial also increased the general awareness of RFID technology throughout the organisations, resulting in suggestions for other potential RFID application areas. Both IKEA and Arla Foods chose to perform the RFID trial at an implementation site and not in a laboratory environment. This enables the companies to verify the technology in an implementation environment with electromagnetic interference, shifting temperatures, liquids, metal etc. Arla Foods' trial also enabled it to choose an RFID system specifically based on its needs and requirements. This, however, was a drawback in IKEA's trial which did not illustrate or convince the company as to what type of RFID system it should use to track steel containers. IKEA would have liked to test numerous types of tags in the trial and gain insight into the different levels of performance they produce.

5.3 *Acceptance*

Gaining user and organisational acceptance of RFID implementations is as important to implementation success as ensuring technological integrity. This suggests that managers should view RFID implementations as an organisational issue rather than one strictly of technology or economics. The perceived usefulness and perceived ease of use are two widely recognised IT implementation success factors (Davis et al. 1989). Training and communication are two important managerial interventions to influence the acceptance of IT (Amoako-Gyampah and Salam 2004). Moreover, there are other organisational interactions which influence implementation processes (Russell and Hoag 2004). Communication, co-ordination and co-operation are three organisational interaction dimensions that play a major role (Stock and Tatikonda 2000).

In Arla Foods' implementation process a shortcoming was not actively involving the users in the receiving organisation at the dairy. The dairy went through major distribution and warehouse restructuring/implementation and because of this did not prioritise actively participating in the RFID implementation (i.e. Arla Foods' implementation steps 1-5). This project co-ordination problem finally resulted in a lack of acceptance from the receiving organisation which manifested itself in the activity of reading the RFID tags in the picking process being neglected. Organisational support and acceptance were gained by informing and communicating with the organisation about the use and importance of tracking the roll containers. Communicating the need and the use of the RFID system and the importance of tracking the roll containers contributed considerably to the outcome of implementation, i.e. elimination of the expected loss of roll container. Communicating the need and use of the RFID system with the dairy organisation spread information concerning the RFID system to lorry drivers and customers and made people aware that the roll containers are tracked. This awareness of the roll containers being tracked resulted in rules and procedures concerning the control of roll containers being followed.

One shortcoming of the IKEA trial was not involving and interacting with all the supply chain organisations which would be involved in an RFID implementation. Even if the trial was limited to the customer DC, co-operation with the other organisations would have been beneficial since they, just as IKEA did, would have gained insights into RFID technology. The other organisations would probably also provide important input into and feedback on the potential implementation of RFID technology, thus generating valuable discussions among the organisations.

5.4 Routinisation

Processing the data collected from the RFID system and using it in daily operations and routines by integrating it in scorecards, internal reports etc. is crucial to fully using the benefits of an implemented RFID system. In the routinisation stage, a technology merely loses its distinction, without guaranteeing the use of technology to its fullest potential (Chang and Lung 2002). Handling all the accumulated data was something that Arla Foods embarked upon late in the implementation process. Arla Foods has basically just started to analyse and interpret the data collected from the RFID system. So far, Arla Foods has been able to learn the fundamentals of the rotation of the roll containers. However, it expects to handle the uncertainty of roll container demand through the granulised data provided by the RFID system. Based on information about real historical demand variations the company aims to manage and control the rotation of roll containers in detail.

5.5 Infusion

Having implemented an RFID system might provide the opportunity to expand the implemented system and gain benefits which were not previously economically viable. A company arrives at the infusion stage when the technology is embedded in the organisation's operational and managerial work and is used to its fullest potential (ibid. 2002). According to Zmud and Apple (1992) higher level of use expresses higher infusion effectiveness. RFID implementations can be expensive, risky and difficult. However, with installed RFID infrastructure (readers and information system) and knowledge attained about the technology involved, RFID technology can be more easily transferred into other parts of the organisation and higher levels of use to generate spin-offs in other application areas. For example, an outcome of Arla Foods' implementation is that it will expand the implemented system to include three other dairies. Moreover, Arla Foods is thinking of tracking other returnable transport items, for example, its traditional roll containers. To track its traditional roll containers Arla Foods already has the necessary software, information systems and an RFID reader installed at the roll container washing machine (the traditional roll container goes through the same roll container washing machine as the new roll container). Attaching an RFID tag to the traditional roll container is easily done, i.e. the same way as the new roll container since both use the same type of wheels. In conclusion, with installed RFID infrastructure that other applications can use might enable other applications which were previously too expensive, risky or difficult. This indicates that tracking returnable transport items are a feasible starting point for organisations during the process of getting started with RFID and trying to adopt RFID technology.

6 Reflections on implementation costs

The cost and benefit of implementing RFID technology to manage and control returnable transport items depend on each specific situation. Consequently, each company situation requires its own specific cost-benefit analysis. However, IKEA and Arla Foods' cost-benefit analyses indicate the magnitude of, and the ratio between different costs and potential benefits. In RFID applications where large numbers of tags are used and then disposed of, the running cost of the tags is a central issue. In tracking returnable transport items where the tags are continuously reused, it seems that the cost of the tags is not a central issue. System integration, the number of readers and the process of applying the tags are issues which in themselves may involve higher costs than the cost of the tags.

Cost is often mentioned as one of the main barriers for a supply chain mass adoption of RFID technology. However, for the application of RFID to track returnable transport items, cost is not generally considered a barrier. Estimated cost-benefit analyses point out that the payback for IKEA's RFID investment would be less than two years, while for Arla Foods' investment the payback period would be approximately 14 months. However, one might ask oneself if the estimated cost-benefit analyses are valid.

Arla Foods' final investment and running costs of the implemented RFID system at the dairy turned out to mirror those of the cost-benefit analysis, except for the additional cost of data analysis software and time spent by Arla Foods employees, all of which was not considered and included in the analysis. Apart from these omissions the cost of the implementation corresponded to the cost-benefit analysis. The running profit from the system is, however, difficult to verify. The running profit is based upon the assumptions that the investment would decrease the annual roll container loss by 7.5 % and reduce the number of roll containers needed by 20 %. The RFID investment resulted in nearly zero per cent loss of roll containers, while a 20 % annual loss was expected by Arla Foods to take place without the investment, indicating that the running profit is based on modest assumptions. Moreover, operational benefits of the RFID investment such as decreases in manual inventory control, sorting, counting, quality control, and reporting are not included in the Arla Foods analysis.

As the calculated payback time cannot be validated it is interesting to see how sensitive Arla Foods' payback period is to the assumptions made in the running profit. To do this, a risk assessment through Monte Carlo simulation is performed. The percentages of decrease in annual roll container loss (min: 0 %, most likely: 7.5 %, max: 20 %) and decrease in number of needed roll containers (min: 0 %, most likely: 20 %, max: 30 %) are modelled using discrete triangular distributions. 100 000 iterations were performed and the resulting histogram of the payback period and the sensitivity analysis in the form of a plotted tornado graph is presented in figure 4. The risk assessment indicates the range of potential payback periods with associated probabilities.

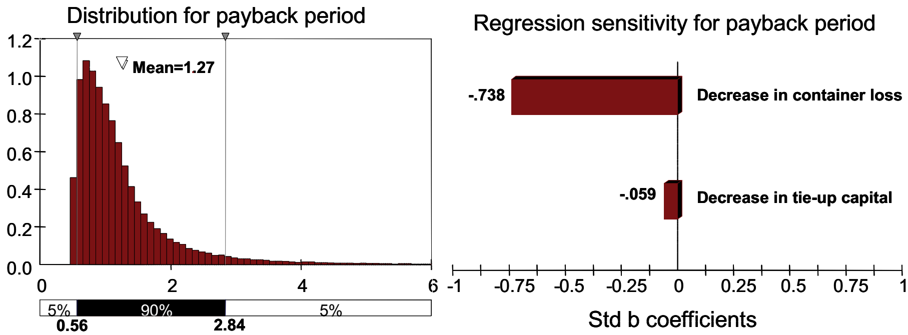

Figure 4. Risk assessment and sensitivity analysis of Arla Foods payback analysis.

Similar to the Arla Foods analysis, IKEA's payback time can not be validated since the running profit is based on the assumption that the investment will eliminate the loss of steel container components. However, IKEA's high loss of steel containers not only results in the recurring costs of additional steel containers, but it also occasionally results in shortages of steel containers. This forces the customer DC to use wooden pallets instead, resulting in a high product damage rate and a low cube utilisation of deliveries. To ensure that shortages do not occur, the customer DC continuously procures steel containers and holds a high inventory level of steel containers. Furthermore, concerted efforts are regularly made to get the steel containers back to the customer DC. The cost of these drawbacks, and other potential benefits; "optimised" pool size, less administration, improved maintenance and cleaning procedures and operational benefits (such as less manual counting) are not included in the running profits. The consequences of steel containers loss and the potential benefits indicates that if an RFID investment eliminated the loss of steel containers, additional benefits would arise which would reduce the payback time for the investment.

To analyse the sensitivity of IKEA's payback period a risk assessment through Monte Carlo simulation is performed. Tag cost, reader equipment cost, hardware installation cost, software cost, running cost are modelled using discrete triangular distributions with min: 80 % of IKEA's estimated value, most likely: the estimated value, max: 120 % of estimated value. The percentage of decrease in annual roll container loss is modelled using discrete triangular distribution with min: 5 %, most likely: 10 %, max: 15 %. 100 000 iterations were performed and the resulting histogram of the payback period and a sensitivity analysis in the form of a plotted tornado graph is presented in figures 5 and 6. Figure 5 represents the risk assessment of the investment scenario where readers are installed at wrapping stations, while figure 6 represents the investment scenario where readers are installed at shipping gates. The risk assessments indicate the range of potential payback periods with associate probabilities for the two investment scenarios.

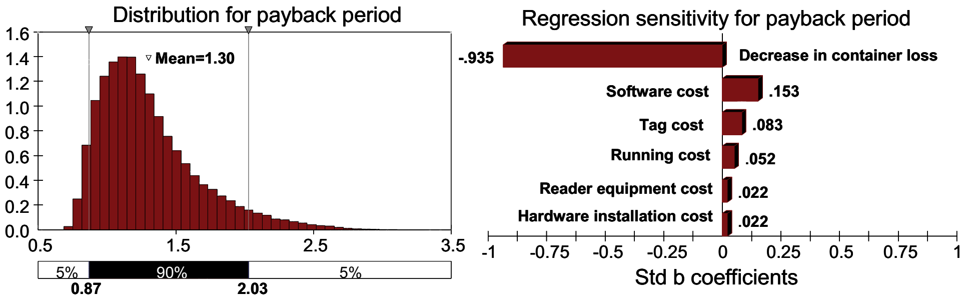

Figure 5. Risk assessment and sensitivity analysis of IKEA's payback analysis for the investment scenario were readers are installed at wrapping stations.

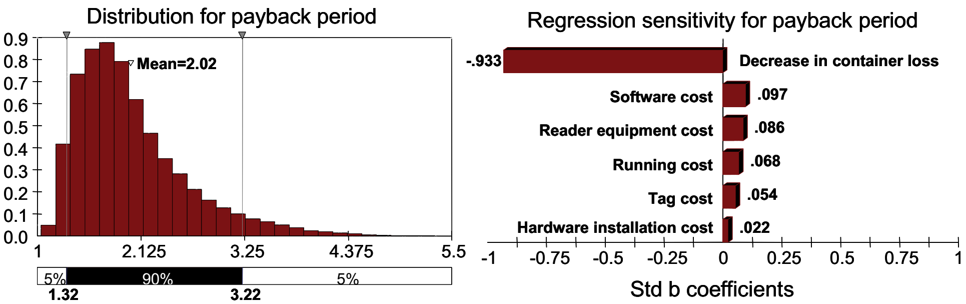

Figure 6. Risk assessment and sensitivity analysis of IKEA's payback analysis for the investment scenario were readers are installed at shipping gates.

7 Concluding remarks

This research makes a modest, but important, contribution to the general understanding of the costs and the process of implementing RFID technology to track returnable transport items. Through an explorative case study of a RFID trial and an RFID implementation, an inductively derived stage model of the RFID implementation process is proposed. In the model, implications for management in the different implementation stages are identified and discussed, to guide managers in the process of implementing RFID technology. One identified implication is that managing organisational interactions in RFID implementations is as important to implementation success as ensuring technological integrity. The model is limited to implementation of RFID technology to track returnable transport items and is not intended to be directly applied in other contexts involving other applications and technology. For example, it cannot be applied to open supply chain system involving different organisations, since the implementation of RFID in such system involves both sharing of information as well as incentive alignments, e.g. risks and gains, among supply chain partners (Pålsson 2005). This does not mean, however, that insights acquired in this research are of no relevance to other contexts. It is hoped that other researchers will build on this model, both through conceptual critiques and through testing of the model against implementation practice.

This empirical investigation of two RFID projects also highlights significant savings as well as the opportunities and risks of implementing RFID to track returnable transport items. Cost is often mentioned as a barrier to implementing RFID technology, but in introducing RFID to track returnable transport items, cost is not generally a barrier.

There is a scientific and industrial need for more rigorous research covering the adoption and impact of RFID in logistics, and supply chain management. More and more firms are beginning to do trials and implement RFID. Potential adoption benefits and barriers, such as technology immaturity and performance, privacy issues, costs and organisational issues need to be investigated. Case study research is one approach that shed light upon these problems and provides insight into how and why organisations implement and assess RFID. This case study research only gives a glimpse into the RFID implementation process, so that there is a great need for more case study research in this area. An interesting logistics and supply chain management concept to use in future studies covering RFID technology implementations and deployments is “risk and gain sharing” (see Norrman 2006 for a detailed discussion of the concept). How are risks and gains from RFID technology shared among supply chain organisations? How do the mindset and power conditions among supply chain organisations influence the applications of RFID technology? Another suggestion for future research is to use diffusion theory in a deductive research approach. Diffusion, one of many social science theories which have been applied to technology adoption in organisations, can be used to explain and predict innovation adoption and implementation decisions. For example, Williams and Rao (1998) apply adoption theories, including diffusion, to predict important implementation factors in the RFID software implementation process at four large US rail companies. Hence, a diffusion perspective can provide valuable insights into RFID implementations.

Appendix: Description of case study firms

Arla Foods is the largest dairy company in Europe which exclusively produces milk-based products. It is a co-operative owned by milk producers in Sweden and Denmark. Besides its main markets in Sweden, Denmark and the UK, Arla Foods runs subsidiaries in 19 other market areas all over the world. Its core business activities are the development, production and distribution of dairy products.

IKEA has been identified as one of the world’s best retailers in terms of its position, sales and number of stores (approximately 214 IKEA stores in 32 countries) (Arnold 2002). Its business idea is to offer a wide range of home furnishings with good design and function at low prices. Logistics and packaging are key strategic areas for IKEA in its aim to manage the flow of goods from thousands of geographically widespread suppliers to the needs of individual IKEA stores. IKEA does most of its packaging and product development and design in-house but does not generally have its own manufacturing facilities.

References

Aberdeen Group, RFID-enabled logistics asset management benchmark report, June 2004.

Amoako-Gyampah, K. and Salam, A. F., An extension of the technology acceptance model in an ERP implementation environment, *Inf. Mgmnt*, 2004, **41**, 731-745.

Angeles, R., RFID technologies: supply chain applications and implementation issues. *Inf. Syst. Mgmnt.*, 2005, **22**, 51-65.

Arnold, S. J., Lessons learned from the world's best retailers. *Int. J. Retail Distrib. Mgmnt.*, 2002, **30**, 562-570.

Baronas, A. K. and Louis, M. R., Restoring a sense of control during implementation: How user involvment leads to system acceptance, *MIS Quarterly*, 1988, **12**, 111-125.

Bowersox, D. J. and Closs, D. J., *Logistical Management -The integrated supply chain process*, 1996 (McGraw-Hill: New York).
Chan, S. L., Information technology in business processes, *Business Process Mgmnt. J.*, 2000, **6**, 224-237.
Chang, P. and Lung, S., Organisational changes for advanced manufacturing technology infusion: an empirical study. *Int. J. Mgmnt.*, 2002, **19**, 206-207.
Chen, M., Technology adoption in response to changes in market conditions: Evidence from the US petroleum refining industry, *Econ. Innovation New Technol.*, 2005, **14**, 735-756.
Cheney, P., Mann, R., and Amoroso, D., Organizational factors affecting the success of end-user computing, *J. Mgmnt. Inf. Syst.*, 1986, **3**, 65-80.
Choi, T. Y. and Liker, J. K., Institutional conformity and technology implementation: A process model of ergonomics dissemination, *J. Engng. Technol. Mgmnt.*, 1992, **9**, 155-195.
Collins, J., Tesco Revises RFID Plans. Available online at: www.rfidjournal.com/article/articleview/2243/1/1 (April 2006)
Cooper, R. B. and Zmud, R. W., Information technology implementation research: a technological diffusion approach. *Mgmnt. Sci.*, 1990, **36**, 123-139.
Coyle, J. J., Bardi, E. J., and Langley, C. J. Jr., *The Management of Business Logistics*, 1996 (West Publishing Company: Minnesota).
Davenport, T. H. and Short, J. E., The new industrial engineering: Information technology and business process redesign, *Sloan Mgmnt. Rev.*, 1990, **31**, 11-28.
Davis, F. D., Bagozzi, R. P., and Warshaw, P. R., User acceptance of computer technology: A comparison of two theoretical models, *Mgmnt. Sci.*, 1989, **25**, 982-1003.
Eisenhardt, K. M., Building theories from case study research. *Academy Mgmnt. Rev.*, 1989, **14**, 532-550.
Ellram, L. M., The use of case study method in logistic research. *J. Business Logistics*, 1996, **17**, 93-138.
Finkenzeller, K., *RFID Handbook: Fundamentals and Applications in Contactless Smart Cards and Identification*, 2003 (Wiley: England).
Fleisch, E. and Tellkamp, C., Inventory inaccuracy and supply chain performance: a simulation study of a retail supply chain. *Int. J. Prod. Econ.* 2005, **95**, 373-385.
Franz, C. R. and Robey, D., Organizational context, user involvement, and the usefulness of information systems, *Decision Sci.*, 1986, **17**, 329-356.
Fusaro, R. A., None of Our Business? *Harvard Business Rev*., 2004, **December**.
Glaser, B. and Strauss, A., *The Discovery of Grounded Theory – Strategies for Qualitative Research*, 1967 (Aldine: Chicago).
Goodman, P. S. and Griffith, T. L., A process approach to the implementation of new technology, *J. Engng. Technol. Mgmnt.*, 1991, **8**, 261-285.
Gummesson, E., *Qualitative Methods in Management Research*, 2000(Sage Publications: California).
Holahan, P. J., Aronson, Z. H., Jurkat, M. P., and Schoorman, F. D., Implementing computer technology: a multiorganizational test of Klein and Sorra's model, *J. Engng. Technol. Mgmnt.*, 2004, **22**, 31-50.
Huberman, A. M. and Miles, M. B., Data Management and Analysis Methods. In *Collecting and Interpreting Qualitative Materials,* edited by *N. K.* Denzin and *Y. S.* Lincoln, pp. 179-210, 1998 (Sage Publications: London).
Ives, B. and Olson, M. H., User involvement and MIS success: A review of research, *Mgmnt. Sci.*, 1984, **30**, 586-604.

