Exploring the potential of using radio frequency identification technology in retail supply chains - A Packaging Logistics perspective

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Exploring the Potential of Using Radio Frequency Identification Technology in Retail Supply Chains

– A Packaging Logistics Perspective

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Exploring the Potential of Using Radio Frequency Identification Technology in Retail Supply Chains

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Abstract

In recent years RFID technology has attracted interest from the retail industry where it is being presented as a possible key to creating more efficient and effective retail supply chains. If RFID technology is to be implemented in packaging throughout retail supply chains, there is a need to develop an understanding of how the technology affects activities and processes within retail supply chains. Accordingly, the overall purpose of this licentiate thesis is to explore how the application of RFID technology to packaging could affect packaging logistics activities in retail supply chains. The packaging logistics activities discussed in this licentiate thesis are those related to ambient fast-moving consumer goods, from the product-filling point at the manufacturer's, where the product is merged with the primary packaging, to the point of sale at retail outlets, where the products are sold to the end consumer.

This thesis is based on multiple research strategies; a case study and a modelling and simulation study. The case study was conducted to describe and gain an in-depth understanding of packaging logistics activities in retail supply chains. A Dutch retail supply chain was chosen as a single-case study. The single-case study was both data-triangulated and investigator-triangulated with three Swedish case studies to further broaden the understanding of packaging logistics activities in retail supply chains. The case study resulted in a framework of packaging logistics activities in retail supply chains.

The modelling and simulation study was conducted to explore how the application of RFID technology to 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 simulation model primarily describes and analyses how the Dutch retail distribution centre (studied in the case study) would behave and perform over time, when RFID technology is applied to the packaging system. Both models increase 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.

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1 INTRODUCTION

1.1 Background

In order to achieve a competitive advantage, companies are continually faced with challenges to improve their processes and customer service. A major area that industry turns to in process improvement and to support its customer services goals, is technology. Technology is embodied in every value activity in a firm, and technological change can affect competition through its impact on virtually any activity (Porter 1985). There have been a large number of technical developments in areas that support logistics, where the major technological developments have been in the information technology area (Bowersox & Closs 1996;Coyle, Bardi, & Langley 1996;Lambert, Stock, & Ellram 1998). Information technologies that have had far-reaching effects on logistic activities are connectivity technologies such as Internet, Electronic Data Interchange (EDI) [1] and Automated Identification (Auto-ID)[2].

Logistics communication is one of the key activities required to facilitate the flow of the product from point of origin to point of consumption (Lambert, Stock, & Ellram 1998). Auto-ID technologies have a profound effect on the way that logistic activities interface with the physical flow of goods, creating the ability to swiftly access accurate information. The speed and quality of information has a direct impact on the entire efficiency of organisations (Lambert, Stock, & Ellram 1998). Identifying and capturing data from the physical flow of goods moving down or upstream in the supply chain are then fundamental logistic issues and are prerequisites to achieving an efficient and effective supply chain.

There are several Auto-ID technologies available today, such as Radio Frequency Identification (RFID), Biometrics, Optical Character Recognition (OCR), and Bar coding (Finkenzeller 2003). Bar coding is the most common Auto-ID technology and is virtually used in every sector of industry. The

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[1] EDI is the electronic, computer-to-computer transfer of standard business documents between organisations (Lambert, Stock, & Ellram 1998, p.84).
[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.

performance capabilities of Auto-ID technologies are continuously being developed, thereby opening up new application areas. More advanced Auto-ID technologies offer the possibility for improved functionality and an opportunity to obtain continuous, accurate and real-time information. In a logistics context, an introduction of more advanced Auto-ID technologies represents a major opportunity to overhaul and improve tracking and tracing systems, process control, and inventory management (McFarlane & Sheffi 2003).

In recent years RFID technology has attracted interest from industry and has shown its potential as a means of increasing efficiency and effectiveness in supply chains (Kärkkäinen & Holmström 2002). Several companies have been able to improve their business processes by using RFID technology (Falkman 2000;Kärkkäinen 2003;March 2002). Currently, the use of this technology has thus far been limited to tracking high-value products, as well as transport packages, containers in closed loop settings where the RFID-tags[3] are continuously reused. Studies of the potential benefits of applying Auto-ID technology, such as RFID, to packaging in retail supply chains have suggested that there is a great opportunity to reduce inventory, labour and shrinkage[4], and at the same time improve customer service and sales (Agarwal 2001;Alexander et al. 2002a;Alexander et al. 2002b;Chappell et al. 2003b;Kambil & Brooks 2002).

If RFID technology has the ability to overcome various technical and economic obstacles, such as standardisation and price per tag, RFID will one day have the potential to be attached on packaging down to item level. Currently, the technical and economic obstacles restrain retail supply chains from utilising the RFID technology, but the performance capabilities of RFID technology are being pushed forward, and price reductions are being worked on. By 2010, industry sources expect the price per tag to have fallen to less than 0.01 EURO (Harrop 2002). This means that it could be economically viable to apply RFID technology to packaging down to item level throughout retail supply chains. Wal-mart, the world's largest retailer, have announced that they are working with their top 100 suppliers to deploy RFID tags for tracking pallets and cases in their supply chain (Langford 2003;Computerworld 2003). Furthermore, Wal-mart have said that they will ask all suppliers to tag pallets and cases by the

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[3] see chapter 3.2.1 The components of RFID systems
[4] Shrinkage incorporates four sources of loss; external (end consumer) theft, internal (employee) theft, supplier fraud and process failures (waste, error).

end of 2006 (Roberti 2003b). This indicates that the application of RFID technology to packaging is an emerging technology in the retail supply chain.

The retail supply chain is one of the major consumers of different types of packaging. In Sweden alone, the food industry represents the consumption of approximately 50 per cent of the total cost of packaging material (Thorén & Vinberg 2000). Furthermore, in Sweden the retail industry handles approximately 1000 million retail packaging units each year. According to a study, DULOG[5] (1997), the potential savings for packaging handling in the Swedish retail chain (only from retail distribution centres to retail outlets), are about five million EURO for every second which can be saved in the packaging handling process. The same study also shows that 16.2 per cent of the end consumer price consists of the handling and selling costs of the product. This indicates that there ought to be several opportunities for efficiency improvements in the packaging handling process in the retail supply chain e.g. through applying RFID technology to packaging.

1.2 Research Question

As mentioned above, RFID technology is gaining acceptance throughout the retail industry and has been presented in studies as one possible key technology in creating more efficient and effective retail supply chains. With the application of RFID technology to packaging the information and communication functions of the packaging system will be emphasized. Based on this, it would be important to develop an understanding of how RFID technology in packaging influences packaging logistics[6]. This leads to the research question:

How and why could the application of RFID technology to packaging affect packaging logistics activities in retail supply chains?

With a better understanding of how and why the application of RFID technology to packaging would affect packaging logistics activities, 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 the development of

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[5] The former Development and Logistic group of the Wholesale and Retail Trade in Sweden

[6] see chapter 3.1 Packaging Logistics

models and methods to illustrate how supply chain performance and behaviour are affected by RFID technology.

1.3 Research Purpose

Based on the research questions above, the purpose of this research is to:

Explore how and why the application of RFID technology to packaging could affect packaging logistics activities in retail supply chains.

1.4 Focus and Demarcations

RFID technology could be applied to all kinds of physical objects, but this research focuses on exploring the application of RFID technology to packaging. That is why the main interest area of this research is directed towards logistic and packaging aspects, and in particular towards the interface between the packaging system and the logistics system. It should be made clear that this research focuses on the whole packaging system i.e. primary packaging (consumer packaging), secondary packaging (case) and tertiary packaging (pallet and roll container).

The use of RFID technology in packaging that is studied and discussed in this research are from the product-filling point at the manufacturer's, where the product is merged with the primary packaging, to the point of sale at retail outlets, where the products are sold to the end consumer. Figure 1.1 illustrates the supply chain studied and discussed in this research. The use of RFID technology in packaging after the point of sale e.g. reuse, recycling, post-sale service and support, is important, but is not taken up in detail in this research.

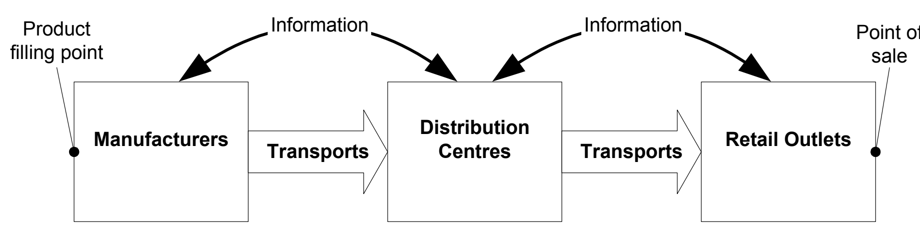

Figure 1.1. Supply chain perspective in the research.

As mentioned before, studies have analysed and discussed the potential benefits of RFID technology in retail supply chains. This research concentrates on packaging logistics activities, since it is these activities that are involved in the packaging function where RFID technology serves as the communication link between packaging and the logistic systems. By focusing on the physical flow of ambient Fast-Moving Consumer Goods (FMCG)[7] it was possible to address the packaging logistics activities, since packaging is strongly connected to the product itself. Ambient FMCG were chosen, since this product category constitutes the majority of the total flow in a retail supply chain. It is important to bear in mind that other activities, such as production and marketing, would also be affected by the introduction of RFID technology in packaging.

Specific technology aspects as hardware and software requirements e.g. tag memory, data formats, and communication protocols etc, are not addressed in detail in this research. One motive for not including detailed aspects of technology is that the performance capability of RFID technology is continuously enhanced, so that a more general RFID system is studied in this research.

I would like to point out that this research is not about developing a RFID system to fit into the retail supply chain or about developing a cost-benefit analysis of RFID technology in retail supply chains. This research is about exploring how the application of RFID technology to packaging could affect packaging logistics activities in retail supply chains.

1.5 Reader(Reading) Guidance

In order to create a logical order of information I would like to advice you to begin read chapter one to four. You should then read appended paper number one, followed by chapter five and appended paper number two. Finally you should read chapter six. Appended paper number three should be read if you like a further introduction and description of discrete-event simulation.

The chapters and papers are described in brief below to further guide you on your way through this thesis.

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[7] 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.

Chapter 1: Introduction

In this first chapter the background to the research area is given together with a discussion and formulation of the research question. Based on the research question, the research purpose is stated, and the focus and demarcations of the research are discussed.

Chapter 2: Research process

In this chapter my methodological thoughts are discussed and the research design is presented. The data collection process and the analysis methods are also presented and described in this chapter.

Chapter 3: Frame of reference

The third chapter presents and discusses the concept of packaging logistics and RFID technology, which are the two of the major theoretical foundations of this research. In the description of the concept of packaging logistics, the packaging system and different definitions of packaging logistics are discussed. The basic principles and considerations of RFID technology are described, and discussed in relation to packaging logistics.

Chapter 4: The Dutch case description

In chapter four the Dutch case description is presented. The case, consisting of a Dutch retail supply chain, describes in detail the packaging logistics activities and processes within the distribution centre and the retail outlet.

Chapter 5: Description and analysis of the conceptual model

This chapter presents and analyses a conceptual model that has been developed to describe how the application of RFID technology to packaging could affect packaging logistics activities in retail supply chains. The conceptual model describes the physical flow of ambient FMCG from the product-filling point at the manufacturer's to the point where the product is sold to the end consumer, when RFID technology is applied to the whole packaging system.

Chapter 6: Concluding discussion

The final chapter discusses the outcome of the analyses of the simulation model and the conceptual model that have been developed and presented in this research. From a bottom-up perspective, this chapter explores how RFID technology in packaging could affect packaging logistics activities, the processes within the retail supply chain, and the whole retail supply chain. In addition, the theoretical and practical contributions of this research are described and finally, a discussion about further research is presented.

Appended papers

There are three appended research papers in this thesis. All the papers have been presented at different logistics conferences. Paper one and paper two have been published in conference proceedings. Paper three was presented as a working paper but has been modified in accordance with comments from the conference referees.

Paper 1: Framework of Packaging Logistics Activities in Retail Supply Chains

This paper presents a framework that describes packaging logistics activities in retail supply chains. The reason for developing such a framework is 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.

Paper 2: A Simulation Model of a Retail Distribution Centre with RFID Technology

This paper presents a simulation model that has been developed to analyse how the application of RFID technology affects material handling activities in a retail distribution centre. The simulation model primarily describes and analyses how the receiving, picking and shipping activities would behave and perform over time, when RFID technology is applied to the packaging system.

Paper 3: Using Discrete-Event Simulation in Supply Chain Planning

In this paper, discrete-event simulation is described and discussed as a technique to improve supply chain planning.

2 RESEARCH PROCESS

During my research process many choices have been made. This chapter aims at showing why and how the choices have been made and will to some extent also illustrate the alternative directions I might have taken during my research process.

2.1 Research Approach

To be able to understand why and how choices have been made, the basic assumptions of reality and ways of thinking must be addressed i.e. the research approach. The research approach is not something that one chooses or tries to apply to a certain problem; it is something that depends on the researcher's background and perception of reality (Burrel & Morgan 1979;Denzin & Lincoln 1998). It is therefore of great importance to discuss and describe my research approach in order to help you, the reader, to understand me, the researcher. By describing the research approach, I also attempt to share my awareness of basic assumptions and different ways of thinking.

In order to describe the research approach the framework of Arbnor & Bjerke (1997), which describes three broad and standardised types of research approach, is used. Before discussing methodological considerations, my ontological and epistemological assumptions are discussed, since these assumptions form the research approach.

2.1.1 Ontological and Epistemological Assumptions

A researcher approaches a subject via explicit or implicit assumptions about the social world and the way in which it may be investigated (Burrel & Morgan 1979). The research approach is therefore formed by individual assumptions concerning philosophical aspects, such as ontology - *the nature of reality* - and epistemology – *the nature of knowledge*.

Ontology

When discussing ontology the central question is: Is there an objective or subjective reality in people's minds? Put another way: Is reality "out there" or is it a product of one's mind?

I see “reality” not completely as a subjective reality; social construction. We all have different opinions and interpret things differently. My “reality” does not have to match yours. However, if I relate to a specific group of people, we could all interpret things more or less in the same way. Even if I see “reality” partly as a social construction, I have tried to be intentionally objective. I have tried to achieve objectivity by incorporating as many viewpoints as possible through listening to and discussing matters with people, especially those who disagree with me. Since I believe that there is no indisputable or absolute truth I always try to keep an open mind, constructing an imperfect picture that others can also relate to. My ontological standpoint can be compared to Lincoln & Guba’s (2000) constructivism, where the realities are local and specifically constructed.

Epistemology

When discussing epistemology the central question is: Is knowledge discovered or created? This question is closely linked with ontology since if one sees an objective world, knowledge and theories are “out there” waiting to be discovered, while one creates knowledge in a subjective world. In the debate of epistemology Burrel & Morgan (1979) describe two broad and polarised perspectives; positivism and anti-positivism. A positivist searches for regularities and cause and effect relationships with the aim of explaining and predicting a phenomenon. An anti-positivist seeks understanding rather than explanations and predictions. Understanding is created from the point of view of the individual who is involved in the subject being studied and its context, where “soft” aspects such as values, attitudes and feeling are considered.