Jones, P., Clark-Hill, C., Shears, P., Comfort, D., and Hillier, D., Radio frequency identification in the UK: opportunities and challenges. *Int. J. Retail Distrib. Mgmnt.*, 2004, **32**, 164-171.
Kambil, A. and Brooks, J., Auto-ID across the value chain: from dramatic potential to greater efficiency and profit, Auto-ID Center White paper, MIT, 2002.
King, G., Keohane, R. O. and Verba, S., *Designing Organizational Inquiry – Scientific Inference in Qualitative Research*, 1994 (Princeton University Press: Princeton, NJ).
Kwon, T. H. and Zmud, R. W., Unifying the fragmented models of information systems implementation. In *Critical issues in information systems research*, edited by R. J. Boland and R. A. Hirschheim, pp. 227-251, 1987 (John Wiley & Sons: New York).
Kärkkäinen, M., Increasing efficiency in the supply chain for short shelf life goods using RFID tagging. *Int. J. Retail Distrib. Mgmnt.*, 2003, **31**, 529-536.
Kärkkäinen, M. and Holmström, J., Wireless product identification: enabler for handling efficiency, customisation and information sharing. *Supply Chain Mgmnt.*, 2002, **7**, 242-253.
Lai, F., Hutchinson, J., and Zhang, G., Radio frequency identification (RFID) in china: opportunities and challenges. *Int. J. Retail Distrib. Mgmnt.*, 2005, **33**, 905-916.
Lambert, D. M., Stock, J. R., and Ellram, L. M., *Fundamentals of Logistics Management*, 1998 (McGraw-Hill: London).
Lieb, R. and Bentz, B. A., The North American third party logistics industry in 2004: the provider CEO perspective, *Int. J. Physical Distrib. Logistics Mgmnt.*, 2005, **35**, 595-611.
LogicaCMG. Making waves: RFID adoption in returnable packaging, May 2004, Available online at: www.logicacmg.com/page/400003596 (February 2007)
Lumsden, K. and Acharjee, P., Business value of improved identification in the spare part consignment chain, in *proceedings of NOFOMA*, 2005, pp. 433-448.
Maloney, D., Returnable savings. *Modern Materials Handling*, 2001, **56**, 37-38.
McFarlane, D. and Sheffi, Y., The impact of automatic identification on supply chain operations. *Int. J. Logistics Mgmnt.*, 2003, **14**, 1-17.
McKerrow, D., What makes reusable packaging systems work. *Logistics Inf. Mgmnt.*, 1996, **9**, 39-42.
Meredith, J. R., The implementation of computer based systems, *J. Operations Mgmnt.*, 1981, **2**, 11-21.
Norrman, A., Supply chain risk sharing contracts from buyes' perspective: content and experiences, in *proceedings of NOFOMA*, 2006.
Pelz, D. C., Innovation complexity and the sequence of innovating stages, *Knowledge: Creation, Diffusion, Utilization*, 1983, **5**, 3-25.
Petroni, A., Critical factors of MRP implementation in small and medium-sized firms. *Int. J. Operations Prod. Mgmnt.*, 2002, **22**, 329-348.
Pålsson, H., Implications of interorganizational RFID implementation - a case study, in *proceedings of ELA*, 2005, pp. 85-100.
Reich, B. H. and Benbasat, I., Factors that influence the social dimension of alignment between business and information technology objectives, *MIS Quarterly*, 2000, **24**, 81-113.
Roberti, M., RFID's case of schizophrenia, Available online at: www.rfidjournal.com/article/articleview/1762/1/2/ (December 2005)
Rogers, E. M., *Diffusion of Innovations*, 2003 (Free Press: New York).
Russell, D. M. and Hoag, A. M., People and information technology in the supply chain: social and organizational influences on adoption. *Int. J. Physical Distrib. Logistics Mgmnt.*, 2004, **34**, 102-122.
Sheffi, Y., RFID and the Innovation Cycle, *Int. J. Logistics Mgmnt.*, 2004, **15**, 1-10.

Smith, A. D., Exploring radio frequency identification and its impact on business systems. *Inf. Mgmnt. Computer Security*, 2005, **13**, 16-28.
Stock, G. N. and Tatikonda, M. V., A typology of project-level technology transfer processes. *J. Operations Mgmnt.*, 2000, **18**, 719-737.
Strauss, A. and Corbin, J., *Basics of qualitative research*, 1998 (Sage Publications: California)
Tait, P. and Vessey, I., The effect of user involvement on system success: A contingency approach, *MIS Quarterly*, 1988, **12**, 91-108.
Tornatzky, L. G. and Fleischer, M., *The Processes of Technological Innovation*, 1990 (Lexington Books: Lexington, MA).
Twede, D., Can you justify returnables? *Transport. Distrib.*, 1999, **April**.
Twede, D. and Clarke, R., Supply chain issues in reusable packaging. *J. Marketing Channels*, 2004, **12**, 7-26.
Venkatraman, N., Henderson, J. C., and Oldach, S., Continuous strategic alignment: Exploiting information technology capabilities for competitive success, *European Mgmnt. J.*, 1993, **11**, 139-150.
Williams, L. and Rao, K., Information technology adoption: using classical adoption models to predict AEI software implementation. *J. Business Logistics*, 1998, **19**, 5-16.
Witt, C. E., Transport packaging: neat and clean or down and dirty? *Mater. Handling Engng.*, 1999, **54**, 71-73.
Witt, C. E., Are reusable containers worth the cost? *Transport. Distrib.*, 2000, **41**, 105-108.
Wong, C. Y. and McFarlane, D., Radio frequency identification data capture and its impact on shelf replenishment, *Int. J. Logistics*, 2007, **10**, 71-93.
Yin, R. K., *Case study research: design and methods*, 2003 (Sage Publications: California).
Zerbe, R. O. and Dively, D. D., *Benefit-Cost Analysis*, 1994 (HarperCollins College Publishers: New York).
Zmud, R. W., An examination of 'push-pull' theory applied to process innovation in knowledge work, *Mgmnt. Sci.*, 1984, **30**, 727-739.
Zmud, R. W. and Apple, E. L., Measuring technology incorporation/infusion. *J. Product Innovation Mgmnt.*, 1992, **9**, 148-155.

PAPER IV

Combining case study and simulation methods in supply chain management research

By Daniel Hellström and Fredrik Nilsson
(The authors contributed equally to this paper)

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COMBINING CASE STUDY AND SIMULATION METHODS IN SUPPLY CHAIN MANAGEMENT RESEARCH

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Summary

Using the case study research method as well as empirical quantitative-based simulation methods are becoming increasingly common in supply chain management research. However, rare signs of efforts of combining these are to be found in literature. This paper contributes to the further development of research practices by presenting and discussing the concept of combining case study and simulation. Combining the methods into a multimethod study allows the researcher to harmonise the weaknesses and assess the relative strengths of the various methods. A model of combining the methods is provided giving guidance and insights into the process of combining the methods.

Keywords: Case study, Simulation, Research Method, Multimethod

Educator and practitioner summary

Combining research methods is a methodological important issue for the academic/research community in supply chain management. This paper investigate the use of alternative research method and describes two research applications where case study and simulation were combined, yielding greater insights than if a single research method hand been employed.

Introduction

There are several ways of conducting research e.g. experiments, surveys, ethnographic studies, modelling, simulation and case studies to mention but a few. Each method has its strengths and weaknesses and the issue is not that one method is better than the other, rather how well the chosen method helps the researcher solve or clarify his/her purpose or problem. An increasingly common research method in logistics and supply chain management is the case study method (Ellram, 1996; Gammelgaard, 2003; Meredith, 1998). While the method has several strengths, critics often argue that the results are simply anecdotal and that the research itself has not been conducted rigorously enough. Another common research method used within logistics and supply chain management research is simulation (Disney, Naim, and Towill, 1997; Fleisch and Tellkamp, 2005). Simulation is used in a variety of disciplines and there are numerous books and journals which document its usage and results. While the impact of this method has several strengths, critics argue that the method is too superficial and only solves problems in the computer and not in the real world. Fortunately these methods can be combined to yield more than either method alone. According to Meredith (1998) alternative research

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methods, such as simulation and case study, are not mutually exclusive and, if combined, can offer great potential for enhancing new theories than either method alone.

The aim of this paper is to contribute to the further development of research practices by presenting and discussing the concept of combining case study and simulation. Two research studies are briefly presented in order to describe the possibilities of combining theses methods in practice. Based on the experience gained from combining the methods in the two research studies, a model of the research process is developed that may guide researchers in combining the methods. We will also discuss the feasibility of combining case study and simulation, since these originate from different methodological assumptions.

Complete details of the research results from the combination efforts are reported elsewhere (Hellström, 2004; Nilsson, 2005). The focus of this paper is not to in detail present the research result, but, instead, to present and discuss the benefits and limitations of combining case study and simulation methods. Furthermore, this paper focuses on discussing the combination of single case studies and empirical quantitative-based simulation models. More specifically, the types of simulation techniques that will be referred to are discrete-event simulation (Banks et al., 2001) and agent-based modelling (Bonabeau, Dorigo, and Theraulaz, 1999; Epstein, 1999), since these are the techniques used in the presented research studies. These types of simulation methods are found to be relevant for supply chain studies since an increased complexity can be considered. However, this does not exclude combining multiple cases study research and non empirical simulation research.

The remainder of this paper is organised as follows; the following two sections provide a discussion of the case study and simulation methods. In the subsequent section a methodological perspective is given for the combination of these methods since they originate from different research paradigms. This is followed by a brief description of two research studies where case study and simulation was combined. Then in the next section the strengths and weaknesses of combining case studies and simulation is presented. This is followed by a discussion of other combinations of methodologies. Finally, conclusions are provided and future research suggested.

Case study research

Case study is a research method with the overall objective of gaining a deep understanding of chosen research phenomena (Stake, 2000). The case study method focuses on understanding the dynamics present within single settings (Eisenhardt, 1989; Ellram 1996). This means that in case studies the focus is directed towards numerous variables and relationships covering all conceivable aspects which are available i.e. ideographic. This could be compared to a survey where only a few variables in a large population are normally studied i.e. nomothetic. According to Yin (2003 p.9) the case study method has a distinct advantage in situations when: "*a "how" or "why" question is being asked about a contemporary set of events, over which the investigator has little or no control.*"

In the research field of supply chain management the case study method provides an opportunity for collecting empirical data with consideration given to the complexity of the real-life setting. Empirical methods, such as case studies, are receiving increased attention due to the increasing call to incorporate real-world data to improve the relevance of research (Ellram 1996). In supply chain management research, which deals with socio-technical aspects, the understanding and sense-making of *why* and *how* activities are carried out by people are of prime importance. Research dealing with socio-technical aspects often requires researchers to deal with dynamic and context-dependent variables and relationships. This complexity requires an in-depth study since there may be numerous interpretations and explanations for the observed outcome. Thus, case studies are preferred in developing new theories or extending and testing existing theories in situations requiring deep understanding of what is happening (Meredith, 1998).

The case study method is still relatively rare in supply chain management research even though it is becoming more and more accepted as a proper scientific method (Gammelgaard 2003; Wacker, 1998). A major criticism of case study research is the paucity of rigour in the case research process and that it relies heavily on the skill and personality of the researcher (Miles, 1979; Stuart et al., 2002). The criticism is generally directed towards weaknesses such as ambiguous or non-existent discussions of what case study designs was chosen, what protocol was used, how cases were selected, how data was collected and analysed and how results were validated. However, to reduce these weaknesses Yin (2003), Meredith (1998), Eisenhardt (1989), Ellram (1996) and Stuart et al. (2002) advocate a systemic and analytical approach to conducting case study research. The approach is generally based on designing, conducting, analysing and reporting case study research in a systematic way, which improves the rigour of the case study process.

Simulation research

According to Banks (2001 p.3) simulation is an "*imitation of the operation of a real-world process or a system over time*". Put in another way, Ball (1996) describes simulation as a method for developing a model of a real or proposed system so that the behaviour of the system may be studied under specific conditions. Simulation studies can have several purposes e.g. prediction, performance, training, education, proof and exploration (Axelrod, 1997). According to Law and Kelton (2000) one of the main advantages of simulation is that it allows the researcher to explore different "what-if" scenarios. Nonetheless, one common denominator is that of increasing the understanding of the behaviour of a specific phenomenon. Simulation enables the researcher to observe how a system performs and behaves over time when different rules and policies are applied (Shapiro, 2001). This means that simulation studies may assist managers in making decisions in the real world since they can understand the behaviours and results of modelled systems. Thus, simulation studies are preferred for testing and modifying new theories or well-established theories in new situations (Meredith, 1998).

Simulation research can be classified into axiomatic or empirical model-based research (Will, Bertrand, and Fransoo, 2002). Axiomatic model-based research relies predominantly on idealised problems and deterministic solutions, consequently, as a result "*implementing solutions based on these models often turned out to be a tedious process, and also frequently failed"* (ibid. 2002 p.244). Axiomatic models are the most frequent type of simulation research presented in journals and often the main objectives of these models are to perform tests and experiments without empirical data (Shafer and Smunt, 2004). Empirical model-based research is primarily driven by empirical findings and forms of measurement and the primary concern of the researcher is to ensure that there is a correlation between reality and the model made of that reality. Empirical simulation is either modelled to represent real situations/environments or data from real situations are used as a basis for setting the levels of parameters in the simulation study (ibid. 2004). In simulation literature empirical simulation is sometimes called simulation case studies. However the case study research method is not an ad hoc method, thus simulation case studies are not to be confused with combining simulation and the case study research method presented in this paper.

In empirical simulation research, the researcher needs to posses a great deal of knowledge about the system under study. In order to motivate the use of simulation methods, such as discrete-event simulation and agent-based modelling, the phenomenon of research interest requires an appropriate degree of complexity. This complexity can be the result of several interacting and interdependent parts, where these parts are affected by several objectives and constraints, and where the behaviour of the phenomenon cannot be distinguished from the behaviour of the individual parts, but instead in the relationship among these. This complexity requires that the researcher posses a great deal of knowledge about the system under study.

In order to capture the real-life behaviour in a simulation the researcher also needs to possess a great deal of knowledge about the characteristics of the system under study. Real-life processes are all different, although there may well be similarities, and have different characteristics, which can evolve over time. Dealing with real-life processes i.e. where not everything behaves rationally, is always done in a subjective and situation-dependent way. Consequently, problematic steps often addressed in simulation studies are how to develop an "objective" way to identify and measure relevant parameters and how to interpret in-put and out-put data. Will, Bertrand, and Fransoo (2002 p.259) state that *"One drawback when conducting simulation research is the lack of methods and techniques in gathering data and interpretations of the phenomenon being studied"*. Simulation researchers often develop their own individual techniques to identify, collect and document data. Identifying and gathering data is done in conjunction with the development of the conceptual model, in which the important components, relationships and measurement of the relevant variables are identified and defined (Pritsker, 1998). This further stresses the need for the researcher to be familiar with the system under study in order to know how to identify and measure the relevant characteristics of the system under study.

In a simulation study the concern of capturing the real-life behaviour is addressed through model verification and validation. Model verification is to ensure that the computer programming of the conceptual model is correct and model validation is according to Schlesinger (1979 p.103) "*substantiation that a computerized model within its domain of applicability possesses a satisfactory range of accuracy consistent with the intended application of the model*". Verification and validation in a modelling development process is described by Sargent (2003) in four steps i.e. data validation, conceptual model validation, computerized model verification and operational validation. In these steps are numerous statistical tests, mathematical procedures and other techniques, such as event and face validation, used (Balci, 1998; Kleijnen, 1995; Sargent, 2003). However, the basis of capturing the real-life behaviour in a simulation is still to have a great deal of knowledge about the modelled system.

Multi-methodological aspects

There are important methodological aspects to discuss when combining case study and simulation since these methods originate from different research paradigms. Supply chain management research is multidisciplinary, attracting researchers from different academic backgrounds such as engineering, business management, organisation etc. Depending on their backgrounds researchers may investigate phenomena from different methodological perspectives. This in turn results in a variety of preferred research strategy, methods and perceptions of problem contexts.

According to Yin (2003, p.5) the selection of a preferred research method depends on three conditions: *(1) The type of research question posed, (2) the extent of control an investigator* *has over behavioural events, and (3) the degree of focus on contemporary events as opposed to historical ones.* One major distinction between case study and simulation here is the extent of the investigator's capability to control and access the actual behaviour of the system. The case study method deals with real-life events whereas simulation deals with models which are abstractions of reality. With simulation the researcher can manipulate parameters and relations of interest whereas in a case study the behaviours cannot be manipulated in a controlled manner.

In addition to Yin's three conditions we would like to add personal biography and paradigm as elements of a fourth condition for selecting research methods. Every researcher is unique because of her/his particular class, racial, cultural and ethnic perspectives (Denzin and Lincoln, 1998). According to Burrel and Morgan (1979) and Meredith (1998) a positivist prefers nomothetic and quantitative research methods e.g. simulation, while an interpretivist prefers ideographic and qualitative research methods e.g. case study. An example of difference between case studies and simulation is that case studies cannot be replicated, whereas simulations can be replicated at any time. Critics then argue that the case study method is unreliable. However, an aspect that should be considered here is time. The context of a case study is continuously changing which may prevent a replicated case study from resulting in the same results. To combat this, cases study use protocols and databases allowing the analysis of the raw data to be replicated.

Even though that there are to some extent paradigmatic differences between case study and simulation, the methods can be successfully combined. Morgan and Smircich (1980) suggest that much debate and criticism over methods involves researchers who are failing to communicate with one another because they hold varying basic assumption about the nature of reality and knowledge. Combining the methods require that the researcher assess the trade-offs between the methods and integrate positivistic and hermeneutic assumptions in the research. We strongly believe that by adopting two methodological perspectives gives an extended view of the phenomenon, for example, incorporating soft aspects such as individual subjective interpretations and understanding, and hard aspects that are measured or quantified. Thus, combining case study and simulation enable supply chain management research to go beyond the methodological limitations that researchers poses on them selves by strictly adhering to only doing case or simulation research. Combining case study and simulation may provide a valuable bridge over the traditional gaps between positivistic and a more hermeneutic approach and quantitative and qualitative methods. Hopefully, this paper will prompt researchers to consider combining different methods.