My epistemological assumption is not based on pure positivist or anti-positivist thoughts. For me, research within an applied science like packaging logistics, is about gaining insight into phenomena and increase the understanding within the context in which it is to be applied. From my perspective knowledge could then be seen as being created from a common understanding of real-life events and phenomena in an industrial context. In this research a description of packaging logistics activities in retail supply chains forms a platform for a common understanding of what, how and why, packaging logistics activities are performed in retail supply chains. Based on this understanding, an insight into how the application of RFID technology to packaging could affect packaging logistics activities is explored within the described context.

2.1.2 Methodology

As mentioned before, the research approach depends on the researcher's background and perception of reality. The research approach also depends on the research field. Within a research field there are common assumptions and beliefs; a research paradigm. As Kuhn (1996, p.46) 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."

Lambert, Stock, & Ellram (1998, p.7) state that: "*The systems approach is a critical concept in logistics.*" Moreover, as Nilsson (2003) describes, logistics is based on positivistic assumptions. Reflecting upon this, I think my mechanical engineering background and the logistic context I am working in have, to a great extent, contributed to my research approach.

Arbnor & Bjerke (1997) have identified three research approaches; the analytical approach, the systems approach and the actor's approach. The actor's approach is based on the assumption and beliefs of the anti-positivist, whereas the analytical approach is founded on positivistic thinking and reductionism. The assumption of the system's approach, stressing a holistic approach to prevent reductionism, is that the whole (system) does not have to be equal to the sum of its parts (elements). The relationships among elements within the system create synergetic effects making the sum of the system larger or less than the sum of the elements. 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.

My research approach is based on the system's approach. The three approaches described by Arbnor & Bjerke (1997) are generalised. Checkland (1999) describes two types of systems approaches; hard and soft-systems thinking. 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. As I declare in my ontology discussion, this does not fit into my way of thinking, where I *try* to distinguish the whole system. My way of thinking is more in the line of soft-system thinking where the reality is described in subjective terms.

As mentioned above, the system's approach repudiates reductionism. But how do I identify the whole system? Either I use a top-down perspective, not to be confused with a holistic perspective, where the system is first identified, or a bottom-up perspective where the elements of the system are first identified. In a top-down perspective the assumption is made that the system exists in a static way, whereas in a bottom-up perspective the system is created based on the dynamic elements representing the system. Using a bottom-up perspective, the first step in investigating how the application of RFID technology in packaging could affect retail supply chains would be to thoroughly describe and gain a better understanding of how and why, packaging logistics activities in retail supply chains are affected by the application of RFID technology in packaging.

2.2 Research Design

The research design is the chain of logic that links the research question to the theoretical and empirical data collected, to the analysis results and, ultimately, to the research conclusions. The aim of the research design is to achieve a methodologically and rigorously sound research strategy for creating reliable results.

2.2.1 Research strategy

There are several ways of doing research e.g. experiments, case studies, surveys and modelling. Each strategy has its advantages and disadvantages and the issue is not that one strategy is better than the other. Each strategy is a different way of collecting and analysing empirical data and is used depending on the type of research at hand. According to Yin (2003, p.5) the selection of a preferred research strategy 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 as opposed to historical events.

I would like to add personal biography and paradigm as a fourth condition for selecting research strategy. Every researcher is unique because of his/her particular class, racial, cultural and ethnic perspective (Denzin & Lincoln 1998). A researcher may have a favourite strategy or does not have the knowledge of other possible existing strategies. According to Burrel & Morgan (1979) a positivist prefers nomothetic and quantitative research strategies, while an anti-positivist prefers ideographic and qualitative research strategies. Personally, I prefer a combination of both strategies and agree with Jick (1979) that qualitative and quantitative methods should be viewed as complementary rather than rival camps.

In order to answer the research question[8] there is a need to understand the existing packaging logistics activities in retail supply chains. An understanding of existing packaging logistics activities is a prerequisite for exploring the application of RFID technology to packaging, leading to the question: "*What packaging logistics activities are performed in retail supply chains? How and why?*" This situation calls for multiple research strategies since the question above is focusing on contemporary events, while the research question focus on possible future events.

The first strategy used in this research is case study. The case study strategy is here used to describe and gain an in-depth understanding and insight into the existing packaging logistics activities and processes in retail supply chains. The second research strategy is a modelling and simulation study, where the aim is to explore and analyse how the application of RFID technology to packaging could affect packaging logistics activities. Modelling and simulation provide the ability to explore possible future activities and behaviours of the retail supply chain, thereby increasing the understanding of how RFID technology in packaging could affect packaging logistics activities in retail supply chains.

There are prejudicial aspects when discussing the used research strategy since modelling and simulation strategy and case study strategy originate from epistemologically different research paradigms. Case study deals with real-life events whereas modelling and simulation deal with models, which can be replicated at any time. With modelling and simulation the researcher can manipulate parameters and relations of interest, whereas in a case study the behaviours cannot be manipulated. Those who are critical of modelling and simulation say that this type of research is characterised by studying cause and effect relationships e.g. cause: changing an input parameter, effect: performance measures (Merriam 1994). This may be true to some extent but often it is not the results of changing an input parameter that is interesting, it is the behaviour of the system that is interesting. Those who are critical of case studies argue that case studies are unreliable since case studies cannot be replicated and heavily depend on the skill and personality of the researcher conducting them (Miles 1979). One aspect that should be considered here is time. The context

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[8] *How and why could the application of RFID technology to packaging affect packaging logistics activities in retail supply chains?*

of the case study is continuously changed, which prevents a replicated case study from resulting in the same findings.

Case study strategy

The case study is a research strategy which focuses on understanding the dynamics present within single settings (Eisenhardt 1989). The strategy has a distinct advantage in a situation when (Yin 2003, p.9):

> *“a "how" or "why" question is being asked about a contemporary set of events, over which the investigator has little or no control.”*

The overall objective of a case study strategy is to gain a deep understanding of phenomena (Stake 2000). In case studies the focus is directed towards numerous variables covering all thinkable aspects that are available, whereas in a survey only a few variables in a large population are normally studied (Merriam 1994). From a statistical point of view the weakness of case studies is then the possibility to generalise with reference to a larger population i.e. population validity. Applying population logic to case studies is misleading since the case study does not claim to reflect a specific population with the aim of determining the frequency of a particular phenomenon. With case studies there is the possibility of generalising from one context to another with the goal of generalising and expanding theoretical propositions and not populations (Yin 2003).

Case study is the chosen strategy for collecting empirical data to gain an in-depth understanding and thoroughly describe how and why packaging logistics activities are performed in retail supply chains. Packaging logistics is an applied multidisciplinary science focusing on the improvement of packaging and logistics systems. Describing and exploring these systems and their contexts are therefore important in the further development of packaging logistics. Another motive for choosing the case study strategy is its focus on understanding contemporary set of events. This offers the opportunity to create a platform where the other used research strategy, modelling and simulation, could be used to look into the future, rather than only focusing on a current situation.

Modelling and simulation study strategy

In a modelling and simulation study an investigator has the capability to control and access the actual behaviour of the system by e.g. applying different rules and policies. From a social science perspective this could be compared to doing experiments where an investigator can manipulate behaviour directly, precisely and systematically (Yin 2003). Modelling and simulation strategies are advantageous when the research goal is to describe the behaviours of conceptual systems or to explore outcomes which depend on certain events or situations.

According to Banks (1998, 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 technique for building a model of a real or proposed system so that the behaviour of the system under specific conditions may be studied. Simulation has the ability to tell how a system performs and behaves over time when different rules and policies are applied (Shapiro 2001). A simulation model is developed to better understand relationships and operations over time as a function of policies and parameters. According to Banks et al. (2001), one of the advantages of simulation is that it allows one to explore different scenarios. This ability to study the performance and behaviour of proposed systems and to explore scenarios, makes modelling and simulation a suitable research strategy for exploring how the application of RFID technology to packaging could affect packaging logistics activities in retail supply chains.

Literature review

An important part of the research strategy is the literature review. Literature review is conducted to create a theoretical foundation within the research field and to obtain inspiration, ideas and insight into different ways of thinking.

Literature reviews have been continuously conducted in my research process. The reason for not conducting a literature review at the beginning of my research was that scientific literature concerning RFID technology applications in supply chains was missing. At the beginning of my research more general areas were reviewed e.g. logistics and packaging. Later in the process more specific Auto-ID fields were reviewed to obtain an in-depth understanding of the fields of interest.

The search for literature was primarily performed using library databases. Numerous databases were explored using different combinations of key words. Furthermore, specific journals were looked through in detail in search of literature concerning my research area (see Appendix A for a list of journals, keywords and databases used when searching for literature). Since literature was continuously involved in my research I came to realise, over time, which researchers were working in the same field, what perspectives they have, their niches etc. This gave me an opportunity to examine their references and at the same time position my research in comparison to them.

2.2.2 Case study design

There are variations in case study designs. A primary distinction is between single and multiple-case designs (Yin 2003). The single-case design could be considered an appropriate design when it represents a critical, extreme, unique or typical case. The single-case design is also appropriate when the aim is to study the case in greater depth. Multiple-case designs are often considered more compelling and powerful compared to a single-case design since it is regarded more robust. However, conducting a multiple-case study often requires more time and resources compared to a single-case study. The researcher also has to find several cases that fit his/her criteria for the research.

A single-case design was selected with the ultimate goal of providing an in-depth study and a rich description of how and why packaging logistics activities are performed in retail supply chains. Dyer & Wilkins (1991) argue that a “rich” description can reveal the underlying dynamics of a case while a “thin” description focus on surface data with the possibility of providing a distorted picture. I found that an in-depth study would enable me to gain a deeper understanding of the performed packaging logistics activities, than if multiple case studies were used.

A Dutch retail supply chain was chosen as the single-case study[9]. When the retail supply chain was chosen, access was an important aspect. The main reason for choosing the Dutch retail supply chain was that the wholesaling and retailing company, the Van Eerd Group (VEG), which is a central part of the studied supply chain, owned the distribution centres and a third of the retail outlets. The Van Eerd Group was very open and supportive and showed great interest in investigating the effect of applying RFID technology to packaging throughout their retail supply chain. They furthermore supported the idea of developing a simulation model[10]. The VEG is a relatively small retailer; in December 2001 they had a market share of 1.7 percent of the Dutch market. Their relatively small size enabled me to examine the majority of their organisation and study all their activities and processes relating to ambient FMCG in detail.

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[9] see chapter 4 The Dutch Case Description

[10] see chapter 2.2.3 Modelling and simulation study design

The Dutch case focuses on describing the information flow and the general physical flow of ambient FMCG[11]. By focusing on the physical flow it was possible to address the packaging logistics activities, since packaging is strongly connected to the product itself. Ambient FMCG were chosen, since this product category constitutes the majority of the total flow in the Dutch retail supply chain.

Triangulation

Triangulation can be generally considered as a process of using multiple perceptions to clarify meaning, verifying the repeatability of an observation or interpretation (Stake 2000). Different data sets and investigators have different strengths and weaknesses concerning the bias of the research. Triangulation is about the verification of results and, in the process, identifying and eliminating methodological shortcomings, data or investigator bias, thus strengthening the validity of the research (Oppermann 2000).

The Dutch case was both data-triangulated and investigator-triangulated with three Swedish case studies (Saghir 2002). The purpose of triangulation can be different depending on the methodology. From an anti-positivistic approach triangulation is a way to further expand and understand the research. From a positivistic approach the problem with case study, especially a single-case study design, is its external validity. The Dutch case could be seen as a non-representative case where I do not capture and describe ordinary packaging logistics activities. 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 triangulation resulted in appended paper number one and is further discussed in section 2.4.

Similar to the Dutch case, the Swedish case studies describe the physical flow, but focus on the flow of three ambient products, from the product-filling point at the manufacturer's to the point where the product is sold to the end consumer (Figure 2.1). Through this multiple triangulation approach both a holistic and an in-depth view of the physical flow were provided, focusing on both product-specific and non-product-specific aspects.

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[11]Fast-moving consumer goods, see chapter 1.4 Focus and Demarcations

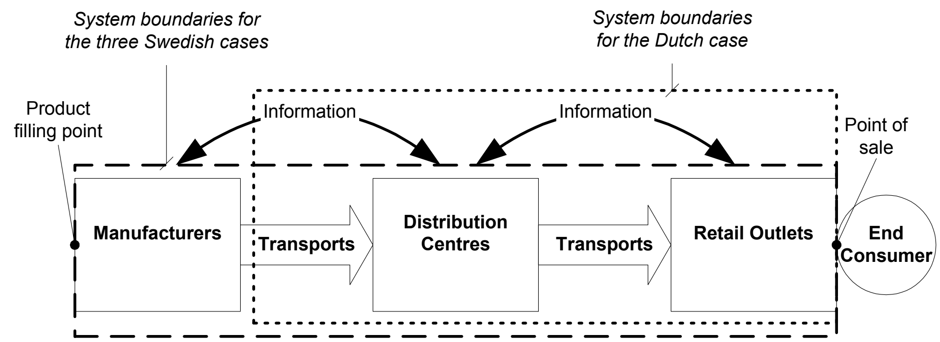

Figure 2.1. Boundaries of the case study.

2.2.3 Modelling and simulation study design

There are different types of modelling and simulation studies. Randell (2002) has identified three general types of modelling and simulation studies:

- An exploratory study of an existing system. The aim of this modelling and simulation study is to increase understanding of the system when e.g. rules or the system itself are changed.

- A validation study of proposed changes to an existing system. This study is somewhat similar to the previous one since it also deals with an existing system, but here the study is used to validate proposed changes, not to explore them.

- A study to design and validate a proposed system. In this case the modelling and simulation study is used in the design process to validate the performance, behaviour or function of the system.

This research encompasses an exploratory modelling and simulation study. The aim of the exploratory modelling and simulation study is to explore how the application of RFID technology to 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[12].

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[12] see chapter 2.4 The Process of Analysis

Developing a simulation model can be achieved by using a number of tools and techniques. The simulation technique used in this research is discrete-event simulation since it facilitates detailed analyses of systems that incorporate both dynamic and stochastic behaviour[13]. The discrete-event simulation tool used in this research, AutoMod™, is mostly used to develop simulation models of material handling systems, manufacturing facilities, warehouses and distribution centres, but is also considered a flexible tool that can be applied in other areas. Furthermore, AutoMod™ uses 3-D animation and is powerful in its descriptions of material handling systems, which enables the researcher to visualise the behaviour of the modelled system. For a more detailed discussion of different simulation tools, please refer to ARGESIM (2003), Banks et al. (2001), Holst (2001), Johansson, Johnsson, & Eriksson (2002), and Klingstam & Gullander (1999).

One of the basic principles in a modelling and simulation study is model conceptualisation (Pritsker 1998). The main purpose of a conceptual model is to identify and describe the important components and relations of the system (Wandel 1985). A conceptual model, graphical representation (visual model), was developed to describe a retail supply chain with RFID technology applied to the packaging system[14]. Process mapping[15] was the technique used to develop the conceptual model, which describes "could-be" processes and activities in retail supply chains, when RFID technology is applied to the packaging system. The building of the conceptual model involved both inductive and deductive reasoning. The studies of existing RFID application and results from pilot studies presented in literature and conferences contributed to the development of the conceptual model[16]. Studies from the Auto-ID Center[17] in co-operation with consultancy firms like Accenture (Chappell et al. 2003a;Chappell et al. 2003b;Chappell et al. 2003c;Chappell et al. 2003d) and IBM Business Consulting Services (Alexander et al. 2002a;Alexander et al. 2002b;Alexander et al. 2003) have also contributed to the development of the conceptual model. The conceptual model also incorporates ideas from experts. These ideas are derived from the function of RFID technology[18].

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[13] see chapter 2.2.5 Discrete-event simulation
[14] see chapter 5 Description and Analysis of the Conceptual Model
[15] see chapter 2.2.4 Process mapping
[16] see chapter 3.2.4 RFID applications
[17] see chapter 3.2.3 The concept of EPC
[18] see chapter 3.2.1 The components of RFID systems

2.2.4 Process mapping

Process mapping is a technique for describing, analysing and documenting processes. Process maps illustrate how input, output and activities are linked within processes. There are many different process-charting techniques to describe, analyse and document processes (Paradisio 2002). Product workflow modelling is a general process-mapping technique, used to facilitate understanding and graphically describe activities, when and where they are performed, the inputs and outputs, the sequences and relationships between the activities. As an analytical technique, process mapping is useful for creating a fundamental understanding of supply chain processes (Lindroth 2001). It facilitates structure and the categorisation of activities. Process maps also elucidate and illustrate events, activities etc. which otherwise might otherwise be difficult to understand. Process mapping can provide a holistic picture of processes, and at the same time, is able to provide an in-depth picture of processes and their activities (Jacka & Keller 2002).

2.2.5 Discrete-event simulation

Generally, a simulation model is a mathematical model that can be classified in three dimensions as being (Anu 1997;Banks 1998;Banks et al. 2001;Law & Kelton 1982):

- Static or dynamic
- Deterministic or stochastic
- Continuous or discrete

A static simulation model represents a "frozen" system at a specific point in time, whereas a dynamic simulation model represents a system that changes over time. A deterministic model does not contain probabilistic variables i.e. the simulation model has known inputs that result in a unique output. In a stochastic simulation model the behaviour of the simulation model is determined by stochastic variables. In continuous systems, variables change continuously over time, whereas in discrete systems the variables only change at discrete sets of points in time i.e. when an event occurs and changes the state of the system. In this research, discrete-event simulation is considered to be a simulation technique for modelling dynamic and stochastic behaviour with discrete-simulation models.

A further description of discrete-event simulation and its usefulness in modelling supply chains is presented in appended paper number three; Using Discrete-Event Simulation in Supply Chain Planning.

2.3 Data Collection Process

The data collection methods used in this research are observations, interviews, documents and archives. The data collection for the case study and the modelling and simulation study was carried out simultaneously and performed in 2001 during a more than one month on-site study of the retail supply chain. In the case study interviews, observations and documents were the main data collection methods used, while observation and archives were the primary methods used for the simulation.

In this multi-method research strategy which encompasses a case study and a modelling and simulation study, both qualitative and quantitative data are of great importance. The case study focused on more qualitative data, while the modelling and simulation study is based on quantitative data. But the studies respectively do not completely rely on qualitative or quantitative data alone. The data sets collected overlapped between the research strategies, creating synergies (see Figure 2.2 where synergies are illustrate by dotted lines). The case study provided the modelling and simulation study with an in-depth description of the processes facilitating the development of the conceptual model[19] and the simulation model[20]. In addition, the data collected for the simulation model provided the case study with an enriched understanding of the dynamics, variances, dependences and relationships among events and activities.

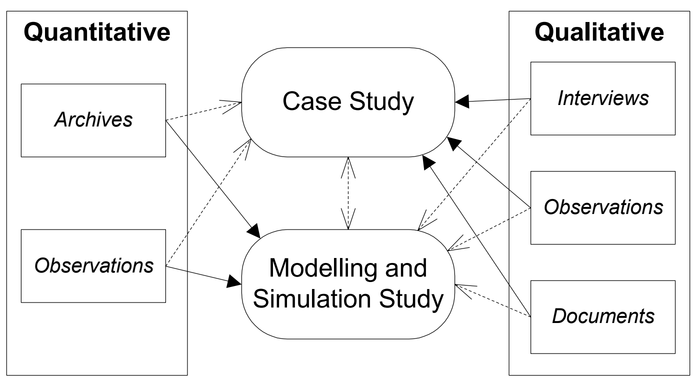

Figure 2.2. Data collection methods used in the research strategy.

[19] see chapter 5 Description and Analysis of the Conceptual Model
[20] see appended paper 2: A Simulation Model of a Retail Distribution Centre with RFID Technology

The process of collecting data at the Dutch retail supply chain can be metaphorically compared to building a puzzle of activities and processes. Every new piece of data expanded the "puzzle" and influenced the next interview or observation, pushing the collection of data forward. The data collected were written down in a case document to stimulate my thinking processes and to create a holistic view of the "puzzle". As I wrote and reflected on the data collected, new questions and issues emerged, expanding the "puzzle". The case document was also used to verify that my interpretations were comparable to the views of those who were interviewed, creating validity in the collected data. The case document was also reviewed by a key informant who confirmed the descriptions. The majority of the data for the simulation model were gathered when a clear picture of the activities and processes was attained. It was then that I knew specifically what quantitative data I needed for the development of the simulation model. The data gathering was brought to an end when saturation was achieved i.e. the new data collected did not serve the aim of the studies.

2.3.1 Observations

Since I spent more than one month on-site studying the retail supply chain, I was able to make a significant number of observations. Both direct observations and participant observations were made to find out how and why packaging logistics activities were performed in the retail supply chain.

Participant observation is a special mode of observation in which the researcher is not merely a passive observer, you actually participate in the event being studied (Yin 2003). For example, I helped a truck driver distribute goods to retail outlets and employees at the distribution centre with the picking activity. During these participant observations time was given to put questions to the workers involved about events, activities, material flow, problems etc. Through participant observation I was able, as a researcher, to expand my perspective and further develop an in-depth understanding of how the activities were performed. Direct observations of activities, working procedures etc. were continuously carried out during my visit. After every observation I registered and organised my observations in my "case document".

One of the weaknesses of observations is that an event may take place differently because it is being observed (Yin 2003). It is therefore important to use multiple sources to reinforce the data e.g. archival records and interviews.

2.3.2 Interviews

There are different forms of interviews depending on the structure of the interview i.e. open, open but focused, semi-structured and structured interviews[21] (Lantz 1993). The structured interview is in the form of a formal survey, while the open interview can be characterised as a guided conversation with methodological awareness.

Open interviews were used in this research since they provided the means of creating an understanding of the activities and processes in the supply chain from the respondent's viewpoint. The purpose of the interviews was to capture the respondents' experience and knowledge by asking open questions which the respondents could elaborate on. Respondents were asked about activities, their opinions of events and activities so that as many viewpoints as possible might be obtained.

Interviews were carried out with all types of staff e.g. managers, planners, truck drivers, pickers etc. In some situations the respondent suggested other persons for me to interview, as well as other sources of data. The selection of staff to interview was based not only on these recommendations from respondents, but also on the aim of choosing people who were involved with an activity or event of interest.

2.3.3 Documents

Documents were also used, to some extent, in data collection. The purpose of using documents was to corroborate data from interviews and observations. Administrative documents concerning activities and progress reports were the main type of documents used e.g. bill of quantities, delivery schedules, consignment/delivery notes, invoices etc. One problem when collecting data from documents was the language as the documents were written in Dutch. This prevented me from looking through all available documents. I just had to rely on recommendations from respondents as to what documents would were of interest; these documents were then freely translated into English.

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[21] Freely translated from Swedish

2.3.4 Archival records

Archive records played a central role in the gathering of data for the development of the simulation model. The archival records that have been collected have mostly been in the form of computer files and blueprints.

One important aspect when dealing with archival records is that just because they could be highly quantitative the data should not automatically be considered as accurate. Most archival records have a purpose and an audience that must be considered when the usefulness and accuracy of the records are to be interpreted (Yin 2003). When collecting records I tried to access the source of the data so no mistakes or misunderstanding would occur. Archival records are important when a time series of events is to be created, such as in this research, when developing a simulation model that represents a system that changes over time. Therefore, it is also important to collect data from particular time periods and identify when specific data were generated.

"Garbage in, garbage out" is a well-known phrase used in the area of simulation. To avoid this, the archival records that were used in the simulation were internally verified with other records and data collection methods to make sure that the data were reliable. The data collected were sometimes corrupted e.g. due to an information system error. Often these errors were easy to identify because the data were highly inconsistent and did not make any sense.

2.4 The Process of Analysis

The process of analysis has been conducted in two different, but integrated, parts; the analysis of the case study and the analysis in the modelling and simulation study. The results of the analyses from the studies are presented in different texts illustrated in Figure 2.3.

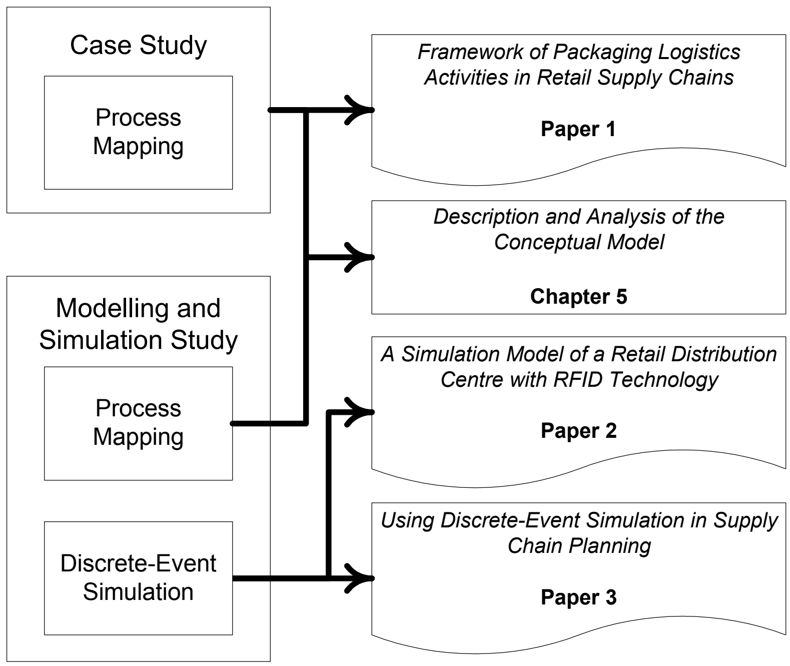

Figure 2.3. Results of the research process.

2.4.1 Case study analysis

The data collected in the Dutch retail supply chain were gradually analysed as the information emerged. The data were carefully examined using different sources, combining both quantitative and qualitative data, which strengthened the internal validity of the case study. Furthermore, the data were categorised into different activities, relationships and processes forming the Dutch case description[22] and the logic for the simulation model[23].

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[22] see chapter 4 The Dutch Case Description

The Dutch case description[24] illustrates what, how and why packaging logistics activities are performed in the Dutch retail supply chain. Process mapping was used for structuring and developing the Dutch case description. With the process maps a holistic perspective of the processes is obtained, which still contained specific and detailed information so that one can understand how and why 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.

As mentioned in section 2.2.2, the Dutch case was data-triangulated and investigator-triangulated with three Swedish case studies (Saghir 2002), to expand the understanding and description of packaging logistics activities in retail supply chains and to strengthen the external validity of the Dutch case. The triangulation of the Dutch case with the three Swedish cases resulted in a framework which describes packaging logistics activities in retail supply chains[25]. The framework describes what, how and why, packaging logistics activities are performed in retail supply chains. The reason for developing such a framework is 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.

2.4.2 Modelling and simulation study analyses

A conceptual model and a simulation model were developed in the modelling and simulation study. Process mapping and discrete-event simulation were both used in the modelling and simulation study as techniques for exploring how the application of RFID technology to packaging could affect packaging logistics activities in retail supply chains.

Process mapping was used to develop the conceptual model[26]. 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 process maps were also used in the development of the discrete-event simulation model

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[23] The simulation model is described in appended paper 2: A Simulation Model of a Retail Distribution Centre with RFID Technology
[24] see chapter 4 The Dutch Case Description
[25] see appended paper 1: Framework of Packaging Logistics Activities in Retail Supply Chains
[26] see chapter 5 Description and Analysis of the Conceptual Model

where the process maps described the structure, components, operating rules and material flow through the system.

Discrete-event simulation was used to develop the simulation model. The simulation model explores how the studied Dutch retail distribution centre could behave and perform over time, if RFID technology was applied to packaging throughout the centre's supply chain. The model developed primarily focuses on how RFID technology to packaging could affect material-handling activities and the order process in the distribution centre. The discrete-event simulation model incorporates both time-dependent behaviours and uncertainty, to further increase an understanding of how RFID technology in packaging could affect packaging logistics activities in a retail supply chain. The results, and a more detailed description of the simulation model, are presented in the appended paper number two; A Simulation Model of a Retail Distribution Centre with RFID Technology. A secondary motive for developing a supply chain simulation model was to determine whether discrete-event simulation could be a technique used in supply chain planning[27].

[27] see appended paper 3: Using Discrete-Event Simulation in Supply Chain Planning

3 FRAME OF REFERENCE

In order to explore how the application of RFID technology in packaging could affect packaging logistics activities, this chapter deals with both packaging logistics and RFID technology. It starts with a brief description of the concept of packaging logistics. After that, the basic principles and considerations of RFID technology are described in order to explore how the application of the technology in packaging could affect packaging logistics activities. In addition, the applications of RFID are described and discussed in relation to packaging logistics activities in retail supply chains.

3.1 Packaging Logistics

Packaging logistics is a multidisciplinary subject that brings together the packaging system and the logistic system with the objective that these two systems should support each other. Packaging logistics focuses on the synergies achieved by integrating the systems with the aim of increasing supply chain efficiency and effectiveness, through the improvement of both packaging and logistics-related activities. It would be difficult to create an efficient logistic system without packaging that supports the logistic system or vice versa, to create an efficient packaging system without the support of the logistics system.

Packaging logistics is not to be confused with logistical packaging, described by Twede (1992) and Bowersox & Closs (1996), which concentrates on packaging development with the aim of improving packaging aspects for the logistical system. Logistical packaging concentrates on a single relationship between the packaging system and the logistical system, where the packaging system adapts to the logistical system. As described above, packaging logistics is about the interface between the packaging system and the logistics system.