As a research strategy

From a research strategy perspective, combining case study and simulation is a way to achieve realism and precision. Ideally, a scientific study should to reach all the three objectives – realism, precision, and generalisability – especially in natural science (McGrath, Martin, and Kulka, 1982). However in management research the three objectives constrain each other. For example, in case study research the main objective is to capture realism, survey focus on generalisability and simulation provides precision. In this sense a research study using one method may result in difficulties in reaching the three objectives. It is then more feasible to cover the objectives by combining research methods. An example is the case survey method, which have the ability to reach realism and generalisability since it allows nomothetically inclined researchers to add idiographic richness and relevance to rigours and generalisable statistical analyses across large data sets (Larsson, 1993). Combining case study and simulation can then help a researcher to generate results that are realistic and precise, since it take advantage of the strength of each method. Hence, the transferability of research results to operational practice can be increased.

Combining case study and simulation may be one way to bridge the gap between precision and managerial applicability. To bridge this gap, however, researchers need to ensure the generalisability of the research results. From a statistical point of view both simulation and case study lack generalisability to new populations and situations since they contain to small sample size. However simulation and case study research does not rely on statistical generalisation, such as in survey research. Simulation studies use assumptive generalization, whereas case studies rely on theoretic generalisation (Meredith 1998; Yin, 2003). Combining case study and simulation provides the researcher with two opportunities to make generalisation i.e. assumptive and theoretic generalisation.

Applications of research combining case study and simulation

Two research studies are briefly described to present the concept of combining case study and simulation in supply chain management research. The description of the research studies focus on conveying why the methods were combined and what it added to the research process and the research itself. Complete details of the research results from the combination efforts are reported elsewhere (see Hellström, 2004; Nilsson, 2005) since the particular focus of this paper in not to present or discuss the result of the research, but, instead, to illustrate the possibilities of combining case study and simulation methods in practice.

How the methods were combined is partly described. Basically, the case study and the simulation study where conducted according to the established research procedures of each method. However, the studies were combined in an iterative and interlinked research process allowing the researcher to gain synergies, harmonise weaknesses and assess the relative strengths of each method.

Research study one

In this exploratory research study the overall purpose was to investigate the potential of using advanced automatic identification technology in retail supply chains. The focus of the study was directed towards the interface between the logistics and packaging systems, and in particular towards the activities and processes related to logistics and packaging. Simulation was the chosen method to explore the potential of the technology. However, a pre-requisite for exploring the potential of the technology was to identify and understand the existing packaging and logistics related activities in the retail supply chain. This called for combining multiple research methods focusing on contemporary and on possible future events i.e. case study and simulation (see Hellström, 2004 for complete details).

The case study method offered in this research the opportunity to create a useful platform from where simulation was used to explore how the technology could affect the performance and behaviour of a retail supply chain. A single-case design was chosen where size and accessibility of the retail chain were important aspects when selecting the case.

Data collection process

The data collection was carried out during more than one month on-site study of the retail supply chain. The primary data collection methods used in the case study was interviews and participating observations while the primary data collection methods used in the simulation study was archival records and interviews. The data collected were written down in a case study document which was used to verify that the researcher's interpretations were comparable to the views of those who were interviewed or performing the activities. The case document was reviewed by a key informant to further strengthening the validity in the collected data.

The different collected data sets overlapped between the studies, which made it possible to triangulate among the data sets. The case study focused on qualitative data, while the simulation study focused on quantitative data. However, the studies respectively did not completely rely on qualitative or quantitative data alone. The majority of the quantitative data were gathered when an understanding of the activities and processes of the retail supply chain had been gained. The understanding of operating procedures, flows, rules, etc facilitated in collecting quantitative data since knowledge had been gained regarding what quantitative data was available and needed for the simulation. The collected quantitative data gave further insight into the retail supply chain, such as variations and patterns over time. When doing consistency checks some quantitative and qualitative data did not fit, questioning rules and flows, which triggered additional investigation and data collection. Finally consensus was reached and a deep understanding of the processes and activities was achieved. These synergies in the systemic process of gathering data made the data collection process more efficient than carrying out a simulation study and case study separately.

Case study process

The collected data were gradually analysed as the information emerged. The data were carefully examined using different sources, combining both quantitative and qualitative data, strengthening the internal validity of the studies. The data were categorised into different activities, processes and relationships resulting in a case description that served as a detailed system description for the simulation. The case description facilitated in defining the scope and assumptions of the simulation model. It also facilitated and formed the conceptual model and logic for the simulation. The case study resulted in a framework of logistics activities related to packaging in retail supply chains illustrating the interface between the packaging system and the logistics processes.

Simulation process

The scope, assumptions and logic for the simulation model was formed and developed based on the understanding of processes and activities provided by the case study. To develop a conceptual model the researcher must have sufficient empirical data and understanding of the system to develop structure and logical relationships. This was also provided by the case study.

The validation process was continuously performed in the simulation study and is usually a time consuming activity. However, the data validation was achieved in the systemic data collection process and in the triangulation among the collected data sets. Furthermore, the data validation and the understanding of the system obtained from the case study facilitated in validating of the conceptual model. When validating the computerized model several runs using actual historical input data were made and evaluated to ensure that the simulation model output corresponded to the real system performance.

When the simulation model was validated different scenarios was performed. This gave another view on the behaviour and performance of the system such as sensitivity, interactions among variables, bottlenecks, cause of delays and waiting times, utilisation of equipment and resources. This in turn enriched the case study with a deeper understanding of the system. The simulation resulted in a model that indicates how the technology could affect the performance and behaviour of a retail supply chain, thus giving further insight into the system.

Research study two

This combined case and simulation study has taken place at a Fast Moving Consumer Goods (FMCG) company in Sweden. The over all purpose was to provide increased understanding for system-wide effects of policy changes made in order to improve service levels and responsiveness. In the initial discussions with managers at the company several opinions and arguments were provided by people responsible for different functions of the company i.e. inventory, production, production planning, marketing, sales, and supply chain management. There was a debate among the functions concerning how to keep total costs low while at the same time increase the level of customer service. In order to gain insights concerning the different problems which the managers in the company provided arguments for, a case study was performed focusing on how and why the managers made decisions. Furthermore, an agent-based simulation model was developed with the purpose of creating an applicable and usable tool for the management to evaluate different improvement efforts for increased service levels without any major costs associated (see Nilsson, 2005 for complete details).

Data collection process

Data for case study and the simulation model was concurrently collected in three ways; interviews, observations, and document/archive studies. Several interviews were conducted with managers responsible for logistics (in-bound, out-bound), supply chain management, operations planning, production, and inventory. In addition, observation was carried out in order to examine the daily behavior of the people involved in the actual activities performed within the company. Three investigators were on site at least once or twice a week during four months, and carried out follow-up interviews, participant observations and ordinary observations on several occasions. Furthermore, quantitative data was gathered from archives and documents from all functions and put into the database for the model.

Case study processes

For the case study, a case study protocol involving key activities, pre-analysis, project management was developed and used. Furthermore, the data gathered was put into a case study database. This data overlapped with the quantitative data and with observations of behaviors from different part of the company, and thus provided the simulation study with insights of key processes and activities. The results form the case study indicated the need for greater understanding for each manager’s perspectives and real-life operations i.e. how production set-up times were decided, how planning was done, what the costs were for full inventory levels etc in order to increase responsiveness and service levels.

Simulation process

Within the company several agents were identified and designed to represent the FMCG company supply chain operations during the agent mapping process. These were found in production, in production planning, in inventory, and in the market. Before any simulations began the model had to be verified and validated. The purpose of the verification was to ensure the individual agent's behavior, while the purpose of the validation was to confirm that the model created a reasonable result compared to real data. The verification process involved meetings with everyone who was represented in some way as an agent in the model. During the first meeting the set of states, constraints, policies, and rules was agreed on and during the second meeting the computer simulation was run and the representative agent was verified by the person him-/herself. The same procedure was done for the other agents as well. The verification process helped to guarantee that company employees involved felt confident that the model actually worked. From the simulation several scenarios were generated and the results from these have had an impact on actual operations, and indications show that service levels are increasing in accordance with the results from one of the scenarios. In a follow-up interview, the Nordic supply chain manager explained that the scenarios created have had an impact on the way system-wide effects are discussed in the company i.e. how intuitively correct changes need to be evaluated with a more holistic perspective since they might have other, unwanted, effects on operations.

Combining case study and simulation

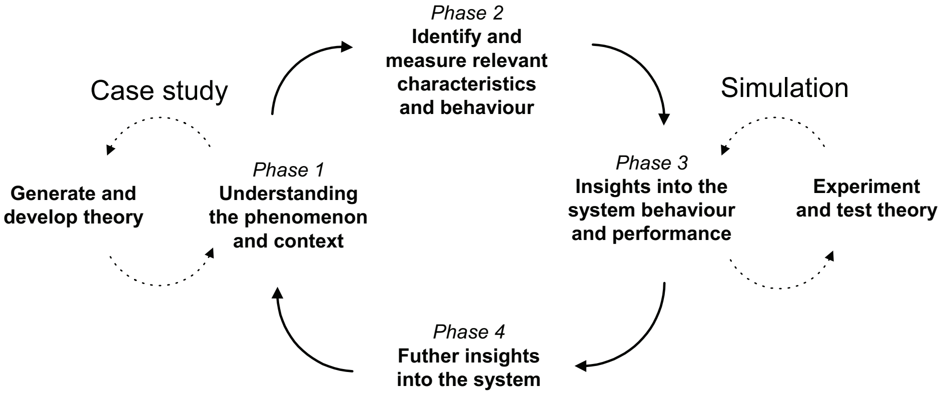
Combining case study and simulation into a multimethod study allows the researcher to harmonise the weaknesses and assess the relative strengths of the various methods. As pointed out in the application of research combining case study and simulation, the studies were conducted according to the established research procedures of each method. A researcher then may start out from performing a simulation study or a case study. Starting from a case studies perspective, the simulation study may be a way to obtain further insights into the behaviour and performance of the system. Starting from a simulation perspective, the case study may be a way to understand the context of the phenomena and to achieve a more rigorous data collection process. However, combining the methods allows the researcher to gain synergies, harmonise weaknesses and assess the relative strengths of each method. Combining the methods facilitates:

- an iterative and interlinked research process (see Figure 1), which in turn provides:
    - a way to identify and measure relevant characteristics of the studied system
    - further insights into the behaviour and performance of the system
    - a way to strengthen the theorizing process
- triangulation between the methods and among different data sets
- systemic data collection process with synergies
- an expanded time horizon of the study

Iterative and interlinked research process

Combining case study and simulation in an iterative and interlinked research process facilitate to work with complexity in real-life settings. In case study research the aim is to in-depth understand the phenomenon and context while in simulation the aim is to get insight into the behaviour and performance of the system. However, in order to get insight into the behaviour and performance of the system the researcher must have in-depth understanding of the system and its context, and vice versa. Hence, combining case study and simulation in an iterative and interlinked research process (as illustrated in Figure 1) provides the researcher with synergies and input to the individual methods that facilitate handling of complexity in real-life settings.

Figure 1. A model of the iterative and interlinked research process.



A motive for combining case study and simulation is that the researcher is able to obtain aid from the case study in identifying and measuring the relevant characteristics and behaviour of the system under study through providing a deep understanding of the phenomenon and the context under investigation (phase one and two in Figure 1). When a researcher is trying to represent phenomenon and its context in a computer simulation, extreme demands are placed on him/her in order to replicate the real-life behaviour as well as possible. The researcher needs to possess a great deal of knowledge about the relationships among sub-systems and their components as well as the purpose of a variety of activities and processes going on in these sub-systems, all of which change dynamically. Should this knowledge be lacking the simulation model will not represent what is being examined. These demands make it difficult for methods such as simulation, designed to predict system behaviour, to reflect the variety among systems and their constituent components. Through the in-depth understanding provided by a case study, knowledge about relationships and pattern of behaviour are gained. This means that a simulation combined with case study would help researchers to identify the relevant characteristics and behaviour of a system.

Another motive for combining simulation and case study is that the researcher is able to obtain help from the simulation in identifying and gaining insights into the system behaviour and performance by validating and experimenting with the model (phase three and four in Figure 1).

Some of the factors influencing the performance and the behaviour of a system may be easy to observe, while others are ambiguous but vital. To produce a reliable simulation, extensive and precise knowledge of real-life behaviour is needed. Furthermore, the combination of several factors might also influence the behaviour and performance of the system. In simulation influential factors could be identified and the insight of the importance of these factors could be gained. In a case study the ability to experiment with influential factors is much more difficult and therefore more difficult to identify.

Combining case study and simulation in an interlinked and iterative process, going back and forth between the methods, strengthens the theorizing process. Case study research primarily aims to generate or develop theory while simulation research primarily aims at experimenting and testing theory. Combining the methods the research may generate a theory, test it, further develop it, and experiment with it. The qualitative understanding provided by case study and the quantitative insight provided by simulation, are often essential for drawing conclusions and communicating the importance of research results. Combining case study and simulation centres on synthesizing from the interlinked and iterative research process.

Triangulation

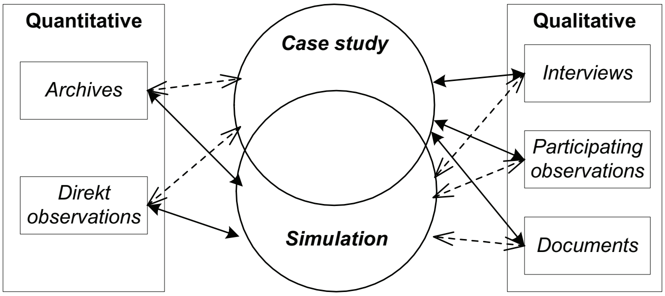
Another motive for combining case study and simulation is the opportunity to triangulate between the two methods. Triangulation can be generally considered as a process of using multiple perceptions to clarify meaning and verifying the repeatability of an observation or interpretation (Stake 2000). A strength of triangulating between case study and simulation is the mixing of a qualitative and a quantitative method where the authors agree with Jick (1979) that quantitative and qualitative methods should be viewed as complementary rather than rival methods. Mangan, Lalwani, and Gardner (2004) provide an excellent application of triangulation and highlight the benefit which can result from combining qualitative and quantitative methodologies.

In addition, combining case study and simulation offers the opportunity to triangulate between the data sets collected in the studies. Different data sets have different strengths and weaknesses concerning the bias of the research. Data sets collected from a simulation perspective might focus more on quantitative data e.g. variances and distributions of events through time, while data collected from a case study perspective might focus more on qualitative data. With two different data sets collected from two different perspectives multiple perceptions are gathered which increase the validity of the research. Furthermore, simulation increases the validity of the research by the validation process of the simulation model. When a simulation model is being validated input data is often questioned and additional data is needed in order for there to be a correlation between the model and the "reality". With a simulation model that does not behave or perform as respondents have explained the researchers are able to identify and eliminate data bias, thus strengthening the validity of the research. Furthermore, the case study increases the validity of the simulation model. By gaining a deep understanding of the phenomenon and the context the researcher is able to perform face validation on the simulation model.

Systemic data collection

Combining case study and simulation in an interlinked and iterative research process systematically enhance the data collection process. When case study and simulation are combined the different data sets gathered in the studies overlap one another creating synergies in the data collection process (see Figure 2). The case study provides simulation with an in-depth description and understanding of activities and processes, facilitating the development of a conceptual model for the simulation model. In addition, the data collected for the simulation provides the case study with an enriched understanding of the dynamics, variances, dependences and relationships between events and activities. Simulation might also provide the case study with additional input data derived from the results of verifying and conducting experiments using the simulation model. The synergies created in the data collection process when case study and simulation are combined is of great importance since it results in fewer resources being needed compared to a situation where separate studies are conducted.

Figure 2. The overlap of different collected data sets.



The case study research method provides empirical simulation research with well-documented data collection methods and techniques. One drawback in when conducting empirical simulation research is the lack of methods and techniques in the data collection process. Simulation research combined with case study research would help the researcher with the collection of necessary data as it would use various well-documented case data collection methods and techniques. Furthermore, the case study provides empirical simulation studies with an instrument to capture the data i.e. case protocol (an excellent source on protocol is Yin (2003)). This would result in a more rigorous platform for collecting input data for empirical simulation models and decrease the risk of “Garbage in, Garbage out”.

Expand the time horizon

Another motive for combining the methods is the opportunity to expand the time horizon of the study. A case study focuses on understanding a contemporary set of events, whereas simulation could be used to look back in time using historical data and/or look forward in time by running different scenarios. Rather than only focusing on the current situation using case study, a combination of the methods provides the opportunity to look back and/or forward in time using simulation and the chance to create a rigorous platform for the current situation.

Limitations

Combining case study and simulation do, however, suffer from a number of weaknesses. The need for additional skills and resources is one of the weaknesses of combining case and simulation. The researcher does not only need more time to conduct the studies but also has to have access to additional tools. However, the main weakness of combining case and simulation is that it requires the researcher to possess knowledge and skill in both of the methods. Nevertheless, this could be prevented by letting several researchers with different skills carry out the studies. This would also give rise to additional types of synergies, such as multiple investigator perspectives.

Conclusion

Combining case study and simulation into a multimethod study can be advantageous and may represent a further challenge in the process of doing case study and simulation research in supply chain management. The paradigmatic differences between case study and simulation require that the researcher assess the trade-offs between the methods and integrate positivistic and hermeneutic assumptions in the research. Adopting two methodological perspectives may provide an extended view of a supply chain phenomenon, for example, incorporating soft aspects such as individual subjective interpretations and understanding, and hard aspects that are measured or quantified. Thus, using contrasting and complementary methods may enable supply chain management research to go beyond the methodological limitations and provide a valuable bridge over the traditional gaps between positivistic and a more hermeneutic approach and quantitative and qualitative methods.