3.1.1 Definition of packaging logistics

In recent 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;Saghir 2002;Twede 1997). There is an ongoing discussion about the concept as such, where several views and definitions have been proposed. To further clarify the meaning of packaging logistics in this thesis, these views and definitions are discussed.

Bjärnemo, Jönson, & 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"

Furthermore, based on the Council of Logistics Management (CLM) definition[28] of logistics management, and Paine's (1981) definition of packaging, Saghir (2002) provides the following definition of packaging logistics:

"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."

These two descriptions highlight the main essence of packaging logistics i.e. the dual relationships between the logistical system and the packaging system. Saghir's (2002) definition addresses these relationships and expands the scope to a supply chain level compared to the Bjärnemo, Jönson, & Johnsson (2000) description of packaging logistics. Furthermore, Saghir (2002) discusses other aspects than logistics, such as environmental and marketing aspects.

Packforsk[29] (Dominic et al. 2000) have defined Packaging Logistics as follows:

"An approach which aims at developing packages and packaging systems in order to support the logistical processes and to meet customer/user demands"

This definition stresses that packaging logistics is an approach towards adapting the packaging system to the logistical system. This could be seen as addressing packaging issues from a logistical point of view and therefore describes more the concept of logistical packaging than packaging logistics itself. Furthermore, packaging logistics is here seen as an approach, not as a subject integrating the packaging and logistic systems.

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[28] The process of planning, implementing and controlling the efficient, cost-effective flow and storage of raw materials, in process inventory, finished goods, services and related information from point of origin to point of consumption (including inbound, outbound, internal and external movements) for the purpose of conforming to customer requirements.
[29] Swedish Institute of Packaging and Distribution

Bramklev et al. (2001) describe packaging logistics as an integrated approach where the logistics system is studied from a packaging perspective. Once again packaging logistics is seen as an approach but this time in an integrated manner between the packaging system and the logistical system.

To conclude, packaging logistics is a multidisciplinary subject, not an approach, that partially focuses on the interrelationships between the logistical system and the packaging system, just as described by Bjärnemo, Jönson, & Johnsson (2000) and Saghir (2002).

3.1.2 The packaging system

Packaging can be used in different contexts, describing different types of packaging. Therefore, before the packaging system is discussed, it has to be defined and discussed. In this thesis Paine's (1981) definition is used, since it is a broad and well-established description of the packaging system. Paine defines 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).

Paine's general definition above describes packaging, but several terms are used by practitioners in different industries when discussing different types of packaging. This does not facilitate communication and could cause difficulties in understanding the packaging system. Table 3.1 summarises some of the terms used to describe different types of packaging.

Packaging can be classified as primary (T), secondary (S) or tertiary (T) (Jönson 2000). This classification should be used when considering packaging as a system, and illustrates the levels of hierarchy in the packaging system, see Figure 3.1. With this system's approach to packaging, the interactions between the different packaging levels are highlighted, facilitating an understanding of the interdependence among the levels of hierarchy in the packaging system. The performance of the packaging system is then not only affected by the performance of each packaging level, but also by the interactions among the packaging levels.

Table 3.1. Terms used to describe different packaging types – modified from Jönson (2000).

Packaging Type	**Definition**
Primary packaging, consumer packaging or sales packaging	Packaging which is in contact with the product. The packaging that the consumer usually takes home.
Secondary packaging	Secondary packaging is designed to contain several primary packages.
Tertiary packaging	Used when a number of primary or secondary packages are assembled on a pallet or roll container.
Group packaging	Packaging which is created to facilitate protection, display, handling, and/or transportation of a number of primary packages.
Transport packaging, industrial packaging, distribution packaging or bulk packaging	Packaging which is created to facilitate handling, transport and storage of a number of primary packages in order to provide efficient production and distribution, as well as to prevent physical handling and damage during transportation.
Display packaging	Same as group packaging, quite often with an emphasis on display features.
Retail packaging	Same as group packaging with a special emphasis on the design to fit in retail.
Used packaging	Packaging/packaging material remaining after the removal of the product it contained.

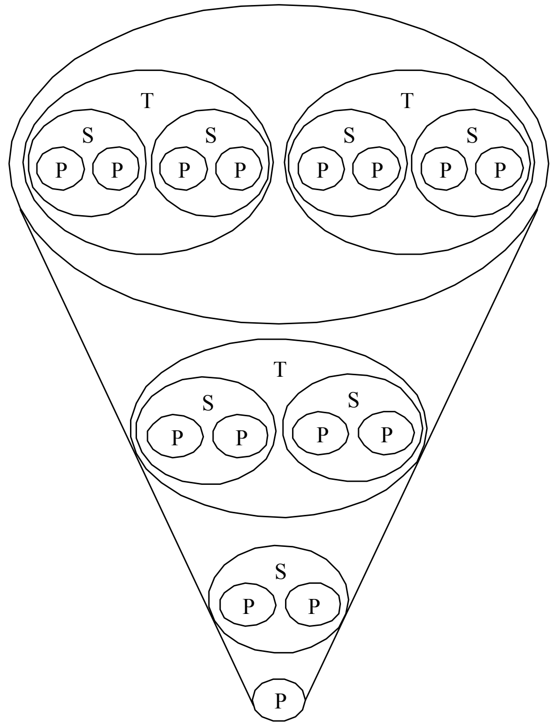

Figure 3.1. Levels of hierarchy in the packaging system - modified from Saghir (2002).

The packaging system has a significant impact on the efficiency of logistical activities as, for example, in manufacturing, distribution, warehousing and handling throughout supply chains (Ebeling 1990;Johnsson 1998;Lockamy III 1995;Twede 1992). Packaging represents an interface between different organizations in supply chains. The activities in these interfaces between organisations determine to some extent the efficiency of the supply chain. Using packaging developed or selected for a limited number of organisations could add extra activities at other organisations, decreasing the efficiency of the supply chain (Johnsson 1998). Examples of relationships between packaging and logistical activities are shown in Table 3.2 where the protection and information functions of packaging, which facilitate efficient transport, warehousing and communication, are highlighted. One should not forget the other logistical aspects of the packaging system where packaging could serve as the means for achieving efficient handling, information transfer, product identification and recovery.

The packaging system also plays an important role concerning the effectiveness of the supply chain since the packaging is the interface between the supply chain and the end consumer. Meeting end consumer convenience, requirements, and expectation are some of the main objectives of logistics where packaging marketing aspects play a decisive role. As Rod (1990) argues, packaging is a vital tool in the marketing mix, too often ignored by companies, still twice as much is annually spent on this as on above-the-line advertising and promotions.

Table 3.2. Packaging cost trade-offs with other logistics activities (Lambert, Stock, & Ellram 1998).

Logistics activity	**Trade-offs**
Transport	
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 standardisation	Decreases handling costs; vehicle waiting time for loading and unloading; increased standardisation; increases modal choices for shipper, and decreases need for specialised 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 utilisation (stacking), but decreases cube utilisation by increasing the size of the product dimensions.
Increased standardisation	Decreases material handling equipment costs.
Communications	
Increased package information	Decreases other communications regarding the product, such as telephone calls to track down lost shipments.

3.2 Radio Frequency Identification Technology

Radio frequency identification (RFID) is an Auto-ID technology that uses radio waves to transfer data between a reader and a movable item to be identified. The physical and operating technicalities of RFID systems originate from the fields of radio and radar engineering and are described below.

3.2.1 The components of RFID systems

By describing the RFID system components and their functions it is possible to understand the technology and issues that influence the application of an RFID system. A typical RFID system (Figure 3.2) is made up of three components:

- the *tag* (transponder), which is the data-carrying device located on the object to be identified;
- the *reader* (or interrogator), which has the overall function of communicating with tags and facilitating data transfer. Readers can be quite sophisticated, all depending on the type of tags that are being supported and the functions they need to perform. As a result, the capabilities and sizes of readers are very dependent on the application e.g. a reader can be stationary (wired) or wireless;
- the *host computer*, which communicates with the reader and e.g. the information management system.

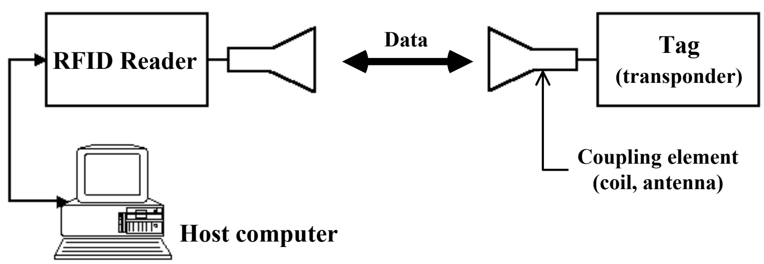

Figure 3.2. The components of a typical RFID system - modified from Finkenzeller (2003).

The tag basically consists of a coupling element (coil, antenna) and an electronic microchip. There are also chipless tag technologies with comparable functionalities to tags containing an electronic microchip. Since there are numerous variants of tags available, they can be characterised depending on several features, which form the functional capabilities of an RFID system:

- Operating frequency
- Communication method
- Tag power supply
- Tag memory and programmable options
- Tag form
- Sensor integration

Operating frequency – Frequency is one important differentiation criterion for RFID systems (Finkenzeller 2003). RFID systems operate over a widely differing spectrum from less than135 kHz to 5.8 GHz. The operating frequency is important to RFID systems as this determines both reading range and reading rate, which are two key performance variables in an RFID system. In general, we could say the higher the frequency, the higher the reading rate can be achieved. The reading range is much more complex and cannot only be related to the frequency used. The reading range also depends on factors such as the coupling element of the tag and the physical condition of the operating environment (Chen & Valerie 2000). The indications of reading range, reading rate, costs etc are illustrated in relation to frequency in Table 3.3. The trends in Table 3.3 are simplifications since the performance variables are affected by every component of an RFID system and its operating environment, and are not a simple function of frequency. Table 3.3 indicates that the cost of tags decreases with increased frequency. Obviously, the cost of tags depends on several factors, such as their functionalities and production volumes.

In general, all types of radio frequency communication are located into separate frequency spectrums. The allocations differ among countries since the countries have individual regulations regarding the use of frequency spectrums. Standardisation attempts are trying to solve this problem for the purpose of creating global standards for available frequencies for RFID systems.

Table 3.3. Comparison of RFID system parameters in different frequencies, derived from Chang (2000), Finkenzeller (2003) and Milne (2003).

Frequency / Performance parameters	LF – less than 135 kHz	HF – 13.56 MHz	UHF – 868 to 956 MHz	Microwave – 2.45 to 5.8 GHz
Reading range	Low Much less than 1.5 m	Low-Medium Less than 1.5m	High Much more than 1.5m	Medium More than 1.5m
Reading rate	Low	Low-Medium	Medium	High
Tag cost	High	High-Medium	Medium	Low
Reader cost	Low	Medium	Medium-High	High
Medium sensitivity	Low	Medium	High	High
Interference	Low	Low	Medium	High

Communication method – The communication method is one important variable when considering the reading range performance of an RFID system (Chen & Valerie 2000). There are three methods of communicating data between tags and readers i.e. inductive coupling (magnetic coupled), backscatter systems (electric coupled, propagation coupling), and two-way systems (AIM Inc. 2001;Finkenzeller 2003;Transponder News 2003). Inductive tags utilise the energy provided by the magnetic field of the reader. The tag then resonates the signal from the reader and communicates it back by modulating[30] the signal. Backscatter tags communicate by reflecting small portions of the electromagnetic waves from the reader, in which the information stored on the tag is encoded. Generally inductive coupling operates within less than 135 kHz – 13.56 MHz while backscatter systems operate within 868 MHz – 5.8 GHz. One could say that inductive coupled systems have a shorter reading range than backscatter systems, which have a shorter reading range than two-way systems. A two-way system incorporates a two-way tag, also called active tag (see below), which consists of a transmitter for communicating with the reader. Two-way systems can communicate 100 meters or more and have an optimal frequency performance in the range of 100 MHz to 1 GHz (Savi Technology 2002b).

Some RFID readers have the ability to identify and read information from several tags simultaneously, called "anti-collision". "Anti-collision" can also include the ability to write information to many tags simultaneously (if the tags are read-and-write tags, see below).

The data transmitted between tags and readers is always influenced by the medium through which it must pass. Some RFID systems are sensitive to media such as liquids. To put it simply, we can say that the sensitivity increases with the frequency used, see Table 3.3. Furthermore, different media can affect RFID communications in different ways i.e. reflection, cancellation and absorption. This kind of interference can be eliminated, depending on how the RFID system, especially the tag antenna, is designed. It is therefore important to consider the design of the product packaging.

Tag power supply - One other important feature of RFID systems is the tag's power supply (Finkenzeller 2003). Based on its power supply and communication a tag can be characterized to be active, passive or semi-passive. An active tag uses an internal power source (battery) within the tag to continuously power the tag, whereas a passive tag generates its power from the magnetic/electrical field of the reader. Active tags often offer better performance concerning reading range, reading rates[31] and noise immunity compared to passive tags (Savi Technology 2002a). However, passive tags are often less expensive, smaller and have a longer lifetime than active tags.

[30] Modulation is the process of altering the signal parameters of a high frequency carrier, i.e. its amplitude, frequency or phase, in relation to the modulated signal (Finkenzeller 2003).
[31] Measured in tags per second

Semi-passive tags are activated like passive tags but incorporate internal power to enhance performance such as reading range and memory capacity.

Tag programmable options – The data on a tag can be read-only, write-once-read-many (WORM) or read-and-write (AIM Inc. 2001). Read-only tags typically have an identification number programmed when manufactured, while WORM tags are programmed by users. Tags with read-and-write memory have the functionality of allowing users to add, modify or delete data stored in the tag. The data on the read-only and WORM tag is static while the data on read-and-write tags has the capability to be dynamic and user-written. The memory has also the ability to be temporarily or permanently locked. Depending on application there are RFID tags designed with different memory capacity. There are tags available from 1 bit and up. The tags with 1 bit memory signal two states; tag in the field or no tag in the field. For this reason 1 bit tags are used in electronic article surveillance (EAS) to identify items as they pass through a gated area. EAS is typically used to prevent theft by alerting unauthorised removal of tagged items e.g. in a store.

Tag form – RFID tags are available in a wide range of sizes and formats. Since they are mechanically robust they can be attached to, or buried into, different materials and be used in a wide range of harsh environments where dust, dirt, humidity, high pressure and temperature are present.

Sensor integration – There are also RFID tags available with integrated sensors (diagnostic indicators), indicating and/or monitoring e.g. temperature, time, vibration, acidity, tilt, shock, humidity, light, heat, or specific chemicals, viruses or bacteria. These tags are often active or semi-passive since they often need to monitor inputs from sensors when the tags are not in the presence of a radio frequency field.

3.2.2 Beyond the bar code

Capturing data by reading a bar code increases the accuracy and speed more than manual key entry (Nelson 1997). This has made it possible to capture data with fewer errors and resources, which in turn has made it economically viable to capture data more often. Bar codes are relatively cheap, reliable, and used by businesses all over the world. However, bar codes often contain limited data and are often fragile unless made expensively as in polyimide or ceramics (Harrop 2002). Moreover, they usually fail to be read if oriented incorrectly, torn or dirtied, and they cannot be read through atmospheric phenomena like steam and dust. An RFID tag can be constructed to allow it to be used in harsh environments and can have the ability to store a greater amount of data than a bar code. Another aspect of bar codes is that they have to be scanned requiring line-of-sight, whereas RFID tags can be read through obstructions and only need be within their transmitting range (active tags) or within a reader's range (passive or semi-passive tags). This means that RFID systems require a lower level of human intervention and facilitates automated data collection and identification of objects. In addition to the ability to remotely capture data through obstructions, an RFID system with anti-collision have the ability to identify several objects simultaneously. Another aspect is that most bar codes often identify a class of products and only contain static information. This means that the information can only be updated by reprinting and relabelling the object, while read-and-write tags contain dynamic data that can be continuously updated without any relabelling activities.

The traditional one-dimensional (1D) bar code has over the years been further developed and improved. For example, 2D bar codes, especially those which exhibit high-density data encoding (Telford 2000), have the ability to contain more data, but unfortunately they still retain the most of the same disadvantages as described earlier.

RFID technology also provides several other functionalities not available from bar codes, for example, a majority of RFID tags have EAS features for anti-theft purposes. Another additional functionality is product authenticity which prevent counterfeiting (Zebra Technologies 2003). Furthermore, complementary sensor technologies provide functions like tamper detection (Roberti 2003a) and the ability to capture and monitor conditions like temperature, humidity etc. Considering the functional benefits of RFID technology, it is important to understand that RFID provides other and more advanced functionalities than bar coding.

3.2.3 The concept of EPC

Electronic Product Code (EPC) is a standard under development for immediate, automatic, and accurate identification of any physical objects. The standard is based on giving every physical object an individual electronic identification number; an electronic product code. Instead of referring to a type of product, like most bar code standards do, the EPC refers to a unique product. The EPC concept, also conceived as the "Internet of Things", currently combines RFID and Internet technologies where the EPC serves as a reference for where on the Internet the information is stored. The EPC concept comprises five integrated elements:

- **Electronic Product Code** (EPC)

- **RFID System**. The EPC number is stored on the tag and identified by readers, which pass the number on to the computer system running a Savant server.
- **Savant** is distributed application software that manages and moves information, like an advanced data router. Savant sends a query through the internet to an Object Name Service database.
- **Object Name Service** (ONS) informs the computer system where to locate the information about the object carrying an EPC, by matching the EPC number to the address of the server which has the information about the product.
- **Physical Mark-up Language** (PML) is the standard "language" for describing the physical objects.

These five integrated elements are being developed as a layer on top of the Internet for making it possible for computers to identify any physical objects, aligning atoms and bits. The RFID system involves read-only tags since the information about the tagged object is located on the Internet and not kept on the tag itself. This still enables the tagged object to be associated with dynamic data without the need for read-and-write which decreases tag costs. Several pilot studies are being conducted using this standard and several large retail companies have announced massive implementation e.g. Wal-Mart, Tesco, Gillette.

The implementation of EPC does not require RFID technology. Any type of identification system with the ability to read a unique ID from an object would work. RFID technology is currently the most likely option, but future technologies, such as using ultra-wide band or amorphous metal threads to identify objects, could be used (Chappell et al. 2003c).

The concept of EPC was initiated and developed by the Auto-ID Center at the Massachusetts Institute of Technology and together with five Auto-ID labs at universities around the globe. The main objective for the Auto-ID Center was to develop a new low-cost RFID system based on open standards allowing industries worldwide to utilize this technology. The Auto-ID Center has handed over the development of the EPC standard to EPCglobal, a joint venture organization between EAN International and the Uniform Code Council, which will support the development of the standard to facilitate worldwide, multi-sector industry adoption. For a more detailed description and discussion about the concept of EPC, please refer to AIM Global (2003), Auto-ID Labs (2003) and EPCglobal (2003).

3.2.4 RFID applications

Although the use of RFID technology in packaging is currently limited, it is being used in a variety of other industrial and commercial applications, such as in access control (to vehicle and buildings), theft prevention, inventory control, tracking animals, airline baggage handling, tracking library books, automated toll collection systems, tracking of railway wagons, trucks, containers etc. Recent years' technological developments, reduction of tag price and emerging standards have facilitated trials and rollouts of RFID technology in packaging. In a study performed by IDTechEx Limited[32] (2002b), 21 trials and rollouts were studied where RFID technology was either fitted to primary packaging, secondary packaging or tertiary packaging. The conclusion of the study is that the main benefits of RFID technology in packaging are better service and lower costs. Below are a few European rollouts and trials described in order to illustrate the applications of RFID technology in packaging.

Procter & Gamble have used RFID technology in a manufacturing plant to increase the speed of loading. Using RFID technology to identify pallets enabled the plant to direct load trucks instead of staging them on the dock. With tagged pallets the order accuracy increased by eliminating errors such as wrong pallet put on a truck. Furthermore, the number of forklift trucks and docks needed decreased (Procter & Gamble 2003).

Marks & Spencer have launched a rollout of 3.5 million tagged returnable food produce delivery trays that will be used throughout the supply chain from supplier to retail outlets. In the initial trial the RFID system improved flexibility, speed and accuracy, which ultimately led to increased productivity, less wastage, shorter lead times and enhanced product freshness (Roberti 2002;William 2003). Marks & Spencer has also begun a trial to tag clothes in one of its stores to improve stock accuracy and product availability for consumers (Marks & Spencer 2003).

Sainsbury's have performed a trial when all returnable transit packaging crates used to distribute chilled products to a retail outlet were tagged with RFID technology. The trial indicated significant savings related to inventory accuracy and control, increased speed of the distribution function, inventory/code check,

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[32] IDTechEx Limited is a company that gives strictly independent marketing, technical and business advice and services on subjects such as Radio Frequency Identification RFID.

replenishment productivity, and reduction of out-of-stock (Falkman 2000;Kärkkäinen 2003).

Tesco started a trial in September 2003 where EPC tags are applied to trays, totes, and cases containing non-food items being shipped from one of their distribution centres to two retail outlets (Tesco 2003c). The aim of the trial is to improve supply chain visibility between the distribution centre and the retail outlets, but also to improve product availability for consumers. Tesco is currently working with suppliers and RFID technology providers to bring about a complete supply chain implementation of case-level RFID tagging. By January 2007 Tesco expects a complete implementation to be complete (Tesco 2003a). Tesco are also performing an item-level trial on Gillette razor blades. This trail has been extended to also include DVD's (Tesco 2003b). The main objective of this trial is to reduce shrinkage but it is also hoped that tagging items would improve product availability.

Based on rollouts and trials, RFID technology in packaging can provide a wide variety of benefits. But there are also major adoption challenges to overcome in deploying the technology. The two key adoption challenges have long been and still are; costs (tags, multi-frequency readers) and standards (RFID spectrum, data standards). As trials and rollouts expand into new contexts and applications new challenges arise, for example, in the Tesco trial described above, people have protested in concern of consumer privacy. In Tesco's extended trial to tag DVD's and in Marks & Spencer's trial to tag clothes a key objective of the trials are to test consumer acceptance of RFID. Other challenges will be, according to Violino (2003), dealing with large volumes of data generated from the RFID technology and making use of it within existing information systems and supply chain applications.

3.2.5 Packaging terms related to RFID technology

The terms "active packaging", "smart packaging" and "intelligent packaging" are commonly used to describe packaging with different types of value-adding technologies. These packaging terms are sometimes seen as interchangeable thereby generating misunderstanding and not facilitating communication, and are therefore discussed in this chapter.

Packaging is described by Rooney (1997) as active when:

" it performs some desired role other than to provide an inert barrier between the product and the outside environment."

Active packaging is used for protecting or preserving the contents of the packaging using controlled release chemicals. The active components may be part of the packaging material or could be inserted or attachment to the inside of the packaging. Active packaging enhances the properties of the packaging to meet the requirements of the content e.g. it maintains or creates an environment around the product that protects or preserves the contents.

Smart packaging and intelligent packaging are loose terms often used when describing responsive packaging features incorporating new or possible future technologies, often placed on or in the package in the form of a "smart label" or "smart tag". According to The Smart Packaging Journal (IDTechEx Limited 2002a) the core of smart packaging is its responsive features, and is described as:

"Packaging that employs features of high added value that enhance the functionality of the product."

These high-value features have a variety of characteristics, but are mainly made up of mechanic or electronic technology features e.g. mechanical medicine dispensers or packaging tagged with electronic devices such as RFID technology. Packaging with sensor devices that reveal something has happened or is happening, is also often included in this description of smart packaging.

Intelligent packaging is often considered to be the same as smart packaging but is more often used to refer to electronic responsive features where data is electronically sensed on the package from a distance, for instance using RFID technology. Schilthuizen (1999) points out that identification and sensor technology enables intelligent functions in packaging. The term "intelligent packaging" is used by Yam (2000) to emphasize the role of the packaging as an intelligent messenger or an information link. In conclusion, packaging incorporating RFID technology is referred to as both smart packaging and intelligent packaging.

4 THE DUTCH CASE DESCRIPTION

This case description illustrates what, how and why packaging logistics activities are performed in the Dutch retail supply chain. In this case description there is a focus on describing the general physical flow of ambient FMCG, including the reverse flow of products and packaging. By focusing on describing the physical flow, it was possible to address the packaging logistics activities, since packaging is closely connected to the product itself. In this case description there is also a focus on describing the order process since the activities are always in some way triggered by the order process. Several administrative activities like planning and controlling the physical flow are also described because these activities describe the context in which packaging logistics activities are performed. In order not to overload the case description, quantitative data collected are not embedded in the description.

4.1 Supply Chain Overview

The described retail supply chain consists of a wholesaler, its carriers and retail outlets, see Figure 4.1. The wholesaler company, the Van Eerd Group (VEG)[33] are a family-owned business that originally only focused on wholesaling. In the mid 1980s the VEG expanded vertically and launched their own chain of retail outlets, JUMBO supermarket[34]. Currently the Jumbo supermarket chain consists of more than 50 retail outlets and is today a central part of the VEG. Furthermore, the VEG are a relatively small and fast-growing retailer; in December 2001 they had a market share of 1.7 per cent of the Dutch market whereas in July 2003 they had 2.75 per cent of the market.

The Van Eerd Group wholesaling business mainly operates in two distribution centres. The distribution centre studied in this thesis handles the ambient FMCG and the other distribution centre handles the ambient slow moving consumer goods and all the fresh and frozen products. The two distribution centres mainly serve three retail chains, which constitute a total of approximately 150 retail outlets. The retail outlets receive deliveries from the two distribution centres and from the manufacturers that provide direct deliveries to retail outlets. Transport activities are performed by separate transport companies or by the VEG themselves.

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[33] www.jumbosupermarkten.nl
[34] In April 2002, the Van Eerd Group changed name to JUMBO Supermarkten

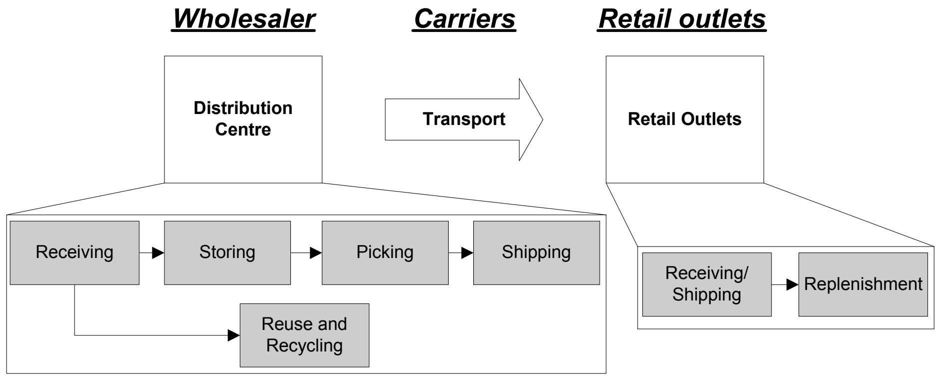

Figure 4.1. The supply chain actors and described processes.

4.2 The Distribution Centre

The distribution centre described handles about 2700 types of ambient FMCG and processes around 350 000 cases (secondary packaging) per week. The distribution centre is divided into five sections of about 4000 square metres each. In one section recycling activities are performed while in the other four sections traditional warehouse activities are performed. The four warehouse sections are divided into zones to enable efficient order picking. The pick locations are fixed and are situated on the lowest rack level. The other rack levels, levels two to five, are used for buffer storage. For high-volume products such as crates of soda and beer, a bulk storage system is used as buffer storage.

Secondary (cases) and tertiary packaging (roll containers and pallets) are handled at the distribution centre. The distribution centre is a member in several pallet pool organisations. Most of the suppliers are also members of one of the pools and subsequently deliver products on their pallets. The suppliers that are not members of any pallet pool organisation deliver products on EUR pallets. The processes described in the distribution centre are receiving, storing, picking, shipping, reuse and recycling, and the order process (Figure 4.1).

4.2.1 The receiving process

The shipments from suppliers are arranged to arrive according to a time schedule. The aim of the time schedule is to facilitate an even flow of incoming shipments which in turn facilitate the efficient use of trucks and docking bays. When a shipment arrives at the distribution centre, the truck is registered, verified and let into the warehouse area by an incoming truck controller, see Figure 4.2. The incoming truck controller keeps track of the incoming shipments and if a shipment is late the supplier is supposed to notify the controller, who then adjusts the schedule. When the truck driver has unloaded the shipment, an incoming goods controller checks the products received. If the shipment is correct, the pallets are labelled and the transport documents are signed by the incoming goods controller. The labels are manually written and contain the information of case quantity, warehouse section, pick location and the arrival week number, see Figure 4.2. If the supplier is not a member of a pallet pool and delivers products on EUR pallets, the truck driver is given the same quantity of EUR pallets that was delivered, or obtains a receipt for the difference.

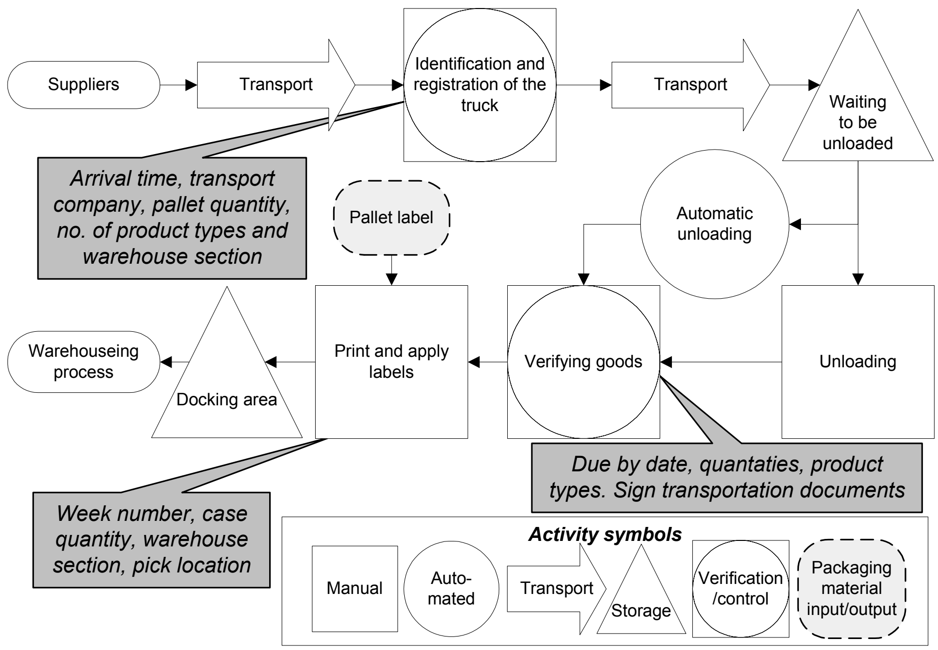

Figure 4.2. The receiving process at the distribution centre.