Even though that there are paradigmatic differences between case study and simulation, the methods can be successfully combined. Combining case study and simulation allows the researcher to harmonise the weaknesses and assess the relative strengths of the various methods. The described research applications indicate advantages in combining case study and simulation. Combining the methods facilitates an iterative and interlinked research process making it possible to identify and measure relevant characteristics and underlying processes of the studied system by using the case study method, and at the same time providing insights into the behaviour and performance of the system using simulation. This iterative and interlinked research process strengthens the theorizing process by going back and forth between the methods. Another valuable benefit is the opportunity for triangulation between the methods and between the different data sets collected in the studies. However, there are a number of limitations and we have much to learn about combining the methods in supply chain management research. One area for further research is for example, develop a procedure to combine cases study and simulation. A systematic procedure is needed and is a further step in the development of combining case study and simulation. Furthermore, there is numerous way of combining different methods. This is an area that needs to be further developed and there is no doubt that the discipline of supply chain management can be enriched by exploring novel combinations of research methods.

References

Axelrod, R., 1997, Advancing the art of simulation in the social sciences, Complexity 3, 16-22.

Balci, O., 1998, Verification, Validation and Testing, in J. Banks, ed., Handbook of Simulation: Principles, Methodology, Advances, Applications, and Practice (John Wiley & Sons, New York) 335-393.

Ball, P. D. Introduction to Discrete Event Simulation, Proceedings of the 2nd DYCOMANS Workshop on Management and Control, Algarve, Portugal, 367-376.

Banks, J., J. S. Carson II, B. L. Nelson, and D. M. Nicol, 2001, Discrete-Event System Simulation, Third ed. (Prentice Hall, New Jersey).

Bonabeau, E., M. Dorigo, and G. Theraulaz, 1999, Swarm Intelligence - From Natural to Artificial Systems, First ed. (Oxford University Press, New York).

Burrel, G. and G. Morgan, 1979, Sociological Paradigms and Organizational Analysis; Elements of the Sociology of Corporate Life, First ed. (Heinemann Educational Books Ltd, London).

Denzin, N. K. and Y. S. Lincoln, 1998, The Landscape of Qualitative Research: Theories and Issues (Sage Publications, London).

Disney, S. M., M. M. Naim, and D. R. Towill, 1997, Dynamic simulation modelling for lean logistics, International Journal of Physical Distribution & Logistics Management 27, 174-196.

Eisenhardt, K. M., 1989, Building Theories from Case Study Research, Academy of Management Review 14, 532-550.

Ellram, L. M., 1996, The use of case study method in logistic research, Journal of Business Logistics 17, 93-138.

Epstein, J. M., 1999, Agent-based computational models and generative social science, Complexity 4, 41-60.

Fleisch, E. and C. Tellkamp, 2005, Inventory inaccuracy and supply chain performance: a simulation study of a retail supply chain, International Journal of Production Economics 95, 373-385.

Gammelgaard, B. 2003, Case Studies in Logistics Research, in: J. Juga, ed., Proceedings of the 15th Annual Conference for Nordic Researchers in Logistics, Oulu, Finland, 556-570.

Hellström, D. 2004, Exploring the Potential of Radio Frequency Identification Technology in Retail Supply Chains - A Packaging Logistics Perspective, Licentiate thesis, Division of Packaging Logistics, Lund University, Lund.

Jick, T. D., 1979, Mixing Qualitative and Quantitative Methods: Triangulation in Action, Administrative Science Quarterly 24, 602-611.

Kleijnen, J. P. C., 1995, Verification and validation of simulation models, European Journal of Operational Research 82, 145-146.

Larsson, R., 1993, Case Survey Methodology: Quantitative Analysis of Patterns across Case Studies, Academy of Management Journal 36, 1515-1546.

Law, A. M. and W. D. Kelton, 2000, Simulation Modeling and Analysis, Third ed. (McGraw-Hill, Singapore).

Mangan, J., Lalwani, C., and Gardner, B. 2004, "Combining quantitative and qualitative methodologies in logistics research", International Journal of Physical Distribution & Logistics Management, vol. 34, no. 7, pp. 565-578.

McGrath, J. E., J. Martin, and R. A. Kulka, 1982, Judgment calls in research (Sage Publications, New York).

Meredith, J., 1998, Building operations management theory through case and field research, Journal of Operations Management 16, 441-454.

Miles, M. B., 1979, Qualitative Data as an Attractive Nuisance: The Problem of Analysis, Administrative Science Quarterly 24, 590-601.

Morgan, G. and Smircich, L. 1980, "The case for qualitative research", Academy of Management Review, vol. 11, no. 4, pp. 491-500.

Nilsson, F. 2005, Adaptive logistics - using complexity theory to facilitate increased effectiveness in logistics, Doctoral thesis, Division of Packaging Logistics, Lund University, Lund.

Pritsker, A. A. B., 1998, Principles of Simulation Modeling, in J. Banks, ed., Handbook of Simulation: Principles, Methodology, Advances, Applications and Practice (John Wiley & Sons, Inc., New York) 31-51.

Sargent, R. G. 2003, Verification and validation of simulation models, in: S. Chick et al., eds., Proceedings of the 2003 Winter Simulation Conference, 37-48.

Schlesinger, S., 1979, Terminology for Model Credibility, Simulation 32, 103-104.

Shafer, S. M. and T. L. Smunt, 2004, Empirical simulation studies in operations management: context, trends, and research opportunities, Journal of Operations Management 22, 345-354.

Shapiro, J. F., 2001, Modeling the Supply Chain, First ed. (Duxbury, Pacific Grove).

Stake, R. E., 2000, Case Studies, in N. K. Denzin and Y. S. Lincoln, eds., Second ed., Handbook of Qualitative Research (Sage Publications, London) 435-453.

Stuart, I., D. McCutcheon, R. Handfield, R. McLachlin, and D. Samson, 2002, Effective case research in operations management: a process perspective, Journal of Operations Management 20, 419-433.

Wacker, J. G., 1998, A definition of theory: research guidelines for different theory-building research methods in operations management, Journal of Operations Management 16, 361-385.

Will, J., M. Bertrand, and J. C. Fransoo, 2002, Operations management research methodologies using quantitative modeling, International Journal of Operations & Production Management 22, 241-264.

Yin, R. K., 2003, Case Study Research: Design and Methods, Third ed. (Sage Publications, California).

Appendix A

CASE STUDY DESCRIPTION OF ARLA FOODS RFID IMPLEMENTATION

This case study describes how and why Arla Foods has carried out an RFID implementation. Furthermore, the outcome of the implementation is analysed and discussed.

ARLA FOODS RFID IMPLEMENTATION

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1 Introduction

1.1 Background

Arla Foods is the largest dairy company in Europe which exclusively produces milk-based products. It is a co-operative owned by milk producers in Sweden and Denmark. Besides its main markets Sweden, Denmark and the UK, Arla Foods runs subsidiaries in 19 other market areas all over the world. Its core business activities are the development, production and distribution of dairy products. In contrast to most other retail suppliers in Sweden, Denmark and UK where products are distributed by the retailers themselves, Arla Foods distributes fresh products directly to retail outlets. In order to distribute its milk-based products efficiently, Arla Foods uses different types of roll containers.

In Sweden, Arla Foods has traditionally used one type of roll container in the distribution of dairy products. This roll container was specifically designed to be used for distribution of fresh milk, which constitutes the single greatest part of the total volume distributed by the company. This roll container is used for transport, externally and internally at dairies, and to display products in retail outlets. However, product introductions and new primary packaging designs have drastically increased the range of dairy products the company offers. This has affected production and distribution processes; one example is the picking process which was previously performed by the truck driver at the truck platform and is now performed in a diary distribution centre. The increased range of products has also resulted in greater volumes of the distributed products being placed and displayed on retail shelves and not in the traditional roll container.

In order to pick and distribute a wide variety of products efficiently Arla Foods has developed a new roll container (see figure 1). This roll container is made of metal, has wheels and measures 430x660mm with a height of 1430mm. The roll container has three compartments which split the roll container horizontally. To enable more efficient return transports the roll container can be widened at one end so empty roll containers can be inserted into one another.

Figure 1. The new roll container.

1.2 Problem

Arla Foods has experienced difficulties in managing and controlling the rotation of roll containers. A large number of roll containers are lost annually and the information concerning how many roll containers are in circulation or how much is in stock at the dairies is not available. A logistics project manager describes the situation thus; ”*it's chaos and the roll containers just disappear*”.

A roll container is a piece of material handling equipment which is absolutely crucial for Arla Foods since without the roll containers the company would not be able to supply its customers with its products. However, Arla Foods roll containers may also be useful for other firms. There are firms, such as moving and catering firms, which build up their internal logistics on other firms' roll containers. These firms steal roll containers from Arla Foods and are the major reason way large number of roll containers are lost annually. Based on historical purchases of roll containers, Arla Foods suspects that roughly ten per cent of its roll containers are lost annually. Arla Foods suspects that the company has approximately 80-100 thousand traditional roll containers. The cost of a roll container is approximately 1,200 SEK so losing ten per cent constitutes a loss of between 10-12 million SEK annually. In total Arla Foods must reinvest more than 20 million SEK annually in returnable assets (roll containers, plastic crates etc.) to cover the assets which are lost.

To decrease its reinvestment costs, Arla Foods has focused on procuring the roll containers at a low price and minimising the amount of roll containers. To combat the loss of roll containers, Arla Foods has assigned a group of employees (called "returnable goods police") to collect lost roll containers and other returnable assets belonging to the company. However, such measures are not the long-term solutions to the problem and Arla Foods is still losing ten per cent of the roll containers annually.

Introducing the new roll container is a major investment. In addition, the new roll container is more useful than the traditional one since it has three enclosed shelves while the traditional one have two shelves with side panels. Based on its experience of use of the traditional roll container Arla Foods has estimated that twice as many new roll containers would be lost compared to loss of the traditional roll container i.e. 20 per cent annually. Consequently, in order to introduce the new roll container Arla Foods needs to be able to manage and control the rotation of the new roll containers.

1.3 Purpose

The purpose of the RFID implementation was twofold. Primarily, the purpose was to ensure traceability of the roll containers in order for the roll containers to be managed and controlled more efficiently. Arla Foods aimed to use RFID technology to automatically identify the new roll containers in order to collect accurate and precise data regarding the roll container flow. Based on this information the company would be able to identify where roll containers are lost and discuss this with the relevant organisations, making them understand that the roll container is a resource needed to produce and distribute products according to customers' wishes. Furthermore, this information would enable Arla Foods to manage and control the roll container flow more efficiently. The secondary purpose of the RFID implementation was to gain experience and insights into RFID technology.

1.4 Focus and demarcations

The RFID implementation was restricted to 6000 roll containers introduced at a dairy distribution centre in Jönköping, Sweden. These 6000 roll containers are so far the only new roll containers introduced at Arla Foods. However, the company is going to introduce the roll container at three other diary distribution centres in Sweden (Gothenburg, Stockholm and Örebro) and estimates that in total 26,000 roll containers will be introduced. Even if the focus is on the new roll container introduced in the Jönköping dairy distribution centre, the three other dairies and their planned introduction of the roll container were considered and taken into account during the RFID implementation. At the Jönköping diary distribution centre the roll container is only used for approximately 20 per cent of the distributed product volume. The remaining product volume is distributed using the traditional roll container. The traditional roll container and other returnable assets were also delimited from the RFID implementation, but were also taken into account during the RFID implementation.

2 Overview of the new roll container rotation

The Jönköping dairy is made up of three physically integrated plants; production plant, warehouse for the finished products and a dairy distribution centre. Milk, cream and sour milk are produced in the dairy. The produced products are stored in the warehouse for finished products, and are distributed from here to Arla Foods' other dairies. In the dairy distribution centre, low-volume products are picked and distributed to retail outlets. High-volume products are directly picked from the warehouse for finished products.

The new roll container is a central component in Arla Foods' physical distribution. The new roll containers circulate in a closed loop between the Jönköping dairy distribution centre and retail outlets (see figure 2). In total, the dairy distribution centre distributes approximately 500 SKU to 2200 delivery points/retail outlets using approximately 80 trucks. On average the dairy distribution centre processes 6000 customer orders, representing a weight of 3500 tons every week. Distributing fresh products with relatively short expiry dates calls for short lead times. The customer order lead time is from 4 to 24 hours. A third-party logistics (3PL) provider performs transport activities between the dairy distribution centre and retail outlets. The central activities connected to the new roll container are described below.

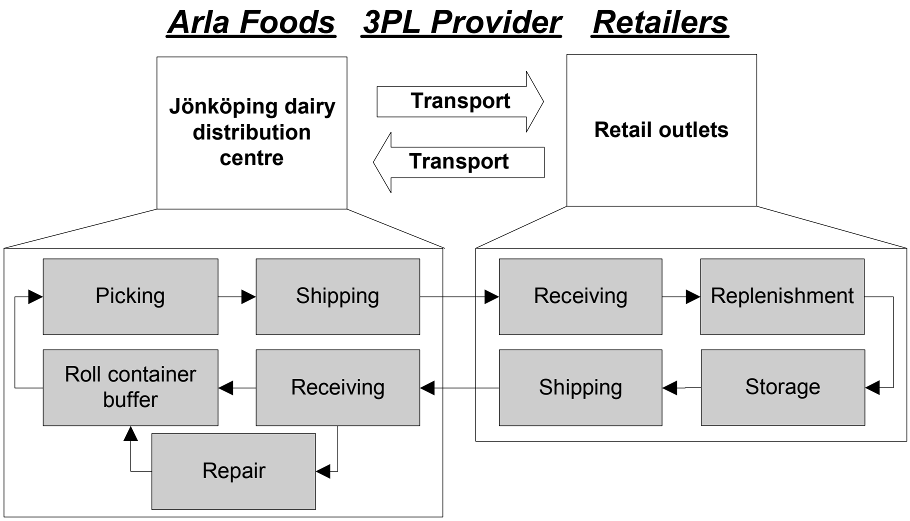

Figure 2. The rotation of the new roll container.

2.1 Picking process

The picking trucks used for picking customer orders at the dairy distribution centre have the capacity to carry four roll containers. The roll containers are collected at a roll container station, see figure 3. The roll containers are brought to the station by a lift from the roll container buffer area. When a picker is given a picking assignment, the warehouse management system (WMS) automatically prints destination labels (bar codes) for each roll container. The picking assignment defines how many roll containers are needed and the order of roll containers on the picking truck. The WMS controls where in each roll container (shelf and side) the picked unit (case) is to be placed. Small customer orders are picked collectively in single roll containers. When all units have been picked according to the pick order(s), the roll containers are placed in a buffer area or at a shipping gate. Finally, the roll containers are rolled into the trucks whose contents are kept at required temperatures of 4-8 degree Celsius. 3PL providers perform transport to the retail outlets.

Figure 3. The roll container station in the dairy distribution centre.

2.2 Retail outlet processes

As the trucks arrive at the retail outlets the roll containers are rolled to the cold storage area. The empty roll containers and other empty returnable goods from the previous shipment are rolled into the truck, which continues its route or sets off back to the dairy or a terminal. In the cold storage area (which consists of display area and storage area) the products on the new roll container are placed on the shelves within the reach of consumers. When a roll container is empty the roll containers is placed among the other empty roll containers. Because of limited space in the retail outlets the empty roll containers and other empty returnable goods may be stored at the receiving gate outside the retail outlet.

2.3 Receiving process

The dairy receives empty returnable goods directly from retail outlets or via 3PL terminals. All returnable goods are unloaded in the returnable goods area. Roll containers which need to be repaired are taken to the repair shop. The other roll containers are put into the roll container washing machine queue in groups of five. When the roll containers have been processed by the washing machine a lift take the roll containers to a buffer area where empty roll containers are stored. From here the roll containers are automatically fed into the dairy distribution centre to be used by the pickers.

3 The RFID implementation process

Arla Foods' implementation process of the RFID system can be divided into eight pragmatic and sequential steps. Some steps were more difficult and time-consuming than others, but Arla Foods' implementation process demonstrates that a key for successful RFID implementation is performing the implementation systematically and from a problem-oriented perspective.

1) *Problem identification.* In this first step the problem was identified and an objective was defined.
2) *Concept development and system design.* In this step different concepts of how to solve the problem are discussed. The different concepts lead to different system designs which may have different information and technology needs.
3) *Return on investment analysis.* In this third step the result of the concept development and system design is assessed economically.
4) *RFID trial.* In this step the technology is tested and put though its working environment in order to verify that it works as anticipated.
5) *Choosing system integrator*. Based upon the result of previous step system integrator(s) are chosen.
6) *Implementation*. This sixth step involves hardware installation and adjustments, software development, process changes and employee training.
7) *Improvements*. Increase the level of automation and performance of the implemented system.

8) *Expand the implementation and application areas.* Use the implemented infrastructure by expanding the use of RFID to other application areas.

The first six implementation steps are described below. Step seven and eight are described in their own chapters since these steps have not fully ended.

3.1 Step one: Problem identification

At the end of 2001, the magnitude of investments in the new roll containers was highlighted by top management. Arla Foods logistics department undertook the task of cutting the fixed and annual costs of the new roll containers. The task was given a high priority since Arla Foods estimated that the loss of the new roll container that was going to be introduced would be twice as much as the traditional roll containers i.e. 20 per cent annually. Furthermore, the new roll container would be a crucial component in the dairy distribution centre that was being set up at Jönköping dairy at that time. A shortage of roll containers would cause major distribution disturbances. In order to decrease the predicted loss, Arla Foods needed to efficiently manage and control the rotation of the new roll container. The question was then; how could this be done?

3.2 Step two: Concept development and system design

In the concept development and system design steps different ways of managing and controlling the rotation of the new roll containers were explored. A fundamental component in managing and controlling the rotation of any returnable asset is to assign a unique identity to each unit, enabling it to be identified at different locations throughout its flow. Subsequently, an essential component is to display the information about the last location the unit was in.

The concept development and system design was carried out during 2002 by Berne Carlson; Head of Logistics and Distribution in Sweden, Eva Blomqvist; Project Manager and two consultants (Rolf Larberg and Gillis Levander) specialized in Auto-ID technology. Workshops were run to find out what information regarding the roll container flow could be useful and what data had to be collected from the roll container flow in order to generate that useful information. The first proposal was to manage and control the roll container in a rental system. A rental system would require registration of roll container identities at four locations; in the receiving process and picking process at dairy, and in the receiving process and shipping process at retail outlets. This would enable Arla Foods to generate four virtual roll container zones; at the dairy, on its way to the customer, at the customer and in transport to the diary (see figure 4). However, in such a system the hardware investment and the additional work for the truck drivers were considered to be too great. Furthermore, such a system would require additional administration and would not be appreciated by the customers. Consequently, a rental system was discarded by Arla foods.