The controller of incoming goods can find several types of errors in a shipment. Wrong types of products, brands, quantities, and expiring date are the most common errors. When a supplier delivers the wrong products, and if the distribution centre does not handle these products, they are not accepted. But otherwise, if the distribution centre does not have too much in stock, the products are often accepted. Delivered products that have a short due by date are purchased by the distribution centre at a reduced price and sold to a special retail outlet at a special price.

4.2.2 The storing process

In the distribution centre there are two reach-trucks in each warehouse section that perform the storing process, see Figure 4.3. The reach-trucks have two functions. One task is to transport the verified and labelled pallets from the docking bay to the buffer storage situated above the pick location. To find an empty storage location for the pallet, the T method is used. The T method is a manual and systematic method designed to find suitable storage locations, and to locate pallets which have to be replenished. The second task for the reach-truck drivers is to replenish the pick locations with products. The reach-truck drivers themselves try to identify which products need to be replenished but they are often notified by order pickers as to which pick locations need to be replenished. When a pick location needs to be replenished, the reach-truck driver searches for the oldest pallet (FIFO)[35], again using the T method. When the oldest pallet is found the shrink film is removed and the pallet is placed at the picking location. The T method is considered time-consuming and with this method there is no assurance that the oldest pallet is taken first.

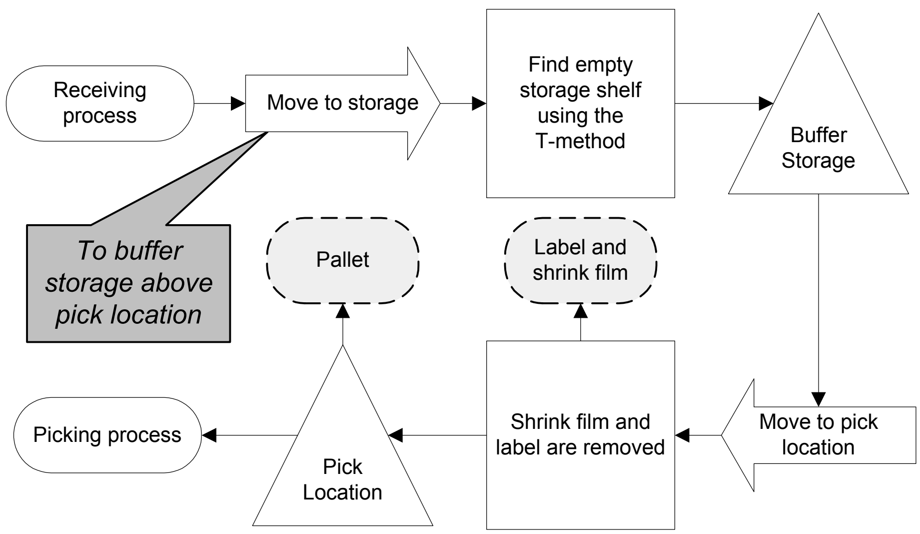

Figure 4.3. The storing process at the distribution centre.

[35] FIFO – First in first out

4.2.3 The picking process

The picking process represents the core process of the distribution centre and is the most labour-intensive process in the distribution centre. The orders received from the retail outlets are divided into pick orders designed for every section and zone to ensure efficient order picking[36]. The first step in the picking process is assigning pick orders, see Figure 4.4. The pick orders are assigned individually, and the skill of an individual employee is taken into consideration. Some employees are specialised in picking heavy products and some in picking few products in large quantities. After the pick order has been received, roll containers are collected and the order picking begins.

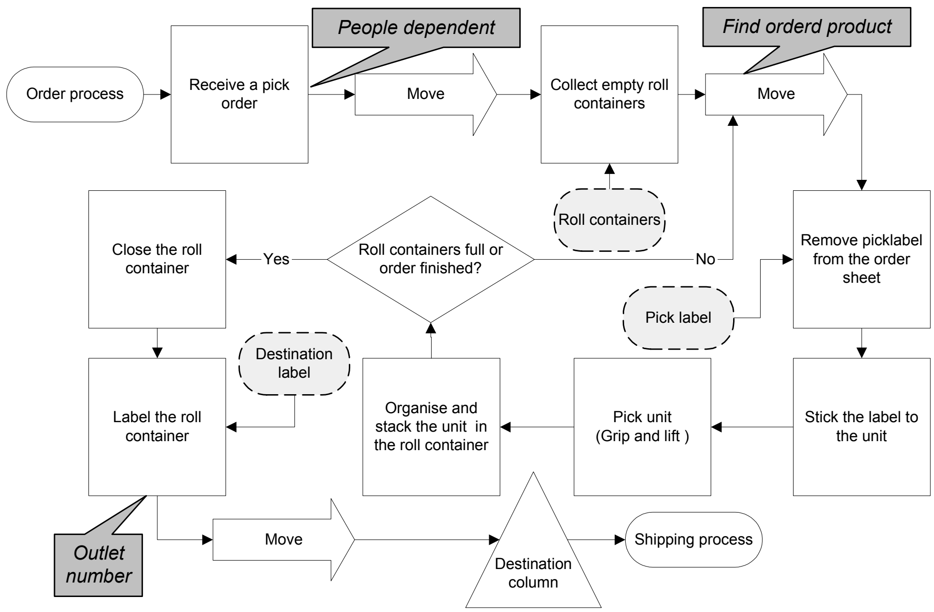

Figure 4.4. The picking process at the distribution centre.

A picking route runs through each section and zone. While the picking route is followed, cases are picked, labelled and stacked in the roll containers (the order of these activities is dependent on the individual picker). It is easy to make mistakes when picking cases. A small distraction can make the picker lose his/her concentration and a mistake is made e.g. picking the wrong product, picking the wrong quantity of the product, incorrect labelling and incorrect

[36] see chapter 4.3.3 The order process

stacking. When stacking the products the order picker has to make sure that the products do not get damaged and that the picking labels are properly placed on the case so that an outgoing goods controller[37] can verify the contents of the roll containers. If a case is placed in a roll container without a visible label, the controller is not able to identify the case and is therefore not able to approve the roll container for shipment.

When a picking location is empty a reach-truck driver replenishes the pick location with the pallet labelled with the earliest incoming week. As described before, the reach-truck drivers are often informed by the pickers of which products need to be replenished. When a picker comes to an empty pick location, the picker often locates a reach-truck driver and informs him/her of the product that needs to be replenished. A picker can also continue to pick the order, without notifying a reach-truck driver, in the hope of meeting the reach-truck driver further on and then informing the driver of which products need to be replenished.

When a roll container is full it is closed, labelled and transported to the front of the destination column. If the picker is not finished with picking the order, new roll containers are collected and the picking continues. Finally, when the picking is finished, the picker reports in and says if there were any problems such as unavailable products. If a retail outlet is able to handle pallets and has ordered a whole pallet of one product, a reach-truck driver is instructed to place a pallet in the destination column.

4.2.4 The shipping process

The shipping process is organised using numbered destination columns. Before the order is picked a shipment planner decides which destination column orders are to be shipped from. The shipment planner uses the amount of products in an order as an indication of how many roll containers the order is composed of. Based on this indication and from experience, each delivery, which could consist of several retail outlet orders depending on truck route, is assigned a specific destination column. When a shipment is picked the planner checks the real amount of roll containers that are being used by each order. This is done to inform the truck drivers of the exact quantity of roll containers they are going to deliver to the retail outlets. It is also done to check if the planned transport schedule is acceptable or if the schedule must be altered.

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[37] see chapter 4.2.4 The shipping process

When the shipment is ready to be delivered, a truck driver receives the information about how many roll containers and pallets there are to be shipped and what docking bay the delivery is located at. The truck driver also receives the transport documents and invoices. If there are any returnable products that are due to go back from any retail outlet the truck driver receives an extra document.

Before the roll containers are loaded on the delivery trucks (Figure 4.5), they are organised and verified by an outgoing goods controller. When a whole retail outlet order is picked the controller arranges the roll containers into the right docking column and the right loading sequence (the loading sequence depend on the route of the delivery truck). The controller then verifies the number of roll containers the order is composed of. For certain shipments, depending on who is the owner of the retail outlet, the controller has to verify the order by counting the amount of cases in the roll containers and by checking that the labelling corresponds with the products.

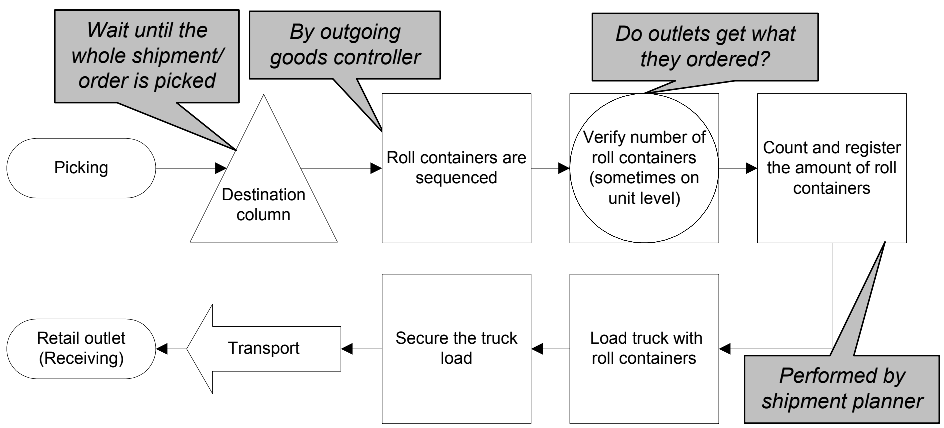

Figure 4.5. The shipping process at the distribution centre.

4.2.5 The reuse and recycling process

The final process associated with the physical flow in the distribution centre is the reuse/recycling process. The reuse/recycling process is performed at the distribution centre but could just as easily be performed at a separate location.

The delivery trucks returning from the retail outlets contain returnable and reusable goods[38]. The trucks are unloaded at the recycling section of the distribution centre. The returned goods are processed differently and can be categorised into the following; roll containers and pallets, returnable products, crates with bottles, returnable plastic crates (RPC) used for fresh and frozen distribution, corrugated board, paper and plastic. Corrugated board, paper and plastic are placed in different containers, while the returnable products that are taken back to the distribution centre are either thrown away or put back into the distribution centre.

The roll containers containing crates with bottles or RPC are organised by the truck driver into retail outlet specific lanes, see Figure 4.6. The truck driver labels the first roll container in the lane. The label provides information about the contents and amount of roll containers that are returned from each retail outlet. This information is verified by a controller who counts and records the number of PRC received and crates. This information is later processed and used in the finance department. When the contents of the roll containers are verified and documented the roll containers are moved to the conveyer sorting systems. There are two sorting systems; a conveyer system for sorting crates and a conveyer belt for sorting RPC.

[38] see chapter 4.3.1 The receiving and shipping processes

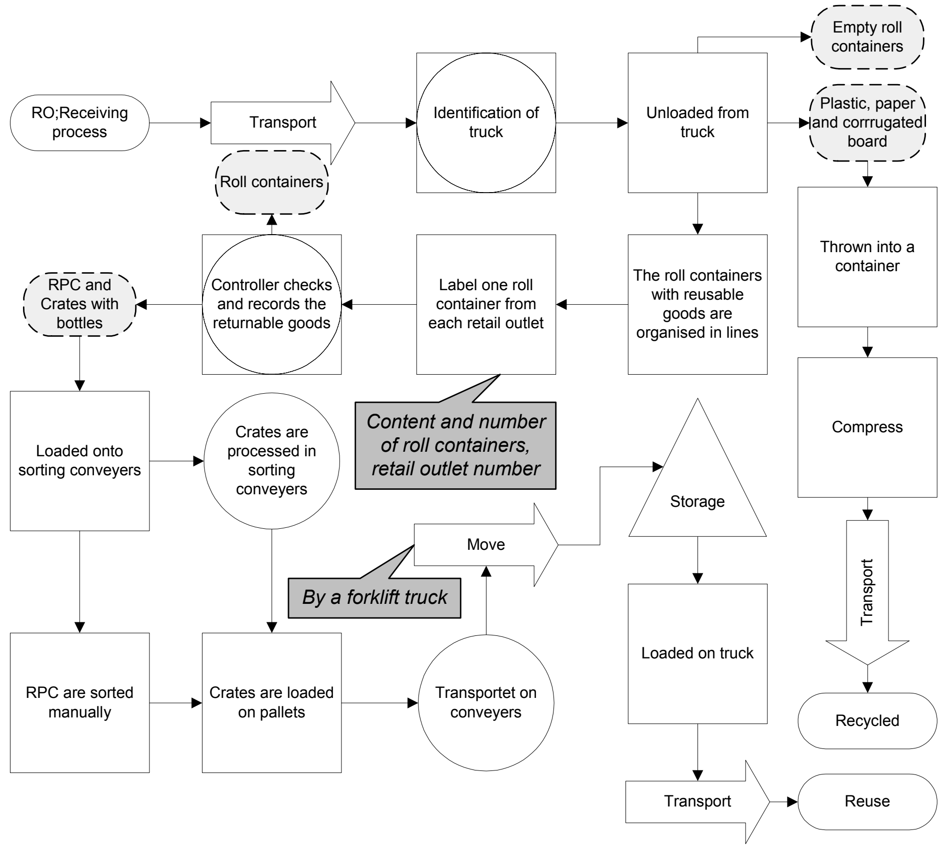

Figure 4.6. The reuse/recycling process at the distribution centre.

The conveyer system used for crates has a capacity of sorting 2200 crates per hour. The crates are manually placed on the conveyer belts. The crates and their contents are identified by a camera and sorted into different conveyer belts depending on the type of crate and its contents. If the crate cannot be identified it is directed to the end of the conveyer where it is sorted manually. About 125 different types of crates are handled by the distribution centre. The twenty most common types of crates represent 60 per cent of the flow and are called A crates. These high-volume crates are sorted and directed to separate conveyer belts by the conveyer system, from where they are manually placed on pallets. The rest of the crates, B and C crates, are directed to another conveyer belt where the sorting activity is done manually. The B crates are directly placed on pallets whereas C crates are manually placed in roll containers and stored in the distribution centre until a whole pallet of one type of crate is accumulated. The conveyer system used a bar code system earlier. With the bar code system the first roll container was scanned, which identified what outlet the crates originated from. The main reason why the bar code system is not used any more is because it could not communicate with the financial system used by the distribution centre, and the identification process using a camera was not entirely reliable and correct.