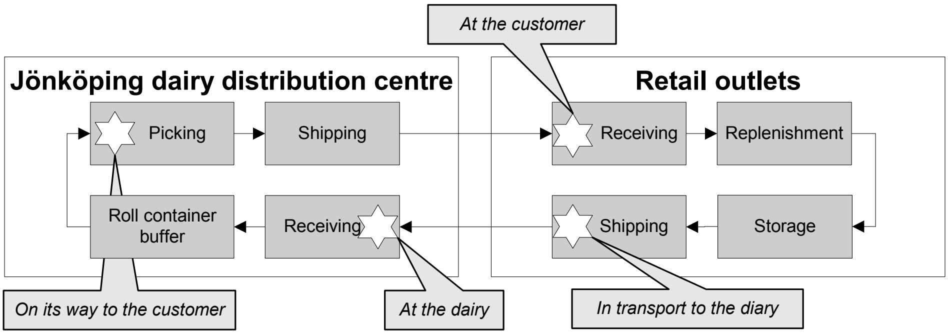

Figure 4. The required identification locations for a rental system.

Based on the experience from the rental system proposal Arla Foods simplified the rental system by only using two of the identification locations; the one in the receiving process at the diary and the one in the picking process at dairy. This would enable Arla Foods to achieve two virtual roll container zones; at the diary or in transport to the dairy via a customer. This would in turn enable Arla Foods to obtain information about which roll container and how many roll containers are located at the dairy or at a specific customer. This solution appealed to Arla Foods since it was relatively simple and required a lower investment than the rental system. The simplicity lies in the fact that roll container flows from the retail outlets converge. All roll containers have to physically pass through the roll container washing machine when they are received. All roll containers must also pass through a roll container station in order to be used in the dairy distribution centre. As all roll containers have to pass through these two places, Arla Foods would relatively easily be able to identify each individual roll container shipped to each customer and each individual roll container returned from all customers. In addition to the two identification locations, an identification location at the repair shop was also suggested (see figure 5). This would enable Arla Foods to achieve a third virtual roll container zone; at repair shop. However, the main benefit of identifying individual roll container at the repair shop would be recording the type of damage and repair to the individual roll container. The data gathered might be used to analyse the physical strengths and weaknesses of the roll containers.

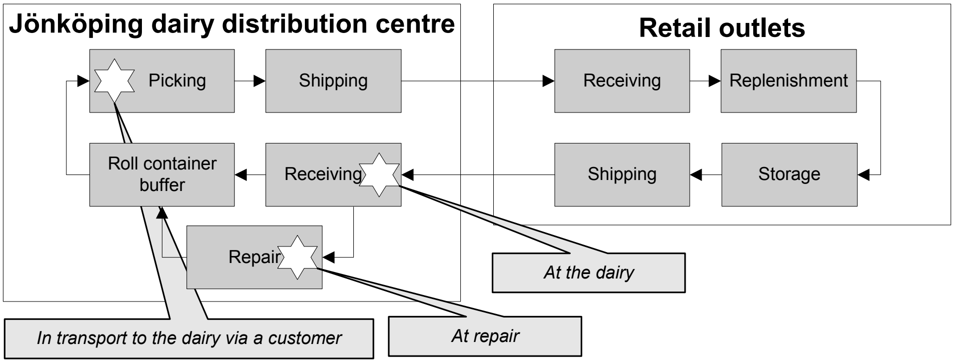

Figure 5. A system using three identification locations.

Arla Foods decided to manage and control the roll containers by using the three identification locations to gather accurate and precise data about the roll container flow. Based on the data gathered, Arla Foods is able to have a discussion with customers who lose or misplace roll containers, informing them that the roll containers are an important resource which must be returned in order for ordered products to be produced and delivered on time and according to customers' wishes. The issue was then to how to gather accurate and precise data, since it does not help to say to a customer that Arla Foods thinks or suspects that roll containers are not being returned from specific retail outlets.

3.2.1 Choosing Auto-ID technology

In order to gather accurate and precise data about the roll container flow some kind of Auto-ID technology is needed. Arla Foods' roll containers and plastic crates are all labelled with bar codes, enabling the company to identify each unique container or crate. Using bar codes to identify the new roll containers would enable Arla Foods to gather data about the roll container flow. However, scanning bar codes is a time-consuming activity which requires considerable human effort. Bar codes are also easily damaged due to rough handling of roll containers. According to Arla Foods, scanning bar codes is regarded by some workers as laborious. As a result, workers do not always scan the bar codes, which undermine the reliability of the system. These bar code drawbacks led to Arla Foods' interest in exploring alternative Auto-ID technologies which might improve the traceability of roll containers. In this sense, RFID technology was considered a useful and interesting technology by Arla Foods.

The interest in exploring RFID technology was also based on the fact that there may be a competitive advantage in gaining knowledge and experience of the technology. Large retail chains, such as Wal-Mart, Metro and Tesco, are in the process of implementing RFID technology on pallet and case levels. Arla Foods wants to be a first-rate supplier to retailers, so that having knowledge and experience of the technology might make Arla Foods a more attractive partner. Another motive is the possibility to increase the corporate levels of customer service. Arla Foods manages and controls the internal flow of its products. However, when the products are shipped from the dairies, Arla Foods loses its ability to manage and control the product flow. Customers have daily questions and complaints regarding deliveries, in particular that deliveries do not arrive at the customers' according to the planned schedule. According to Arla Foods, RFID technology may be a key technology in improving the process of information exchange between Arla Foods and its customers, thereby improving the possibility to increase the customer service offered by the company.

3.2.2 Type of RFID system

There are numerous types of RFID systems using different types of tags (read-only, read-and-write, active, passive), frequencies, standards, etc, all of which have different performance (reading rates and reading range) and costs. In the beginning, Arla Foods was influenced by hardware suppliers and was interested in writing and storing different kind of data on the RFID tag, data such as destination (in order to use the destination data on the tag for sorting roll containers in cross docking terminals). However, Arla Foods quickly realised that it only needed a passive read-only RFID tag containing a unique identification number to refer to all the information stored in a database.

3.3 Step 3: Return on investment analysis

A return on investment analysis based on the suggested system design was carried out. The analysis indicated a payback period of approximately 14 months (see table 1). The total cost of the investment was estimated at approximately 3 million SEK. The investment costs included attaching a tag to 26,000 roll containers and installing three readers at each of the four dairies which would use the roll container. The development of the software (middleware) which integrates the RFID system with Arla Foods WMS and ERP systems was assumed to suit all the four dairies.

	Estimated figures			
	Amount per dairy	Total amount	Cost	
Hardware				
Tags				
Transponder		26,000	10	260,000
Plastic plate		26,000	8	208,000
Readers				
Process unit	3	12	20,000	240,000
Antenna	3	12	10,000	120,000
Station	3	12	5,000	60,000
Servers	1	4	30,000	120,000
System Integration				
Man-hours; hardware installation				
Tags		2,200	375	825,000
Readers	25	100	400	40,000
Software develop. & implementation		1	750,000	750,000
Trial				300,000
Training				100,000
Cost of investment (SEK)				**3,023,000**
System maintenance and support				100,000
Running costs (SEK)				**100,000**
Decreased loss of roll containers				2,340,000
Decreased tied-up capital				312,000
Running profit (SEK)				**2,652,000**
Payback period (years)				**1.2**

Table 1. Payback analysis of the RFID system.

The total running profit of the investment was estimated at approximately 2.6 million SEK annually. Arla Foods expected that up to 20 per cent of its 26,000 roll containers would be lost annually. However, an RFID system would not eliminate the whole loss. Arla Foods made a moderate estimation that the loss would at least decrease by 7.5 per cent, which equals approximately

(26,000*1,200*0.075) 2.4 million SEK annually in decreased loss of roll containers. In the analysis the tied-up capital was also embedded in the running profit. The RFID system aimed to increase the control of the roll containers, resulting in the possibility of reducing the number of roll containers needed by 20-30 per cent. Assuming 20 per cent fewer roll containers and an interest rate of 5 per cent, the decreased tied-up capital was estimated at (26,000*0.2*1200*0.05); approximately 0.3 million annually. A benefit that was not included in the analysis was the decrease of cost related to operational disturbances to the dairies. Operational disturbances, due to few roll containers, are an uncommon problem. However, when there is disturbance it results in extremely high costs.

Based on the short payback period and company interest in exploring the use of RFID technology, Arla Foods decided to further investigate this technology in order to automatically identify roll containers. The next step towards ensuring traceability of the roll containers was to really see if RFID technology could be used to automatically identify roll containers. In order to evaluate this, an RFID trial was carried out in real conditions at the company's Örebro dairy.

3.4 Step four: RFID trial

Two consultants who specialised in Auto-ID technology were responsible for carrying out the RFID trial at Arla Foods' Örebro dairy. The RFID trial was carried out in the middle of 2003 and the reason behind performing a trial was to assess if RFID technology could be used to automatically identify roll containers. Two different RFID systems, operating on 125 kHz and 13.56 MHz frequency, from two different system integrators, were evaluated in the trial. Different tag locations and ways of attaching a tag to a roll container were also investigated.

The trial indicated that both RFID systems could be used to automatically identify roll containers and that the two different systems were essentially equivalent. Both the systems had a reading rate of approximately 100 per cent and a reading range that was sufficient for the needs of the company. One surprising result from the trial was the tag location on the roll container that was suggested. From experience Arla Foods knew that the wheel house is a fragile component on a roll container and recommended that the RFID tag should be applied elsewhere. However, numerous tests were carried out and from a reading rate perspective the wheel house turned out to be the best location (see figure 6). Another advantage of applying the tag to the wheel house is that the wheel (including the wheel house) is a standardised roll container component, also used by Arla Foods' traditional roll containers, which is easily replaced.

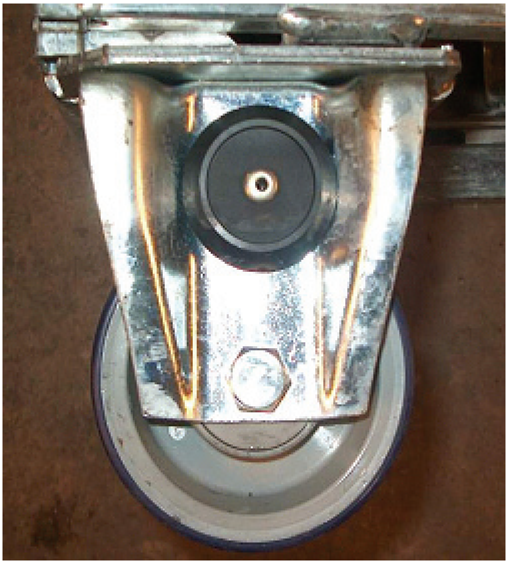

Figure 6. An RFID tag attached to a wheel house.

Based on the short payback period and the result of the trial, Arla Foods decided to implement an RFID system operating on 125 kHz frequency. According to Arla Foods the 125 kHz frequency system was slightly more robust and meant slightly lower costs than the 13.56 MHz system. When choosing an RFID system, Arla Foods did not take into account what RFID systems other retail firms or organisations used since the RFID system for identifying the roll containers is only to be used by Arla Foods. For example, Svenska Retursystem, which runs a pool of plastic pallets for the Swedish food industry and retail trade, had equipped its pallets with 13.56 MHz tags. Arla Foods chose the system which the trial indicated was the best and did not consider what RFID systems other firms or organizations used.

3.5 Step five: Choosing system integrator

Four system integrators submitted an offer for supplying a 125 kHz RFID system. Arla Foods chose ELGAB which had participated actively in the trial and supplied the 125 kHz RFID system tested in the trial. The major reason for choosing ELGAB was the company's great commitment to getting the RFID systems to work perfectly in the trial. Arla Foods was given the impression by some other system integrators that they only wanted to sell RFID hardware. Furthermore, the company felt that there was no reason to choose another system integrator than the one participating in the trial, where Arla Foods had been presented with a functioning RFID system, which the company knew functioned satisfactorily.

3.5.1 The RFID system

ELGAB purchased RFID hardware from different suppliers of components. The hardware purchased consisted of standard RFID components and equipment, so no RFID components or equipment were customised for Arla Food. ELGAB also installed the hardware and fine-tuned the system in order to ensure high system performance.

The RFID tag was applied to the front left wheel house of the roll containers during the production of the roll containers. The tag, Epoxy Disc Unique, is produced by Sokymat and contains a unique 64-bit identification number. The tag is passive and read-only. The tag is 30mm in diameter and is 1.6mm thick. In ideal conditions the reading range is approximately 250-300mm. However, the tag is not specifically designed to be applied to metal, such as roll containers. So in order to use the tag, the two consultants constructed an 8mm plastic plate on which the tag was fitted. On the roll container the plastic plate creates a distance between the tag and the metal, facilitating a reading range of approximately 100mm from an antenna.

In total, three readers (control unit and antenna) were installed. With the relatively short reading range of approximately 100mm, the readers were mounted on rails which the roll container is rolled through so that the tag attached to the roll container can be read. The RFID system is able to read a roll container passing by at a velocity of 20 metres per second. This is much faster than a roll container can be rolled, so reading speed is definitely not a system constraint.

Middleware is needed so that the RFID system can be integrated with a WMS or an ERP system. Middleware is the software that collects, processes and transfers the information from the RFID system to a WMS or ERP system.

ISAB (Industrisystem AB) developed middleware for Arla Foods. The middleware was specifically developed for Arla Foods' needs, but the company was also forced to make some changes to its ERP system (Movex) in order to integrate the RFID system.

3.6 Step six: Implementation

The RFID system was intended to go live in October 2003, at the same time as the roll container was introduced in the company's Jönköping diary. The roll container was introduced when the distribution area of the Jönköping diary increased, at the same time as a new automated warehouse system and a WMS were introduced. The RFID system components were installed, tested and ready to be used, but the start-up of the WMS did not go as planned. This forced the dairy to prioritise on implementing and getting the WMS to function properly. This resulted in the start-up of the RFID system being postponed. However, Arla Foods was still forced to introduce the roll container and in order to keep track of the roll containers a stand-alone (not integrated with WMS or ERP systems) bar code system was used. As the WMS started to work properly and the dairy distribution centre organisation got used to the new systems Arla Foods gradually introduced the RFID system in different phases. Finally, in April 2004, Arla Foods had implemented the whole RFID system and got it running properly. From this date, all information has been collected in Arla Foods' ERP system. The roll container flow with activities related to the RFID system and implementation issues are described below.

3.6.1 Description of the roll container flow with activities related to the RFID system

As mentioned earlier, roll containers are brought to a roll container station by a lift from the roll container buffer area. At the roll container station, pickers collect roll containers. When a picker is given a picking assignment, the WMS automatically prints destination bar code labels. The picker applies the labels to the collected roll containers. To link a roll container to a customer, the roll container is rolled through a RFID station (an RFID reader mounted on a rail) located a couple of metres away from the roll container station. The unique identity of the tag is identified and displayed on a screen. The picker scans the destination bar code on the roll container, linking the roll container to a customer (see figure 7). The status of the roll container in the ERP system will now say that the roll container is "to be found" at the specific customer's. Very small pick orders (from small customers) are picked collectively in single roll containers. These roll containers are not linked to the customer, but to the delivery route. When roll containers are linked to specific customers/routes, the picking begins, and once this has been finished the roll containers are placed in a buffer area or at a shipping gate, waiting to be shipped. It may turn out that roll containers linked to customer/route are not needed. These roll containers are brought to the roll container station to be used in a new picking assignment where each one is linked to a new customer/route.

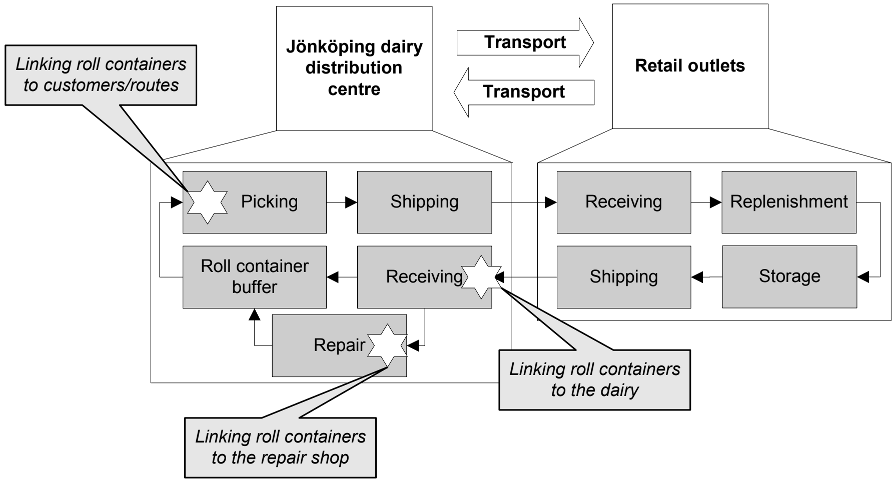

Figure 7. Locations where roll containers are linked to dairy or customer/route.

The roll containers received at the dairy are unloaded in the returnable goods area. The roll containers which need to be repaired are brought to the repair shop while the other roll containers are put into the roll container washing machine queue in groups of five. When the roll containers are put in this queue, the RFID tags attached to the roll containers are identified, linking the roll containers to the dairy. If all five RFID tags are not identified, the operator receives an error signal. Figure 8 shows the gate of the roll container washing machine with the RFID reader mounted on a rail. When the roll containers have been processed by the washing machine they are brought to the buffer area where empty roll containers are stored. The roll containers brought to the repair shop are linked to the repair shop using the same type of RFID reader i.e. mounted on rails, as used at the roll container washing machine. The type of repair and damage to every roll container is recorded in the system.

Figure 8. The RFID reader at the gate of the roll container washing machine.

Apart from an RFID tag, all the roll containers have a bar code label which can also be used to identify roll containers. This bar code was used in the introduction of the roll containers when the installed RFID system could not be used due to WMS problems. The bar code system is not only used as a backup for the RFID system, but for performing checks on customers who may have difficulties returning roll containers. When performing checks the truck drivers scan the roll containers delivered and received from the customer, verifying the transfer. Doing checks by reading RFID tags is inconvenient since the tag is located in the wheel house while the bar code is located on the side of the roll container, thus is relatively easily scanned.

All accumulated data are stored in Arla Foods' ERP system. Developing a user-friendly interface module/tool in Arla Foods' ERP system was too expensive, so Arla Foods uses a data analysis software tool (Qlikview) to analyse and interpret accumulated data. This software enables Arla Foods to investigate the roll container rotation from different perspectives i.e. from the view of individual roll containers, customers/routes, maintenance, and time periods.