About 15 standard types of RPC are handled by the distribution centre. Previously, the RPC were also sorted in the conveyer system for crates, but the camera was unable to properly identify the different RPC so they are now processed on a separate conveyer system. RPC are manually unloaded on a conveyer belt where the sorting and stacking activities are done manually.

4.2.6 The order processes

Two types of orders are processed at the distribution centre; orders received from retail outlets and orders generated at the distribution centre and sent to the suppliers.

Orders received from the retail outlets first enter an information system, named PDT pal. Orders are divided up within this system and directed to the different distribution centres and manufacturers (some products like meat and cheese are directly ordered from manufacturers). Each distribution centre receives an order of what products they are to handle. At the distribution centre, the orders received from the PDT pal system enter another information system in form of an "Hterm.dat" file. In this system product accessibility is verified, stock registration is carried out and the order picking assignment for each distribution centre section is arranged. There are several reasons as to why a product could be inaccessible e.g. the product due by date has expired, product recall, incorrect stock levels, the product is out of stock or the retail outlet has no authority to sell the product.

The "Hterm.dat" file is processed five times a day, printing the invoices and the pick orders (picking labels) for every distribution centre section. The invoice informs the retail outlet of which products are accessible or not accessible. Occasionally stock levels are incorrect, due to theft and damage or errors in the picking. Since the invoices are processed before the orders are picked the problem of incorrect stock levels is not taken into consideration. If there is a discrepancy between a shipment and an invoice, the retail outlet receives a credit note from the finance department. In addition, the products that not are delivered are marked in the invoice and delivered the next time that the products are available. The printed pick orders are sorted manually according to priority and sometimes split into several pick orders depending on the amount of cases and how fast the order needs to be picked. If an order is urgent, the picking order is divided into smaller picking orders so that more resources can be used. Every pick order is marked with a specific docking bay number, which the shipment planner has determined, where the order is going to be shipped from.

The orders generated by the distribution centre and sent to suppliers are managed by an ordering system that automatically surveys the stock levels according to an ordering schedule. Each product is ordered according to an order schedule, which describes what weekday(s) the product can be ordered on. When the stock level falls below a predefined point the system recommends what quantity the distribution centre should order. A purchaser has to verify the suggested order and if the purchaser does not think that the quantity is adequate due to fluctuation in the demand, the quantity can be changed. The order is sent by EDI, fax or post, depending on the supplier. Most of the products are ordered in pallet quantities. There are only a few products that can be ordered in pallet layer quantities.

4.3 The Retail Outlets

Approximately 150 retail outlets are supplied by the distribution centre. The retail outlets are located all over the Netherlands and in Belgium and mainly consist of three different retail outlet chains. The retail outlet chains are categorised in several different retailing concepts depending on their size, location, appearance and level of service towards their consumers. Depending on the retailing concept, retail outlets have different arrangements regarding order processing schedules, order frequency, order accuracy and delivery schedules from the two distribution centres and manufacturers. This means that the activities in the retail outlet can vary depending on the retailing concept. The activities in the retail outlets cover all levels of packaging and the processes that are described are receiving and shipping, replenishment and order processes.

4.3.1 The receiving and shipping processes

The products that are delivered to the retail outlets from the distribution centre are often delivered in roll containers. Pallets of high volume products are also delivered if the outlets are able to handle pallets. The first manual handling activity in the receiving process is removing the fixation equipment in the truck, see Figure 4.7. The truck is then unloaded by the truck driver. The unloading activity is performed differently depending on whether the retail outlet has a docking bay or not. If there is no docking bay the unloading is done by using the end lift of the truck. This takes longer than using a docking bay since the end lift only has a capacity of six roll containers and means more work for the truck driver. Meanwhile, when the truck is being unloaded, the unloaded roll containers are verified and checked by the retail outlet manager who makes sure that the shipment corresponds to what has been ordered. The verified roll containers are then placed in the retail outlet storage, awaiting replenishment. The verification activity is always performed on roll container level where the amount of received roll containers are verified against the number of roll containers shipped from the distribution centre. But if the distribution centre and the retail outlet do not have the same owner the verification can also be performed on case level. When the shipment is unloaded, roll containers with returnable and reusable goods are verified and loaded on the truck. Finally, the invoice is handed over to the outlet manager and transport documents are signed.

Each retail outlet has two types of deliveries, one with fresh and frozen products and one with ambient products. The truck that delivers fresh and frozen products does not bring back any roll containers with returnable or reusable goods because the temperature in the trailer must be stable. This means the amount of roll containers back from the retail outlet is higher then the amount delivered by the trucks that deliver ambient products.

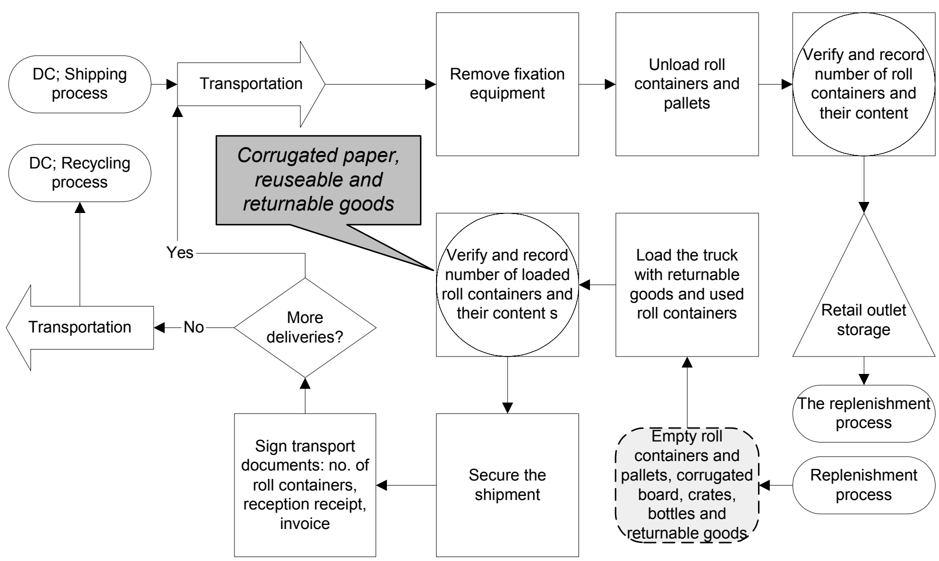

Figure 4.7. The receiving and shipping processes at the retail outlets.

4.3.2 The replenishment process

The replenishment process depends not only on the product itself but also on the retailing concept of the retail outlet. Some outlets prioritised customer perception and replenished primary packaging (singe products) on shelf. Others focused on replenishing cases on shelves or whole pallets on the floor. Figure 4.8 illustrates the replenishment process for primary packaging, cases and pallets.

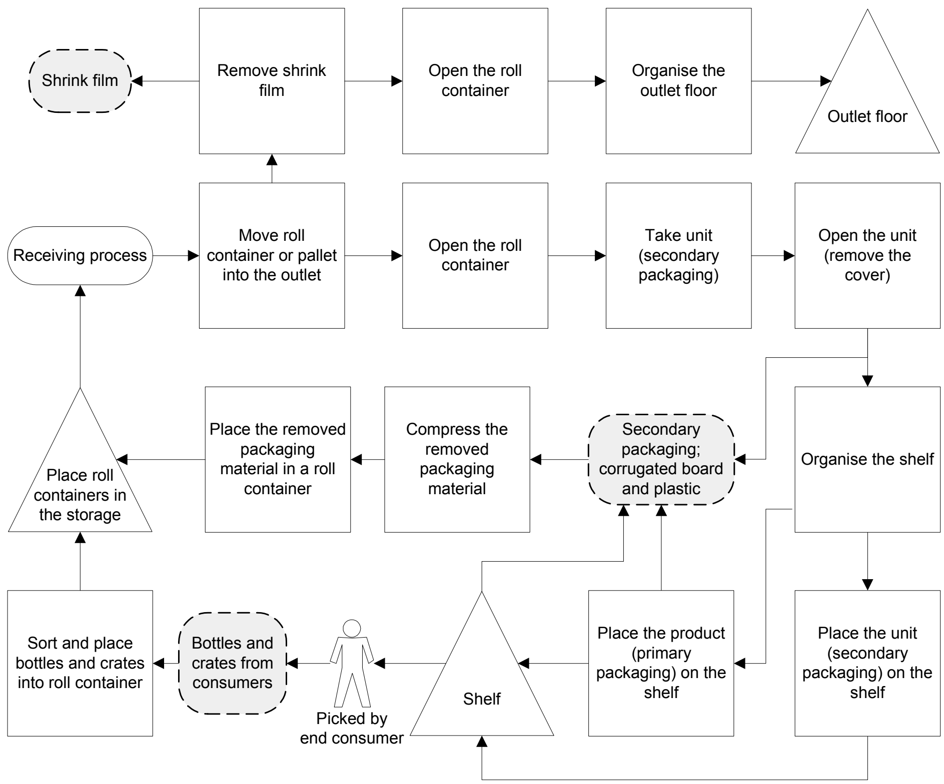

Figure 4.8. The replenishment process at the retail outlets.

4.3.3 The order process

The process of generating orders is performed differently in different retail outlets. The majority of the retail outlets generate orders using a handheld terminal. They use the terminal to scan the product shelf bar code and register the amount of cases they would like to order by pressing the digits on the terminal. When the retail outlet wants to send the order, the order information is sent electronically by EDI. Some of the retail outlets have a point-of-sale system. This system keeps track of the stock levels in the retail outlet and assists with the ordering by suggesting quantities and the products that should be ordered. Very few small retail outlets send their orders by fax or post; these orders are recorded manually in the warehouse management systems (WMS) at the distribution centre.

Each retail outlet has its own time schedule when it is supposed to send its orders. The time schedule is made up by a "time window". The length of the "time window" depends on the retailing concept of the retail outlet and is in agreement with the distribution centre. The time schedule is of great importance when orders are placed with the handheld terminal. Some retail outlets scan all the shelves, creating one order, while other outlets scan separate sections of the retail outlet thereby generating numerous section orders. Section orders are automatically consolidated into one order at the distribution centre if they are sent in accordance with the time schedule. If not, several orders will be created and handled individually in the distribution centre. Instead of having one order to pick in each zone a retail outlet could have several orders in one zone, resulting in inefficient picking.

The timing and execution of the order process depend on several aspects, such as number of deliveries per week, the order schedule and ordering method. For example, the order process for a retail outlet that receives one delivery each day and has no back-room inventory could be carried out in the following way: The order is send to the distribution centre in the evening after the received goods have been put onto the shelves. It is not until the retail outlet has closed and the shelves have been replenished that the retail outlet knows what products and quantity to order. The order is probably picked the next day before two o'clock since the shipment must be transported to the outlet. When the shipment arrives at the retail outlet the receiving and replenishment processes are carried out. When the retail outlet finally closes for the day a new order is generated.

The ordering process of promotion products is slightly different to the ordering process for ordinary products. There are two types of promotions; one on regular products and one on special products that are not ordinarily kept in stock. Ordering regular promotion products the retail outlet has to register the desired amount of cases six weeks before the promotion. The registration is only a rough estimate of what the retail outlet assumes it can sell. When the promotion begins the retail outlet does not have to accept the registered cases. When ordering special promotion products the retail outlet also has to register the desirable amount six weeks before the promotion. However, the order quantities of special promotion products are binding, meaning that retail outlet must accept all the special promotion products that they have signed up for.

5 DESCRIPTION AND ANALYSIS OF THE CONCEPTUAL MODEL

This chapter presents and analyses a conceptual model describing how the application of RFID technology to packaging could affect packaging logistics activities in retail supply chains. The conceptual model is a result of the modelling and simulation study and is based on the framework[39] developed in the case study. The aim of the conceptual model is to create an 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.

To explore the application of RFID technology to packaging, some assumptions have to be made concerning what type of RFID system is used. In the conceptual model a whole RFID system is assumed to have been implemented, adopted and utilised throughout the whole retail supply chain. The RFID system is also assumed to have been integrated with other existing information system software and solutions, such as Enterprise Resource Planning (ERP) and Warehouse-Management Systems (WMS). Furthermore, it is assumed that this technology provides accurate reading rates and offers reading ranges adapted to the application described in the process maps. In the conceptual model it is also assumed the RFID tags have the capacity to contain or refer to dynamic data, either in the form of read-and-write tags or by updating a database which refers to RFID tags.

5.1 Retail Supply Chain Processes

The conceptual model describes "could-be" processes and activities in retail supply chains when RFID technology is applied to the packaging system. The focus of the conceptual model is on the physical flow of ambient FMCG from the product filling point at the manufacturer's, to the point where the product is sold to the end consumer, see Figure 5.1. The order processes are also described and analysed to provide a wider exploration of how RFID technology in packaging affects activities in retail supply chains. The conceptual model illustrates how packaging inputs, outputs and activities and their relationships

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[39] see appended paper 1: Framework of Packaging Logistics Activities in Retail Supply Chains

within processes would be influenced when RFID technology is applied to packaging. The conceptual model focuses on describing the whole packaging system with RFID technology; item level tagging (primary packaging), case level tagging (secondary packaging) and pallet and roll container level tagging (tertiary packaging). Since the data in the RFID tag is dependent on the packaging level and application, the process maps also incorporate the description of some examples of data exchange among activities.

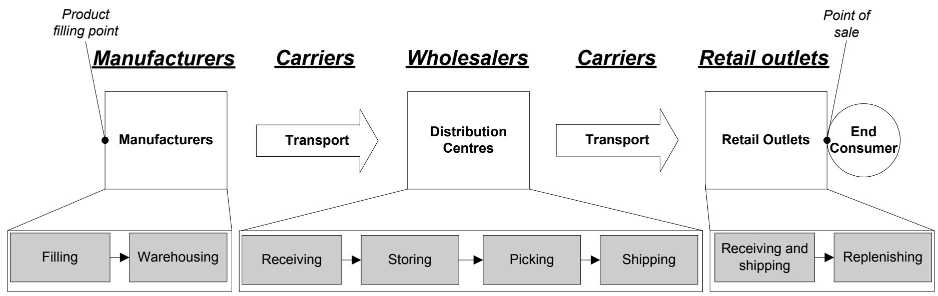

Figure 5.1. The processes described and analysed in the conceptual model.

5.2 Manufacturer

5.2.1 Filling process

In the filing process the primary packaging is filled with the products. From this moment on the product and the primary packaging are considered as one unified and inseparable unit until they reach the point of consumption. Label application is an important activity in the filling process, where labels are automatically applied to primary, secondary and tertiary packaging to enable downstream identification and provide information about products. RFID tags do not have to be applied to the packaging, they could be embedded in the products or the packaging. RFID technology does not influence how the filling process is performed, but it is in the filling process that RFID tags are applied to enable downstream utilisation of the technology, see Figure 5.2 (activities coloured grey indicate RFID involvement).