3.6.2 Implementation issues

Implementing a traceability system based on RFID technology has not been without problems. However, the problems were not caused by RFID technology or any information system, but, by the dairy distribution centre organisation and the RFID backup system i.e. the bar code system. The system design is based on a situation where all roll containers have unique identities. Unfortunately, the bar code manufacturer had accidentally made duplicates of numerous bar code identities, which led to numerous roll containers being assigned the same bar code identity. When the roll container was introduced the RFID system could not be used since the new WMS did not work correctly, so the bar code system was used to link roll containers to customers/routes. This resulted in "very strange" data in the ERP system, which indicated that something was wrong. A lot of resources were put into identifying the source of the problem and when Arla Foods finally identified the problem, extra equipment and software were installed by the RFID reader at the roll container washing machine. This enabled Arla Foods to identify the duplicate roll containers. This equipment is still functioning, so Arla Foods is able to single out any unique roll containers as they are put through the washing machine.

The second implementation problem was gaining acceptance from the dairy distribution centre organisation, particularly from the pickers and their managers. In situations where the dairy distribution centre had difficulties meeting deadlines, such as time schedules for deliveries, linking roll containers to customers/routes was neglected since it was seen as an unnecessary and time-consuming activity. This meant that the dairy distribution centre did not always link roll container to customers/routes all the time, which ruined the whole idea of the implemented system. The extra activities to link a roll container to customers/routes are rolling the roll containers through the RFID station and scanning the destination bar code. This requires only a few more seconds than just collecting empty roll containers. However, the source of the problem is that the container station is a bottleneck. Now and then a queue forms at the container station and to prevent a queue situation roll containers are taken out of the roll container station in advance and are buffered besides the station. As a logical consequence of this is a queue was formed at the RFID station instead of one at the roll container station. Arla Foods tackled the lack of acceptance by informing the staff involved about the importance of linking roll containers to customers/routes and by providing them with training. Time studies were also performed to illustrate that linking roll containers does not take much more additional time.

4 The outcome of implementation

The implementation of RFID technology has resulted in success, since the loss of roll containers have been far below Arla Foods' expectations. Introducing the roll container involved a risk of losing one in five roll containers annually, and until the beginning of 2006 close to zero roll containers have been lost. The elimination of the expected loss has mainly been due to people's awareness that the roll containers are tracked and traced than actual action from Arla Foods. Arla Foods has not formally informed its organisation, 3PL provider or its customers about the implementation, but word has spread that Arla Foods has an automated system based on RFID for tracking and tracing roll containers. This awareness of the system has made the dairy distribution centre organisation, truck drivers and customers pay more attention to the rules and procedures concerning the control of roll containers. Arla Foods has not yet shown its customers the capabilities and precision of the system. Nor have any findings been presented to the 3PL provider or the customers to demonstrate that the system actually works. Consequently, Arla Foods feels it is important to begin to inform and show customers the capabilities and precision of the system. If it does not inform and show its customers the system, roll container might begin to "disappear", forcing Arla Foods to confront those who lose roll containers.

Even though the implementation has resulted in hardly any loss of roll containers, Arla Foods' view is that the greatest value of the implementation has not yet been explored i.e. the opportunity the system offers in managing and controlling the rotation of roll containers more efficiently. In order to manage and control the rotation of its roll containers more efficiently Arla Foods needs to learn and gain understanding about the rotation of the roll containers by analysing and interpreting the data collected from the system implemented. Based on the accumulated data so far, Arla Foods has been able to learn the fundamentals of the rotation of the roll containers. For example, the distribution of the roll container cycle time which indicate that nearly all roll containers are returned back to the dairy within three to four days (see figure 9). This roll container cycle time data and with data concerning how many roll containers are used in each customer shipment enables Arla Foods to simulate the rotation of the roll containers in order to find out how many roll containers they need. However, cycles and demand variations of roll containers related to weekends and holidays are still unexplored. It is these aspects which are important in order to plan how many roll containers are needed in stock and how to control the roll container flow between dairies and terminals. In a long-term perspective Arla Foods also aims to have a system that generates alarms when deviations occur, such as when a roll container has been away more than ten days.

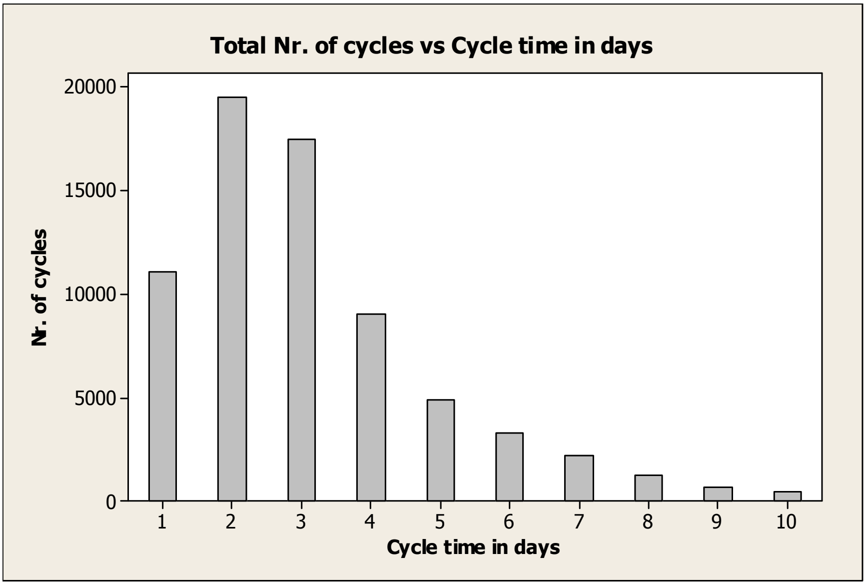

Figure 9. Distribution of roll container cycle time.

Strength of the implemented RFID system is that it enables Arla Foods to handle the uncertainty of the roll container demand. The system provides Arla Foods with granulised data which enables detailed decision based on real historical demand. Figure 10 illustrate the kind of data that is provided by the implemented system and might be used in managing and controlling the rotation of roll containers.

Other accumulated data that will be analysed are the repair data. When roll containers are repaired the individual roll container identification number is registered and the type of repair and damage is recorded. This means that Arla Foods can identify the physical strengths and weaknesses of the roll containers and relate the damage to, for example, who produced the roll container, batch number, the previous customer/route of the roll container or its repair history etc. Based on this kind of analysis Arla Foods aims to identify the underlying core problems behind damaged roll containers.

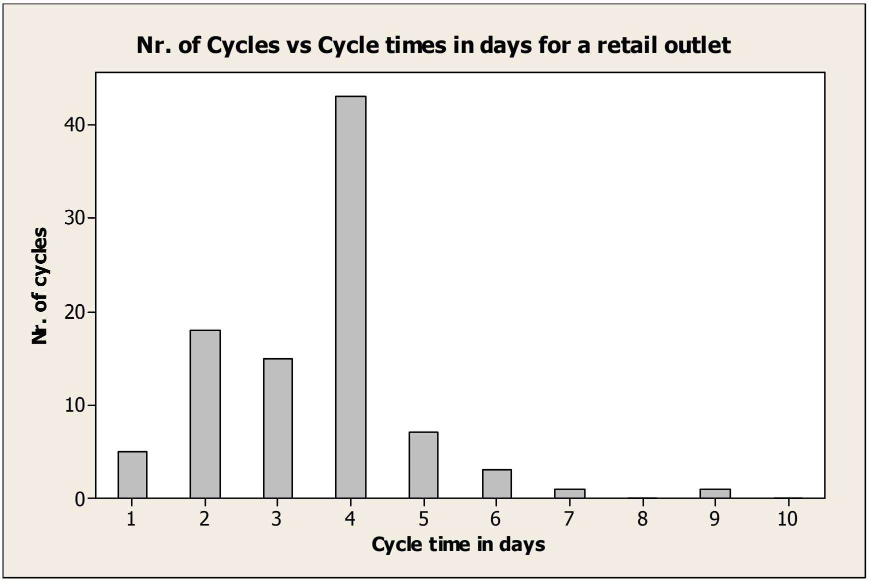

Figure 10. Distribution of cycle time for a retail outlet.

5 Planned improvements

Arla Foods has planned to improve the performance of the implemented system by eliminating the manual activities and time required to link roll containers to customers/routes. As described earlier, one of the implementation problems was organisational acceptance, which mainly originated from people thinking that linking roll containers to customers/routes took too much time. Moving the RFID station and placing it in line with the roll container station and letting the WMS keep track of the order in which roll containers are rolled from the container station, through the RFID station, and put on a picking truck, mean that the extra time associated with linking roll containers to customers/routes will be eliminated. This improvement will also eliminate the activity of scanning the destination bar code, thus improving the reliability of the system. A consequence of this improvement will be that the picking instructions from the WMS will state what roll container the picker is to place the products in instead of stating to what customer the products are picked for. With this improvement Arla Foods will be able to gather information concerning which units have been picked, in what roll containers and where in the roll containers the units been placed. In a product recall, Arla Foods would then know in which roll containers and where in those roll containers the recalled products are located. This would improve the precision of Arla Foods' traceability system which currently provides information concerning what customers have received a particular product batch number.

An improvement that has been discussed concerning the utilisation of the roll containers is informing the customers and making them aware of the system. This might make them more determined to return the roll container as soon as possible, resulting in lower cycle time. One suggestion for making the customers more aware of the system is printing the roll container ID number on the bill of delivery.

6 Next step for Arla Foods

The RFID implementation was restricted to 6.000 roll containers introduced in the company's Jönköping dairy distribution centre. However, Arla Foods is going to introduce the roll container at three other diary distribution centres in Sweden. The dairy distribution centre in Gothenburg is the next dairy where the roll container will be introduced. Even though an RFID system similar to that in Jönköping will be implemented in Gothenburg the circumstances are completely different. The dairy distribution centre in Gothenburg has recently been modernised and its organisations have wanted to introduce the new roll container and the accompanying RFID system for a long time. This means that the implementation in Gothenburg will probably be slightly easier since the organisation has already accepted the RFID system and wants to implement it. However, the dairy distribution centre in Gothenburg has a different picking system and a different WMS, which may cause problems with the middleware. Even if these differences were considered in the development of the middleware, it has not been verified that the middleware will work at the Gothenburg dairy or at the other dairies.

The RFID implementation in Gothenburg dairy distribution centre is planned to be up and running before the end of 2006. The implementation makes it possible for the Jönköping and Gothenburg dairies to use the roll container as a joint resource. This will probably decrease the total amount of roll containers needed. The implementation also makes it possible to identify roll container flows between the dairies; current use of the traditional roll container requires considerable manual work and is prone to error. For Arla Foods, the implementation makes it possible to compare the rotation of the roll containers at the two dairy distribution centres.

An outcome of the implementation result is that Arla Foods is thinking of to attaching RFID tags to other returnable assets, for example, applying RFID tags to all traditional roll containers. Basically, Arla Foods already has the middleware and just needs to expand the ERP system database and apply an RFID tag to each roll container which is relatively easy (the wheel manufacturer attach RFID tags to new wheels, Arla Foods remove the old wheel and then screw on a new wheel with an attached RFID tag). A first implementation step has been suggested where it might be enough to apply tags to 20 per cent of the traditional roll containers which are read by the existing RFID reader at the roll container washing machine (the traditional roll container also goes through the roll container washing machine). This would provide Arla Foods with cycle times, indicating how many roll containers are needed. A second step could be linking the traditional roll containers to customers/routes. Currently, this second step is difficult to achieve since it may require new shipping processes.

7 Discussion

Implementing an RFID system at the Jönköping dairy resulted in hardly any loss of roll containers. Furthermore, the RFID system provides Arla Foods with the opportunity to manage and control the rotation of the roll containers more efficiently. However, the implementation has also given Arla Foods insights into the opportunities and limitations of the RFID technology involved and into the aspects of implementing an RFID system. These insights are highly valued since they promote and improve collaboration with Arla Foods' customers and enable Arla Foods to be at the forefront of logistics development.

7.1 Technology insights

RFID implementation provided Arla Foods with insights into RFID system components, functionalities, performance and influential factors such as metals and liquids. Identifying roll containers by using RFID provides Arla Foods with reliable information concerning the rotation of roll containers. The strength of RFID in providing reliable information lies in the fact that the identification activity is non-manual, so that no “extra” activity needs to be performed. This in turn results in that the identification activity does not interrupt daily working procedure. Another important technological insight is how RFID technology and bar code technology complement each other. For example, bar codes are used for backup, linking roll containers to customers/routes and for performing checks on customers who may have difficulties in returning roll containers.

Based on the trial, Arla Foods concluded that both 125 KHz and 13.56 MHz RFID systems could be used and that the two systems were essentially equivalent. Arla Foods chose to implement the system using 125 KHz frequency since it was slightly more robust and involved slightly lower hardware costs. There have not been any technology- oriented problems with the RFID system, even if it has been used in an environment dominated by metals, liquids and rough handling. The performance of the technology surprised Arla Foods. For example, the RFID system has almost a 100% reading rate and nearly no RFID tags have been broken. The RFID tag is even more durable than the roll container.

Since Arla Foods chose to implement an RFID system operating on 125 KHz frequency much progress has been made concerning RFID technology. For example, Ultra High Frequency (UHF) has gained acceptance by the retail industry and standards are now being proposed by various organisations, such as GS1. However, this has not made Arla Foods regret its choice to implement a system operating on 125 KHz frequency. According to Arla Foods, if there would be any benefit or need, say customers’ wishes, to change the RFID technology, such as to UHF, this would be a relatively easy thing to do.

7.2 Implementation insights

Arla Foods argue that its RFID implementation has been successful. One key ingredient was performing the implementation systematically and from a problem-oriented perspective and not from a technology-oriented perspective. From a project standpoint, this was not an “RFID project”. The overall purpose was to ensure traceability of the roll containers in order to manage and control the roll containers more efficiently. RFID was the Auto-ID technology chosen to do the job of identifying roll containers, resulting in the project becoming an RFID implementation project. According to Arla Foods, one is all too easily blinded by the extensive opportunities offered by RFID technology, causing one to focus on the technology and not on the problem. Performing RFID projects for the sake of technology may end up in a business application with limited benefits.

As mentioned earlier, the implementation process can be divided into eight pragmatic and sequential steps. In each step Arla Foods took decisions which have an effect on the direction of the implementation. According to Arla Foods, the two most central decisions made were to keep the system simple and to perform the RFID trial at a dairy. Keeping the system simple (by not introducing a rental system or using a more advanced RFID system) with the possibility to later extend and scale the implementation, enabled Arla Foods to achieve a reliable and functioning system with relatively low investment costs. Performing the RFID trial at a dairy and not in a lab environment enabled Arla Foods to verify the concept and the technology in an implementation environment with electromagnetic interference, shifting temperatures, liquids, metal etc. Furthermore, it enabled Arla Foods to choose an RFID system specifically based on the company’s requirements and needs.

The major shortcoming of the implementation process was not actively involving the receiving organisation at the Jönköping diary. As described earlier, the Jönköping diary went through major distribution and warehouse restructuring and did not have much time to actively participate in the project. Arla Foods carried out the implementation without any active participation from the Jönköping diary. According to Arla Foods this was a major oversight, which finally resulted in a lack of support and acceptance from the receiving organisation. A consequence of not having any system owner participating actively in the project was that a lot of effort had to be made to gain organisational support and acceptance, effort which could have put into improving and further developing the RFID system.

Another shortcoming was represented by the measures for handling all the accumulated data. It is easy to forget how all the accumulated data are going to be analysed, interpreted and displayed. This was something that Arla Foods embarked upon late in the implementation process. Processing the data and using it in daily operations by integrating it in scorecards and internal reports is crucial to fully use the potential benefits of the implemented system.

7.3 Investment insights

One might ask oneself if the return on investment analysis, which indicated a payback period of approximately 14 months, is valid. The final investment and running costs of the RFID system turned out to mirror those of the return on investment analysis except for the additional cost of the data analysis software which was not considered when the analysis was performed. The cost of implementing the system (time spent by Arla Foods employees) was not included in the analysis and this cost increased due to organisational problems at the dairy. Apart from these omissions the cost of the implementation corresponded with the return on investment analysis. The running profit from the system is, however, difficult to verify. This is something that cannot be verified, but, one should remember that the analysis is only based upon a 7.5 per cent decrease in roll container loss while Arla Foods assumed that 20 per cent would be lost annually.

Arla Foods puts considerable efforts and resources in trying to manage and control all its returnable asset flows. The returnable assets that are returned to dairies are manually sorted, counted, checked for damage, reported in the ERP system etc. Arla Foods also performs manual inventory control every week at the dairies to make sure that there are enough roll containers in stock. Furthermore, dairy managers have a forum where they often discuss returnable asset issues such as roll container debts among dairies and plans for the purchase of roll containers. However, the implemented system enables Arla Foods to manage and control the rotation of the new roll containers more efficiently by using the roll container as a joint resource among the dairies and eliminating manual activities such as inventory control. The return on investment analysis does not include these benefits, thus the total benefit of the implementation is greater than indicated in the return on investment analysis.

8 CONCLUSIONS

According to Arla Foods its implementation of an RFID system resulted in success. Introducing the new roll container involved a risk of losing one in five roll containers annually and after introducing 6,000 roll containers and having the system running for approximately two years nearly zero roll containers have been lost. Furthermore, the implemented RFID system provides Arla Foods with an opportunity to manage and control the rotation of its new roll containers more efficiently. The result of the RFID implementation has meant that Arla Foods will implement a similar system at other dairies where the new roll container is going to be introduced. The implementation gave Arla Foods insights into the opportunities and limitations of the RFID technology involved and into the aspects of implementing an RFID system. A key insight is performing the implementation systematically and from a problem-oriented perspective. Arla Foods' implementation process of the RFID system can be divided into eight pragmatic and sequential steps. These steps might be used as practical guidelines for the implementation of an RFID system.

Appendix B

CASE STUDY DESCRIPTION OF IKEA'S RFID TRIAL

This case study describes how and why IKEA has carried out an RFID trial. Furthermore, the outcome of the trial and are analysed and discussed.

CASE STUDY DESCRIPTION OF IKEA'S RFID TRIAL

1 Introduction

1.1 Background

IKEA is inconsistent in its way of identifying goods throughout its supply chain. In the material flow from manufacturers to distribution centres, IKEA works on a consignment identification level i.e. type of product, number of unit loads, manufacturers and transport unit destination. At the distribution centres, where unit loads are unloaded from the transport units, IKEA (re)labels the unit loads providing them with unique ID. This unit load identification is used downstream, all the way to the receiving process at IKEA stores. Consequently, IKEA has limited visibility and traceability of the goods since IKEA works with aggregated data from consignment and unit load levels of identification.

IKEA aims to strengthen the link between the information flow and the physical flow of goods by developing a new structure for identifying goods in its supply chain. The first step IKEA focuses on is to gain traceability down to unit load level i.e. from manufacturers to IKEA stores. To achieve this IKEA is modernising its information system, which is based on bar code technology, and integrating it throughout its supply chain. However, within this project, IKEA also explores other automatic identification technologies which may improve IKEA's traceability. In this sense, an RFID trial was conducted to explore RFID technology and its possibilities it presents within supply chain applications. The RFID trial was the first project concerning RFID technology conducted by IKEA.

1.2 Problem

The RFID trial was conducted at the turn of the year 2004 at a customer distribution centre (CDC) in Sweden. The CDC distributes all of IKEA's customer orders in the Nordic region i.e. Sweden, Finland, Norway and Denmark. Customer orders can either be placed in person at a store, by telephone, fax, regular mail or via internet and are directly distributed home to the end-consumer. The CDC is owned by IKEA but the daily operations are run by a logistic provider. The CDC contains conventional storage area and an automatic storage system with 6000 pick locations, whereas 1500 of those are dynamic. The CDC process about 300000 cubic metres of goods annually, which represents fifteen per cent of IKEA's total Nordic flow of goods. Transport of goods, from the CDC to end-consumers is carried out by transport providers. The CDC is critical for IKEA since IKEA stores do not have the warehouse or shelf space for all the products IKEA offers. IKEA provides these products from the CDC. The main objective of the CDC is to provide high service levels for end-consumers, namely, to deliver the right goods on time in an efficient manner.

The CDC uses steel containers (see Figure 1) in order to enable efficient handling of goods and to achieve an acceptable cube utilisation of the deliveries to customers. The steel container consists of two components; a platform and side bars. Depending on what products a steel container is supposed to contain and protect, different side bars are placed in different positions on a platform, forming the unit load carrier. Using traditional EUR pallets would limit the cube utilization of transport units since distributing customer-ordered products on EUR pallets does not allow stackability. Furthermore, the EUR pallet does not protect and contain the product as the steel container does. In order to enable efficient return transport, the steel container is collapsible.

The CDC has difficulties managing and controlling the rotation of steel containers. A steel container is relatively expensive. Moreover, it is a piece of material handling equipment which may be useful for other purposes and to other firms. However, due to IKEA's lack of traceability the CDC loses roughly ten per cent of the steel containers components annually. This equals a value of approximately 420000 Euros per year. In total, the CDC has about fifteen thousand steel containers.

The consequences of the high loss of steel containers are not only the recurring costs of additional steel containers. The high loss of steel containers also forces the CDC to use EUR pallets when there is shortage of steel containers; this results in higher product damage rate and low cube utilization of deliveries. When the shortage problem was at its worse, IKEA had a cube utilization of transport units between 16 and 17 per cent i.e. one layer of EUR pallets at the bottom of the trucks. Furthermore, concerted efforts are regularly put into getting the steel containers back to the CDC. Administrative staff at the CDC spends several hours every day on the phone with transport providers trying to get the steel containers back to the CDC. As a result, the CDC had to procure a large number of steel containers to ensure that a shortage does not occur. Naturally, this resulted in a high inventory of steel containers. As a manager described it" *We just pumped money into the steel containers*".

Figure 1. An assembled steel container with goods.

The source of the loss of steel containers is difficult to pinpoint and IKEA does not know if the steel containers are lost internally or externally. However, one thing is clear; that the CDC does not keep check of the steel containers. The CDC does not know where they are lost, how many are lost, or how much is in stock at the CDC or at the transport providers'. Consequently, one way to solve this problem is to attach RFID tags to the steel containers, which would enable IKEA to verify how many steel containers are going out from the CDC and to whom, and how many steel containers are received and from whom.

1.3 Purpose

The purpose of the RFID trial was to gain insights into RFID technology and see if the technology could be used in ensuring traceability of steel containers in order to improve the process of managing and controlling the rotation of steel containers. By performing an RFID trial, IKEA also aimed to gain an understanding of how to set up a possible RFID implementation at the CDC.

1.4 Demarcations

The focus of the RFID trial was on the activities and processes connected with the steel containers at the CDC, see Figure 2, and on the RFID technology itself. Gaining traceability of the steel containers within the CDC does not prevent the external loss of the steel containers. To prevent the loss of the steel containers, traceability throughput the whole distribution network is needed. However in this trial, IKEA only explored the technology within the CDC.

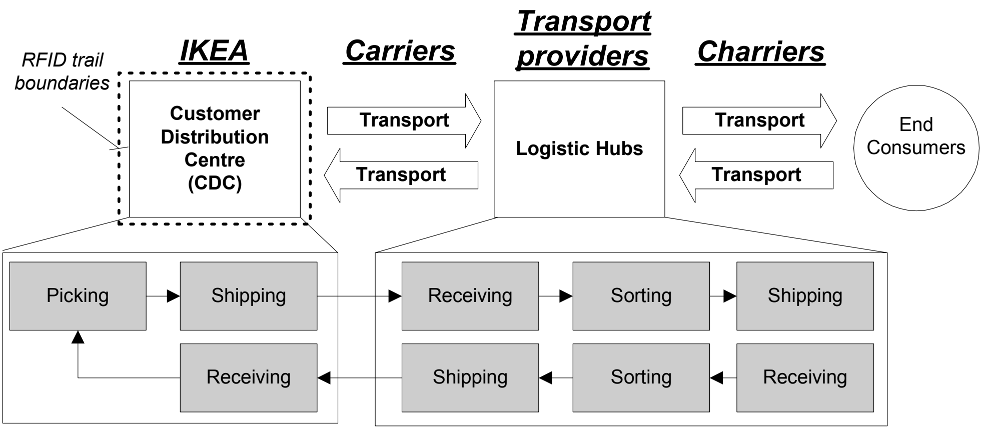

Figure 2. The rotation of steel containers.

2 THE PROCESS OF MANAGING AND CONTROLLING STEEL CONTAINERS

The steel containers are managed in a transfer system. In the transfer system, IKEA is responsible for administration, monitoring (accounts), cleaning, maintenance and storage. IKEA also ensures that the number of steel container components needed is adequate. The problem IKEA has with the transfer system is the lack of consensus among the actors i.e. the CDC, and transport providers about how much is received and shipped. Even if the CDC manually counts the steel container components several times, these manual counting operations are likely to cause errors, generating disagreements among the actors. If the CDC says that it has shipped and received a certain amount of components, the transport providers say that they have received and shipped another amount. At the end of the day, IKEA is not able to claim compensation from any of the partners. An RFID system would bridge the gap among the actors since the quantity of steel containers transported among the actors would not be based on manual counting operations.

At the CDC, the steel container components are manually counted three times. The first count is performed by the picker when she/he assembles the steel container components. However, order pickers do not always report what type of components or how many are used. The second time the components are counted is when the truck is loaded and the number of components is written down in the bill of delivery. However, counting and writing down the number of steel container components in the bill of delivery are activities which are not prioritised. When carrying out last-minute changes and rearranging within shipments the focus is to ensure a full truck load with high cube utilization, and to load complete, correct customer orders on the shipment. Finally, when the steel container components are received from the transport providers, the steel container components are counted for the third time at the CDC. In addition to these three times, the components are counted several times by the transport providers, and all these occasions can cause errors. Consequently, there are many processes throughout the supply chain where counting operations could go wrong. The CDC processes linked to steel containers are briefly described below.

2.1 The picking process

When a picker receives a pick order he/she browses through the order lines. Based on previous experience the picker decides what steel container components are needed and assembles a steel container. The steel container components are registered and linked by the picker to the customer order in the Warehouse Management System (WMS). When a steel container is assembled and registered the picker begins to pick the order. When the pick order is complete the steel container is wrapped in stretch film and a bar code label is applied to the stretch film, this identifies the customer order(s) and the steel container components. When the steel container has been wrapped and labelled, it is taken to the shipping area.

2.2 Shipping process

At the shipping area the bar code is scanned to obtain the gate allocation. When the steel containers are placed at the gate area, a gate bar code is scanned to report that the order is ready for delivery. When a shipment is ready, the CDC rearranges customer orders among and within shipments to achieve full truck loads with high cube utilization. When the truck has been loaded, the carrier receives a bill of delivery containing the customer orders and the amount of steel container components the shipment contains. The transport provider's account of steel container is adjusted based on the amount of steel container components the shipment contains.

The transport providers distribute the goods via hubs to the end-consumer. On the end- consumer's premises, the transport providers unload the goods and bring back the steel container. The steel containers are brought back to the hubs where the steel containers are disassembled, sorted and stacked. The steel containers are then transported back to the CDC.

2.3 Receiving process

When the steel containers from transport providers are received the truck delivering the steel containers is directed to one of the four predestined gates at the CDC. The steel containers are counted, checked for damage, and moved into the storage area. The transport provider's account of steel container is adjusted based on the count.

3 THE RFID SYSTEM

The main reason for using RFID technology, and not bar code technology, is the harsh environment the steel container passes through. Bar codes are not an option in this environment since they would be easily damaged. Furthermore, scanning bar codes is a time-consuming activity and requires considerable human effort. Manually scanning bar codes would also generate faulty data since the activity is prone to human errors.

When the RFID system was selected for the trial three system integrators were invited to present their RFID equipment. IKEA had two requirements; the system integrators had to be able to supply equipment according to a time schedule and the RFID system had to be based on the EPC standard. Only one system integrator, i.e. IBM, was able to meet the requirements, so IBM was chosen. IBM supplied RFID equipment from the hardware manufacturer Symbol technologies/Matrics. According to IKEA, IBM had a say in which RFID components (tags, readers and antennas) were chosen for the trial.

The tags that were supplied by IBM were EPC tags class 0, see Figure 3. This means that a tag contains a unique 96-bit identification number and is passive and read-only. The tags were designed to be used in metal environments, i.e. they were embedded in rubber. However, they were not specifically designed, e.g. antenna design, to be applied to the steel container. IKEA required EPC tags since it expects that EPC will probably become a global standard. The reason for using a standardized tag is to ensure interoperability. When selecting the type of EPC tag to be used, IKEA wanted to have a read-and-write tag. However, these tags were not available on the market.

Figure 3. The EPC class 0 tag of model; Matrics i1010.

The type of readers or antennas was not an issue for IKEA. IBM supplied a Matrics AR 400 reader. Since IKEA performed a trial, a stand-alone information system was used in processing the data collected from the tags i.e. the data was not integrated with any WMS or Enterprise Resource Planning (ERP) systems.

4 THE RFID TRIAL

4.1 Design and set-up

In order to achieve internal traceability and control of steel container component, IKEA decided to test readers positioned at a shipping gate and at a receiving gate. A reader was also positioned at a wrapping machine in order to evaluate the scenario of only having RFID readers at the eight wrapping machines instead of having RFID readers at all the 59 shipping gates. At the shipping and receiving gates multi-antenna “portals” were used, whereas at the wrapping machine a reader with two antennas was mounted vertically beside the wrapping machine, see Figure 4.

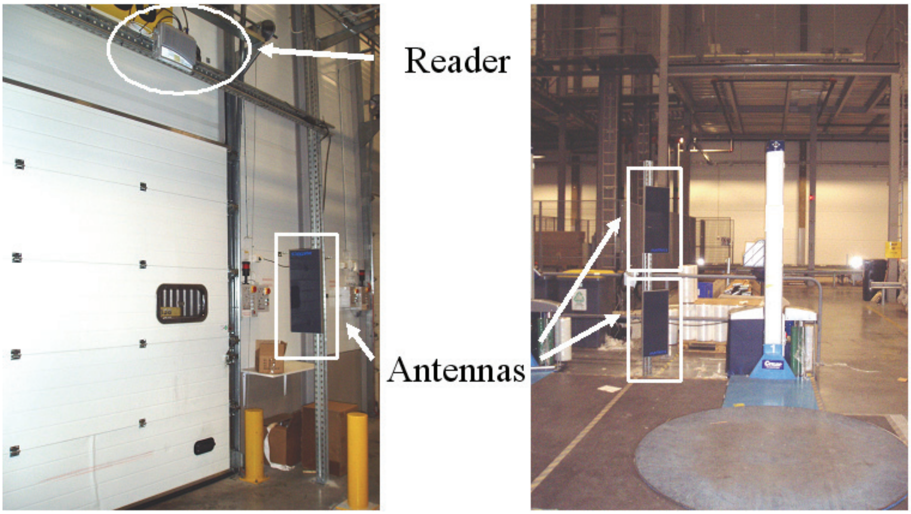

Figure 4. The RFID readers and antennas at the gates and the wrapping machine.

In the trial approximately 300 steel container platforms and side bars were tagged. With the tagged steel container components, different sets of handling units were put together and tested in the three reading positions. The different handling units which had been put together represented the different units handled in each reading position. At the shipping gate and at the wrapping machine various steel containers containing products were tested. When steel containers are received, they are stacked and put together into compact units. These units were tested at the receiving gate.

In the trial numerous tag locations on the steel container components were also tested. The four major aspects that were taken into consideration when decisions were taken on the location of the tags were:

1. Facilitate a high reading rate

2. Protect the tag from being damaged

3. The tag should be replaceable e.g. if it is broken

4. Cost of applying the tag

4.2 Trial outcome

For the steel container platform, the reading rate at the shipping gate, receiving gate and at the wrapping machine was about 100 per cent. The tag was attached underneath the platform on a supporting beam. In this location the tag is protected from the material handles rough handing of steel containers. Since this location enabled a high reading rate, other locations were not explored.

Four tag locations were tested on side bars. All four locations provided a reading rate of approximately 100 per cent at the shipping gate and at the wrapping machine. However, at the receiving gate there were difficulties obtaining readings from the tagged side bars since metal interfered and blocked the radio waves. In order to obtain any readings from the side bars at the receiving gate, IKEA had to attach the tags to the outer surface of the side bars. However, tags positioned on the outer surface of the side bars would not last long, as the side bars are roughly handled. In order to obtain readings from the side bars at the receiving gate IKEA has to change the receiving process. The two different solutions that were put forward were constructing an RFID tunnel which handling units could be passed through, or manually using handheld portable RFID readers. However, neither of these suggestions was tested in the trial.

In order to obtain a high reading rate at the shipping gate, the reader had to have four antennas; two on each side. At the receiving gate a reader had to have five antennas in order to achieve a high reading rate; two on each side and one at the top (of the gate). At the wrapping machine two antennas were sufficient for a high reading range to be obtained.

The major problem with the readers at the receiving gate was signal propagation. All materials reduce the power of the radio frequency signal to some extent, affecting the RFID tag reading performance. However, metal can cause particular problems since metals reflect radio frequency signals. Reflections from metal may combine signals to give a stronger signal or they might cancel each other out i.e. interference. At a receiving gate in the CDC, IKEA had difficulties in getting reliable readings. The RFID supplier assisted in identifying the source, which was an aluminium wall by the side of the gate causing interference. The RFID supplier also assisted in solving the problem by orienting the antennas at slightly different angles and positions, and by changing the output power of the antenna transmitting the signals which reflected onto the aluminium wall, thereby causing the interference.

4.3 Budget

The total cost of the trial was 20 000 Euro. Hardware costs constituted only a fraction of the total costs. IKEA borrowed the readers and antennas during the trial period but bought approximately 300 tags (1.5 Euro per tag). Basically, half of the trial costs were made up of man-hours for IKEA staff and the other half were consultancy fees. IKEA bought several hours of consultancy from IBM and Symbol. The guidance from these firms was crucial, e.g. in arranging and adjusting the antennas and readers, and suggesting locations for placing the tags.

5 ANALYSIS

5.1 Payback of investment

In order to understand the magnitude and perhaps even justify an RFID investment, the payback period for such an investment was calculated. Payback calculations indicated that the payback period would be between 15 to 23 months depending on what type of investments were carried out. The payback period was based on cost of investments (hardware, system integration, trial) and running profits (running revenues and cost).

The major aspect which determines the difference in the payback periods is having readers at the eight wrapping stations or at the 59 shipping gates, see Table 1. IKEA definitely favours the idea of having readers at the shipping gates since this is the “yellow line” between the CDC and its transport providers. It is at the yellow line that the responsibility for the steel pallets is transferred to the transport providers. Furthermore, at the shipping gates many final adjustments are made e.g. rearranging among and within orders in order to increase cube utilization. Consequently, identifying steel container components at the wrapping stations would not accurately show which steel container components are used to distribute customer orders.

	Readers at wrapping stations			Readers at shipping gates		
	Amount	Cost		Amount	Cost	
Hardware						
Tags						
Platform	16000	15	240,000	16000	15	240,000
Side bars	64000	15	960,000	64000	15	960,000
Readers						
Process unit	12	10,000	120,000	63	10,000	630,000
Antenna	36	5,000	180,000	256	5,000	1,280,000
Servers	3	9,000	27,000	3	9,000	27,000
Cables		40,000	40,000		200,000	200,000
System Integration						
Man-hours; hardware installation	1500	200	300,000	2500	200	500,000
Software development	1350	1,200	1,620,000	1350	1,200	1,620,000
Man-hours; software implementation	450	1,200	540,000	450	1,200	540,000
Trial			200,000			200,000
Cost of investment (SEK)			4,227,000			6,197,000
Replacing hardware						
Tags						
Platform	400	15	6,000	400	15	6,000
Side bars	1000	15	15,000	1000	15	15,000
Readers						
Process units	1	10,000	10,000	4	10,000	40,000
Antennas	10	5,000	50,000	20	5,000	100,000
Man-hours; hardware replacement	20	400	8,000	100	400	40,000
System maintenance						
Software licence			200,000			200,000
Software development			100,000			100,000
Operating the system			150,000			200,000
Running costs (SEK)			539,000			701,000
Running profit (SEK)			4,000,000			4,000,000
Payback period (years)			1.2			1.9

Table 1. Payback period in the two investment scenarios.

When calculating the running profit from an RFID investment, IKEA only considered eliminating the loss of steel container components. Implementing an RFID system would not in itself reduce the loss of steel container components, but it would enable IKEA to invoice those who lose the steel container components. Other potential profits such as reduced inventory of steel container components, less administration, improved maintenance and cleaning procedures of steel containers, process improvements (less manual counting operations), increased cube utilization of transport units and less transport damage are not included in the running profits. For the CDC, quality of delivery is fundamental i.e. delivering the right goods on time. Ensuring that the CDC uses steel containers, and is not forced to use EUR pallets which cause product damage and low cube utilization of transport units, are vital elements in providing a high-quality service in an efficient manner.

5.2 Barriers to adoption

Cost, standards and technology are often the issues mentioned as the main barriers for mass adoption of RFID technology. However, for the application of RFID to steel containers in closed loop settings, cost is not a barrier. According to IKEA, the barriers are standards and IKEA's understanding of RFID technology e.g. real performance versus expectations, different vendor technologies and equipment. IKEA will not implement any RFID solution that is not standardized and which ensures interoperability among RFID systems. Implementing an RFID solution that will only be used by IKEA and its supply chain partners e.g. transport providers, will reduce IKEA's flexibility. IKEA wants to integrate its supply chain partners, but not to the extent where IKEA does not have the option of changing partners. Logistics or transport providers want to integrate themselves with customers to provide efficiency and ensure customer service. However, integrating themselves with customers by using non-standardized and non-interoperable systems such as EDI, bar codes or RFID, creates barriers for the transport providers' competitors. Furthermore, interoperability reduces the risk of RFID vendor lock-in, which carries its own set of risks, such as price inelasticity, limited solution range and exposure to vendor financial distress.

6 RESULTS

By performing an RFID trial at the CDC, IKEA gained insights into the opportunities and limitations of the RFID technology involved and into aspects of running an RFID project. The trial indicated that the technology could be used in gaining traceability of the steel containers and that the payback for such an investment would be less than two years. However, the trial also raised questions concerning what type of RFID system IKEA should use, what items should be tagged, and how the rotation of steel containers should be managed and controlled.

6.1 Technology insights

Carrying out the trial provided insights into RFID system components, functionalities (identifying numerous items simultaneously requiring no line of sight, read-only/read-and-write), performance (reading range, reading rates, power limits), costs, trial set-up (tag locations, location of readers and antennas) and influencing factors (infrastructure and the surroundings, signal propagation, standards). This increased the general awareness of RFID technology throughout IKEA organizations, especially at the CDC where numerous other application areas and ideas were suggested.

For example, one application suggested was using the RFID tags on the steel container components to identify the volume each order would occupy in the transport unit. The CDC must book a certain volume in a transport unit for each pick order. Currently, staff book the average volume of a pick order, since it is impossible to know in advance how much volume a pick order requires. This generates half-full to over-full transports units, which in turn leads to low filling rates or a lot of additional work in rescheduling orders. The volume occupied by an order depends on what steel container components are used when the order is picked. So if the CDC knew what steel container components are used when picking an order, it would automatically know how much volume the pick order occupies in the transport unit. Identifying the steel container components used when the order is picked would enable the CDC to overbook a shipment and when the shipment is full the CDC would redirect the remaining picking orders toward the next shipment. This would enable full truck loads and would not constantly require rescheduling, which is currently a time-consuming activity at the CDC.

6.2 Project insights

From a project perspective, the trial indicated that in performing an RFID project it is important to plan the project in detail by familiarizing oneself with the processes, identifying the core problem, identifying the value of RFID versus other automatic identification technologies. Based on that, the next step is to develop various business case scenarios. This means that the project needs to be problem-oriented and not technology-oriented. One shortcoming of the trial was not involving all organizations that would be involved in an RFID implementation. Even if the trial was limited to the CDC, the involvement of the other organizations would have been beneficial since they would have, just as IKEA had, gained insights into RFID technology and the application area i.e. closed loop. The other organizations would probably also provide important input into and feedback on the trial, thus generating valuable discussions among the organizations.

Another insight from the trial was that it took a lot of time. One should not underestimate the time it takes to plan and design the set-up, obtain equipment, do the set-up, fine-tune the equipment, execute the trial, measure and analyse the results, and write a report. Furthermore, RFID is not plug-and-play, and when exploring technology under development often requires additional time. IKEA received assistance from the RFID supplier when it encountered problems. For example, during the problem of achieving reliable readings at the shipping gate, the RFID supplier assisted by identifying the source (aluminium wall) and solving the problem (signals propagation). This support was very valuable and enabled IKEA to continue with the trial. The trial was heavily affected by time constraints and, in view of its experiences, today IKEA would plan to involve two people for six months for a similar project.

6.3 Type of RFID system

The trial indicated that RFID technology could be used to gain traceability of steel containers. However, it did not illustrate what type of system IKEA needs or should use to gain traceability. The type of tag chosen is a key decision since it has an effect on the performance and functionality of RFID systems. IKEA decided to perform the RFID trial using passive UHF tags based on EPC standard. This decision was based on the fact that this system has the greatest potential to become a global standard. However, standardization in not the only aspect influencing the choice of tag. Tag cost, functionality (data exchange needs) and performance in the operating environment are other important aspects which need to be considered.

IKEA wanted to use a read-and-write tag, but this tag functionality was not available so it decided to perform a trial using a read-only tag. Actually, IKEA would like to test numerous types of tags and gain insight into the different levels of performance they produce. However, IKEA realized that in order to test various types of tags applied to steel containers the company would need a laboratory, where it could experiment with various types of tags. The RFID system integrator offered the service of performing experiments with various types of tags on multi-packs (secondary packaging), but IKEA turned that offer down since IKEA what to develop that competence within the company.

6.4 Level of tagging

One doubt raised in the trial was the level of tagging. The drawback of not obtaining any readings from the tagged side bars at the receiving gate prompted IKEA to consider what items need to be tagged. Tagging every component i.e. all the platforms and side bars, might be unnecessary. The platform is a fundamental component of the steel container and without the platform the side bars are practically useless. Hence, preventing the loss of steel container platforms might indirectly mean that fewer side bars are also lost. Historical data indicate that this might be the case i.e. the loss of one platform equals 3.5 lost side bars, which is the average number of side bars used when a steel container is assembled. Consequently, it might be enough to tag the steel container platforms in order to reduce the loss of steel containers. In addition, the platform represents the major cost of a steel container. Since identifying the steel container platforms at the receiving gate was not problematic, the suggestion of redesigning the receiving process by using portable handheld readers or RFID tunnels is unnecessary.

6.5 Managing the rotation of the steel containers

Implementing an RFID system would enable IKEA to manage the rotation of steel containers differently. Currently, the steel containers are managed in a transfer system. However, gaining traceability of each individual steel container would enable IKEA to shift from using a transfer system to using a rental system. In a rental system, IKEA would rent the steel containers to the logistics and transport providers. This would encourage the transport providers to increase the utilization rate (cut lead times) and reduce the loss rate. In a rental system, IKEA would still administer, clean, repair, store and manage the number of steel containers.

7 NEXT STEP FOR IKEA

The RFID trial did not represent an implementation since no RFID tagged steel containers were put through the ordinary supply chain processes. However, the trial indicated that the RFID technology could be used in gaining traceability of steel containers and that the cost of this technology is not a major obstacle. The trial also generated questions i.e. how should the rotation of steel containers be managed, what steel container component the company should tag, what type of RFID system should be used. These are questions which IKEA needs to address in order to move forward towards performing a pilot or implementing RFID technology.

In the trial IKEA was very technology-oriented. Based on the insights from performing the trial IKEA has realized that it needs to be more problem-oriented when looking into different applications of RFID technology. Focusing first on the main problems and then on the numerous benefits RFID technology might enable throughout the supply chain, IKEA is able to systematically and in detail, plan and develop different business case scenarios. From the different business cases IKEA can evaluate which scenario to opt for.

The major reason IKEA was technology-oriented in the trial was that the company needs to develop corporate general guidelines and standards. The vision for IKEA concerning RFID technology, is to apply tags to case and item levels i.e. to multi-packs and products sold in IKEA stores. However, this is a very long-term vision. In order to get started with RFID technology, IKEA has chosen to focus on closed loop applications, such as gaining traceability of the steel containers in order to improve the process of managing and controlling the rotation of steel containers. In order to prevent internal organizations in IKEA from starting to use different RFID technologies and solutions, IKEA stresses that general guidelines and standards for frequencies, tags etc, need to be developed. These guidelines and standards must be developed before IKEA can decide to implement RFID technology at the CDC since the implementation must be in line with IKEA's, which in turn must be in line with IKEA's long-term RFID vision. As RFID technology continuously evolves and standards are being developed, IKEA has difficulties in developing these guiding principles. Using guiding principles might enable IKEA to develop several business cases using one fundamental infrastructure i.e. one which contained readers, antennas and information systems. For example, implementing an RFID system for managing and controlling steel containers at the CDC might enable IKEA to utilize the RFID infrastructure in other business cases, thus improve its return on investments.

8 CONCLUSIONS

IKEA began to explore RFID technology by performing a trial to achieve traceability of steel containers in a closed loop setting. The result of the trial indicated that RFID technology could be used in ensuring traceability of steel containers in order to improve the process of managing and controlling the rotation of steel containers. By performing an RFID trial, IKEA gained insights into the opportunities and limitations of RFID technology. Costs are often mentioned as one of the main obstacle to adopting RFID technology. However, for IKEA the application of RFID to steel containers in closed loop settings, cost is not a major obstacle. For IKEA, the main obstacles are technology standards and interoperability. By performing an RFID trial, IKEA also gained insights into aspects of running an RFID project. For example, IKEA realised if an RFID project is going to be successful it needs to be problem-oriented and not technology-oriented. The trial also raised questions which IKEA needs to address in order to move forward towards performing a pilot or implementing RFID technology.

Appendix C

INTERVIEW GUIDE FOR THE ARLA FOODS AND THE IKEA CASE STUDY

INTERVJUGUIDE

Frågorna nedan är avsedda för flera olika RFID pilot/implementerings-projektet. Därför passar inte alla frågor in i alla intervjuer. Vissa frågor kan även korsa varandra och på så sätt göra andra frågor överflödiga. En del frågor är breda och omfattande, för dessa krävs eventuellt att man ritar upp en beskrivning, visar befintliga processkartor eller uppvisar projektdokumentation.

Delområde 1 – Introduktion och projektorganisation

Syfte: Skapa en övergripande bild av RFID pilot/implementeringsprojektet.

1. Berätta om din roll på företaget och i RFID projektet?
2. Vad var backgrunden till projektet? Varför en RFID pilot/implementering? Hur uppstod projektet? Var det ett behov eller en påtryckning?
3. Vad var målet med projektet?
4. Fanns det ett specifikt fokus (vad studerades?) eller några avgränsningar med projektet (utesluten information eller materialflöde)?
5. Hur var pilot/implementeringen utformad(tidsramar, resurser, budget)? Gjordes några förstudier eller laboratorietester innan projektet?
6. Vem var med i projektgruppen? Vilken roll hade de medverkande?

Delområde 2 – Aktiviteter och processer

Syfte: Kartlägga och förstå aktiviteter och processer som påverkas av projektet.

7. Beskriv företagets försörjningskedja.
8. Hur fungerade arbetsprocesserna innan piloten/implementeringen?
    - Hur såg materialflödet ut och vilka aktiviteter var kopplade till flödet?
    - Hur såg informationsflödet ut och varför?
    - Hur och var skedde identifikationen?

9. Vilka specifika problem försökte ni åtgärda med hjälp av RFID-systemet?
10. Vilka processer planerade ni att förändra vid införandet av RFID teknologin? Hur planerade ni att förändra processerna?
11. Vilka processer har RFID-systemet påverkat (enskilda operationer och aktiviteter, materialflödet, informationsflödet, planering, styrning, beslutfattande etc.)? Hur har de påverkats?
12. Vilka företag och andra organisationer var involverade i projektet? Vilken roll hade de olika aktörerna?
13. Vilka delar av organisationen var drivande, passiva eller tog avstånd från projektet?
14. Vilka svårigheter uppkom p.g.a. att systemlösningen gick över organisationsgränser?

Delområde 3 – RFID systemet

Syfte: Skapa förståelse och få en inblick i RFID systemet.

15. Varför valdes RFID-teknologi och inte t.ex. streckkodsteknologi?
16. Vilka kompletterande teknologier användes (GPS, WLAN)?
17. Vilken typ av tag används och varför valdes denna typ av tag? Vilken hänsyn togs till nuvarande eller kommande standarder?
18. Hur placeras taggen och varför? Vilka avvägningar gjordes vid val av taggningsnivå och varför?
19. Vilken information är inprogrammerad på taggen och varför valdes denna information?
20. Hur är ”läsdelen” av RFID-systemet konstruerat?
    - Vilken typ av läsare används?
    - Hur många läsare finns det i systemet?
    - Vart är läsarna placerade och varför valdes dessa placeringar?
21. Hur fungerar läsningen av taggar i systemet?
    - Vad är lästillförlitligheten?

- Vad är systemets läshastighet?
- Hur hanterar ni lässtörningar t.ex. från metall och vätskor?

22. Hur fungerar datakommunikationen mellan läsarna och informationssystemen (bl.a. affärssystemet)?
23. Vilken data kommuniceras och hur ofta? Hur lagras, hanteras, filtreras, fördelas, används och styrs den? Ger detta någon tillgång till ny typ av information?
24. Vilket är systemets begränsningar (teknologin, informationssystem, kostnader, kunskap, organisation)?
25. Vem levererade de olika RFID komponenterna? Vilken inflytande på val av komponenter och design av implementering hade leverantören?

Delområde 4 – Resultat

Syfte: Beskriva och få en förståelse av RFID projektets slutliga resultat.

26. Vilken och hur mycket nytta (kvantitativa och kvalitativa) har uppnåtts med RFID-systemet?
27. Vad har varit mest drivande vid bedömningen av projektet, kvantitativa och kvalitativa aspekter?
28. Vilka mätetal har blivit påverkade och med hur mycket?
29. Vilken ekonomisk vinst eller förlust uppskattar ni att RFID-systemet har gett upphov till?
    - Vad är den totala kostnaden för projektet? Hur är kostnaderna fördelade (planeringskostnader, hårdvara, mjukvara, utbildning, administration, underhållkostnader, personalkostnader etc.)?
    - Vad är den totala kostnadsbesparingen och resultatförbättringen för projektet?
30. Gjordes någon ekonomisk analys i planeringsstadiet av projektet (Return on Investment, Payback, Cost-benefit)?
    - Hur såg denna ut?

- Stämde den ekonomiska analysen överens med det slutliga resultatet?

31. Hur pass representativ för en möjlig fullskala var piloten?

Delområde 5 – Reflektioner på projektet

Syfte: Ge en bild av genomförandet av projektet.

32. Vad lyckades mycket bra i projektet och varför?
33. Vilka svårigheter och problem uppkom i projektet? Hur bemästrades dessa?
34. Finns det några fallgropar i RFID-projekt? Hur undviker man dessa?
35. Vad fungerade sämre än väntat i projektet (teknologin, informationssystem, kunskap, kostnader, organisation)?
36. Vad fungerade bättre än väntat i projektet (teknologin, informationssystem, kunskap, kostnader, organisation)?
37. Vilka huvudsakliga lärdomar har ni fått från RFID-projektet?

Delområde 6 – Framtida tankar

Syfte: Kunskap om hur RFID teknologi möjligen kommer att forma morgondagens företag.

38. Hur ser er vision ut angående RFID-teknologi?
39. Hur mycket är visioner om framtida vinster drivande?
40. Baserat på denna RFID pilot/implementering, kommer fler liknande projekt med RFID-teknologi att initieras? Finns det planer och hur ser dessa ut? Vad är den ekonomiska potentialen som kan förväntas att uppnå t.ex. vid en fullskalig implementering?
41. Har er organisation någon RFID-strategi? Hur ser denna ut och hur är den kopplad till olika områden och andra strategier (IT, förpackningar, logistik, marknadsföring, kompetens)?

DISSERTATIONS AND LICENTIATE THESES AT DIVISION OF PACKAGING LOGISTICS, LUND UNIVERSITY, LUND, SWEDEN

DIVISION OF PACKAGING LOGISTICS, LUND UNIVERSITY

Dissertations and Licentiate theses

Hahn, K. 1991, A study of the compressive behaviour of corrugated board panels, Licentiate thesis.

Renman, M. 1994, A mechanical characterization of creased zones of corrugated board, Licentiate thesis.

Borglin, J. 1995, Development of a decision support system for the selection process of corrugated packaging, Licentiate thesis.

Patel, P. 1996, Biaxial failure of corrugated board, Licentiate thesis.

Aquilon, M. 1997, Cultural factors in logistics management, Licentiate thesis.

Henriksson, L. 1998, Packaging requirements in the Swedish retail trade, Licentiate thesis.

Johnsson, M. 1998, Packaging logistics – a value added approach, PhD dissertation.

Patel, P. 1999, Nonlinear creep model of paper and corrugated board materials, PhD dissertation.

Persson, E. 1999, Creating a competitive advantage in the corrugated board industry, Licentiate thesis.

Berglund, A. 1999, Incorporating environmental aspects in transport purchasing, Licentiate thesis.

Bergström, P. 2000, A strategic view on relationship in the grocery supply chain – the case of a low complex product, Licentiate thesis.

Saghir, M. 2002, Packaging logistics evaluation in the Swedish retail supply chain, Licentiate thesis.

Olsson, A. 2002, The integration of customer needs in e-business systems, Licentiate thesis.

Wallin, C. 2003, Contract packaging and its implications for the supply chain – a case study of a contract packager, Licentiate thesis.

Nilsson, F. 2003, A complex adaptive systems approach on logistics – implications from adopting a complexity perspective, Licentiate thesis.

Abukhader, S. 2003, The environmental implications of electronic commerce – the assessment approach problem, Licentiate thesis.

Orremo, F. 2003, E-business in an established customer vendor relationship, Licentiate thesis.

Hellström, D. 2004, Exploring the potential of using radio frequency identification technology in retail supply chains, Licentiate thesis.

Bramklev, C. 2004, Concurrent development of product and packaging – towards an integrated development procedure, Licentiate thesis.

Saghir, M. 2004, A platform for packaging logistics development: a systems approach, PhD dissertation.

Klevås, J. 2005, On opportunities of integrated packaging, logistics and product development – experiences from a case study at IKEA, Licentiate thesis.

Gustafsson, K. 2005, The process of creating a nation-wide pool system for transport packaging – from vision to decision, Licentiate thesis.

Abukhader, S. 2005, Towards horizontal environmental assessment for supply chain and logistics management, PhD dissertation.

Nilsson, F. 2005, Adaptive logistics – using complexity theory to facilitate increased effectiveness, PhD dissertation.

Olsson, A. 2006, The change from feature focus to customer focus in packaging development, PhD dissertation.

Johansson, O. 2006, Towards a model for managing uncertainty in logistics operations – a simulation modelling perspective, Licentiate thesis.

Dominic, C. 2006, Packaging Networks - a framework for integrating packaging suppliers in the Demand Chain, Licentiate thesis.

Beckeman, M. 2006, The rise of the Swedish food sector after WW II. What, why, how and who?, Licentiate thesis.

Svanberg, J. 2006, A constructive approach to the interaction between risk and logistics, PhD dissertation.

Påhlsson, H. 2006, Interorganizational collaboration in the context of introducing new technology, Licentiate thesis.