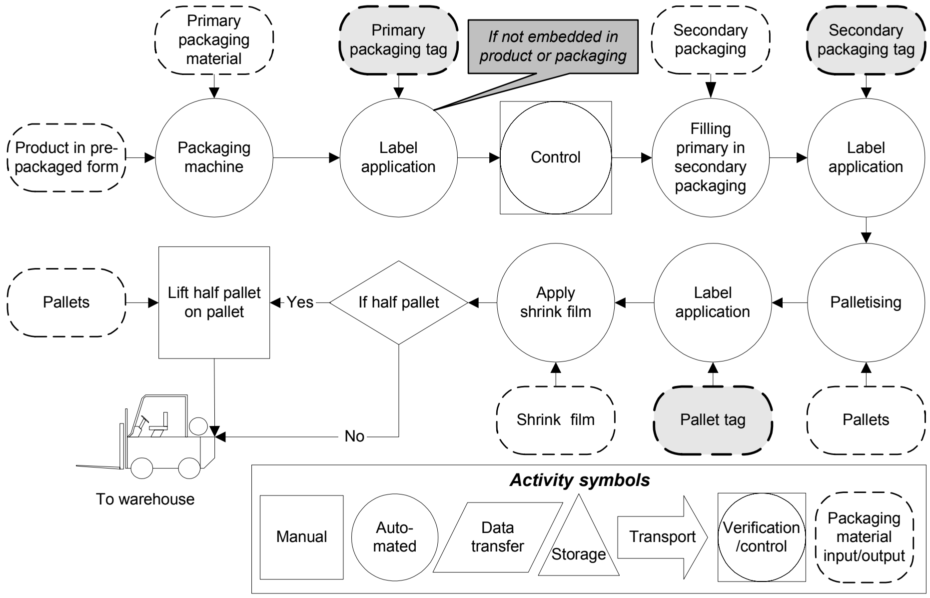

Figure 5.2. The filling process at the manufacturer's incorporating RFID technology.

Aspects such as how and where the tags are applied or embedded in the packaging or product depend on the type of product, packaging design and packaging material. Material aspects like the substance of the product and the packaging material must always be considered when applying or embedding RFID tags in products or packaging, since RFID communications are influenced by the media through which it must pass. Furthermore, RFID tags do not have to be properly oriented as bar codes since the tags do not need line-of-sight. Having a permanent RFID tag on the pallet would make it possible to automatically track the pallets, making it possible to find out where pallets have been damaged, stolen etc.

An important aspect is the information carried or referred to by the RFID tag applied during the filling process. The information depends on the level of packaging. Currently, primary packaging label information is directed towards end consumers, while secondary and tertiary packaging label information is used to identify and verify aggregations of products, ideally along the whole supply chain. In the case study, labels applied to secondary and tertiary packaging during the filling process were only used internally at the manufacturer's. Secondary and tertiary packaging were relabelled several times along the supply chain. Applying RFID tags to primary, secondary and tertiary packaging would enable the whole supply chain to utilise the technology and eliminate all relabelling activities. Furthermore, tagging of primary packaging would not only direct information towards end consumers, but also towards the supply chain. Tagging primary packaging would facilitate identification and verification of primary packaging instead of product aggregates (secondary or tertiary packaging) and thereby increasing the level of detailed information available for the supply chain. A few examples of data that could be stored or referred to by a tag are; type of products, quantities, manufacturer date, price, batch, due by date, owner, shipper, receiver, order number, current location, locations the products has passed through, who have handled the products.

5.2.2 Warehousing process

Pallets are the main unit load handled throughout the warehouse process and that is why this process has been analysed due to the fact that pallets are tagged with RFID technology. Tagging on a pallet level requires fewer tags to be read than case or item tagging. The added value of case or item tagging would be that the true contents of the pallet were identified instead of the aggregated data of the pallet.

The warehouse process includes storage, picking and shipping activities, and if a central warehouse is used for distributing the manufactured products, additional activities are needed i.e. receiving, storage, picking and shipping. Below are the storage, picking and shipping activities described when tagged pallets are used. The receiving activity is similar to the receiving process at the distribution centre and is therefore described in detail in section 5.3.1.

With RFID tagged pallets and readers strategically placed in the warehouse it would be possible to automatically convey accurate and near real-time data such as quantities, type of products, distribution points the pallets have passed through and where pallets are currently located in storage. There are several different ways to track and locate pallets in storage using the RFID tags attached to pallets e.g. using readers with the ability to locate the position of tags. Another way to track and locate pallets in the storage would be to use forklift trucks with readers that identify the pallet being handled and the physical storage location (in each physical storage location there would be a tag informing the forklift of the storage location). The capability to automatically locate, track and quantify all pallets and their contents by using RFID tags increases the inventory visibility in the storage, eliminating the need for manual physical inventory counts/checks and problems associated with incorrect inventory levels in WMS. The inventory visibility would also improve the accuracy of finding suitable storage placements for pallets. It would also ensure that pallets are picked depending on the expiry date of their contents, making the downstream supply chain consume products depending on remaining shelf life, see Figure 5.3 where the thin dotted lines indicate previous activities without RFID. This would lead to less wastage and fewer rejections based on insufficient shelf life throughout the supply chain.

With RFID tagging on a pallet level and readers by shipping doors, pallets would be automatically identified when loaded into delivery trucks, thus generating information on what quantities and products are being shipped. This information would be used to verify the shipment, making sure that the shipment is composed of the products ordered. This would eliminate the manual verification activity, reducing theft and shrinkage, and speeding up the shipping activity. Furthermore, an Advanced Shipping Notification (ASN) could be automatically generated, providing the central warehouse or distribution centre with detailed information on quantities, products and the possible time the shipment will be received. The information would also be used to automatically generate invoices and as proof of shipment, which eliminates the work involved in invoicing and the need for shipping documents to be signed.

By using tagged pallets and readers by shipping doors, the RFID system would eliminate the likelihood of putting the wrong pallet on a truck. This would enable forklift truck drivers to directly load trucks instead of staging pallets in the shipping area. This would result in trucks being loaded more quickly, which in turn reduces the number of forklift trucks and docks needed.

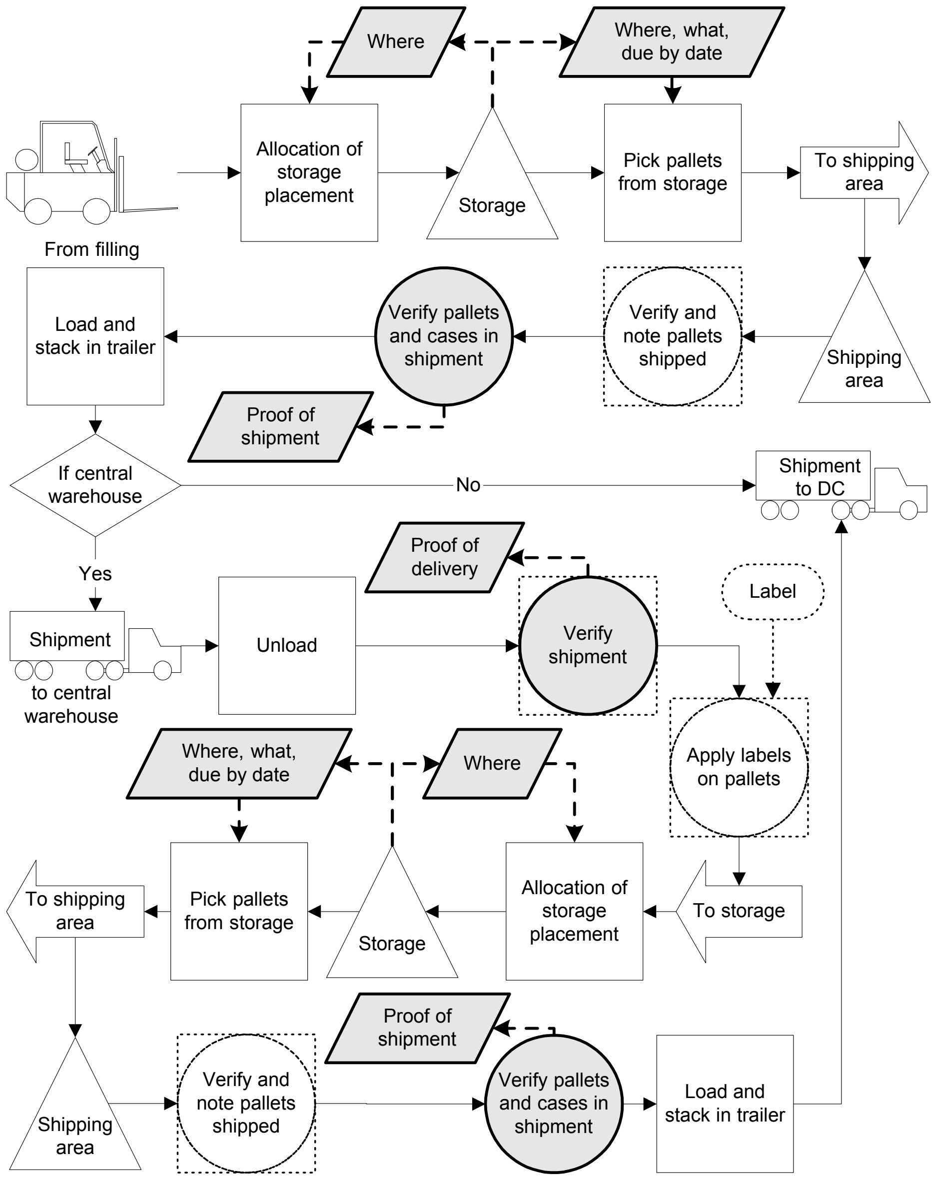

Figure 5.3. The warehouse process at the manufacturer's incorporating RFID technology.

5.3 Distribution Centre

5.3.1 Receiving process

When a shipment arrives at the distribution centre the truck driver unloads the shipment. If RFID tags on a pallet level are used, readers by the receiving doors would automatically identify pallets when they are unloaded at the distribution centre, see Figure 5.4. The pallet tag would e.g. provide the information on what products, expiry dates and quantities are being received at the distribution centre. This would eliminate verification and label application activities, resulting in less labour and reduced receiving time, which results in better utilisation of docking door, docking space, delivery truck and truck driver.

The information generated when tagged pallets are being unloaded could be used to generate proof of delivery, which could be sent to the manufacturer and the transport company, notifying them of what products have been received at the distribution centre. This would eliminate the need for transport documents to be signed and reduces administration work associated with receiving goods.

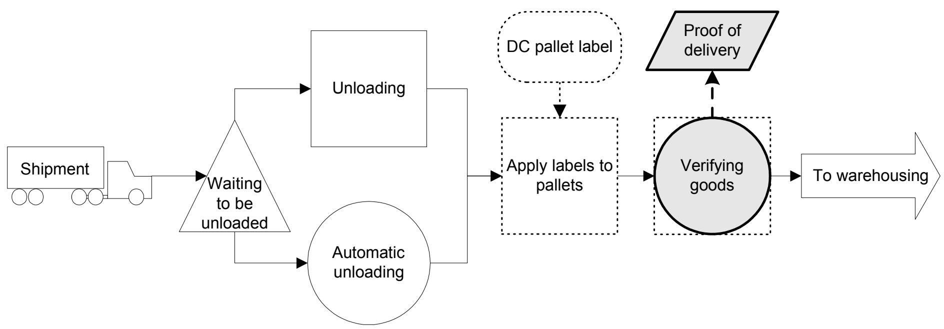

Figure 5.4. The receiving process at distribution centres incorporating RFID technology.

An RFID system would increase the accuracy of former manual activities. Manual verification does not identify all errors, especially in complex deliveries of numerous product types and quantities. Errors could result in a company providing its customer with free products or a company paying for products it did not receive. Manual labelling of pallets is also associated with errors, which reduces inventory accuracy. An RFID system that automatically verifies and eliminates the labelling activity would then increase the inventory accuracy at the distribution centre.

Using RFID tagging on a case level would increase data accuracy since an RFID system would automatically identify individual cases and not the aggregated data representing the contents of the pallets. Allowing individual cases of different product types, quantities and expiry dates to be automatically identified increases the reliability of the received goods. With pallet level tagging, the distribution centre will have to perform random checks or just trust that the information on the pallet tag is correct and corresponds with the contents.

5.3.2 Storing process

In the distribution centres studied, the storing process was performed by reach-truck drivers. The reach-truck drivers have two responsibilities; to allocate storage placements and transport incoming pallets to storage, and to replenish empty pick locations. With an RFID system the accuracy and timing of these activities are increased, as the system would convey accurate and near real-time information on what, how much, and where products are located in the distribution centre. The capability to automatically locate and identify tagged pallets and cases in the distribution centre by using RFID tags also decreases manual effort, and speeds up the storing and picking process.

In the distribution centres studied several methods were used to allocate storage placement, all with the overall aim of placing the pallet received close to the pick location. The manual T method[40] used in the Dutch distribution centre is time-consuming and prone to human errors. An RFID system with tagged pallets would be able to convey where empty pallet locations are located in the storage and direct reach-truck drivers to place the pallets received to suitable empty locations, thereby eliminating manual work and problems associated with incorrect inventory levels, see Figure 5.5.

When replenishing empty pick locations the distribution centres aim to use the first-in first-out rule (FIFO) to avoid products exceeding their expiry dates and rejection of products due to insufficient remaining shelf life. For example, in the Dutch distribution, they try centre try to use the FIFO rule but the reach-truck drivers are unaware of where the oldest products are located. This forces the drivers to replenish pallets they think are the oldest. Furthermore, products received from a manufacturer occasionally have differing expiry dates; this means that the FIFO rule is not an appropriate rule when replenishing pallets.

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[40] see chapter 4.2.2 The Storing Process

Consequently, this means that inventory will be out of date since the oldest products are not always replenished. With RFID tagging on pallets the oldest products can be visible, thereby facilitating replenishment of products depending on remaining shelf life. If the wrong pallets are being replenished or products remaining shelf life is approaching its limit, a system could notify the distribution centre. This would lead to fewer rejections based on insufficient shelf life and increased customer service.

The replenishment of empty pick locations is important to ensure high pick efficiency. When order pickers encounter empty pick locations, the pickers often locate a reach-truck driver and inform him/her what product(s) need to be replenished. Order pickers can also proceed, in the hope of meeting the reach-truck driver further on in the picking process, and then inform him/her of what needs to be replenished. Letting order pickers wait for products to be replenished or letting them proceed and return later is unproductive and duplicative. With tagged cases an RFID system would provide the WMS system with information on what, where and how many cases are at the picking locations. Based on this information reach-truck drivers could receive replenishment orders when products need to be replenished, in turn increasing pick efficiency, see Figure 5.5. This would also eliminate errors associated with replenishing pick locations and makes it easier to ensure that the right types of products are replenished.

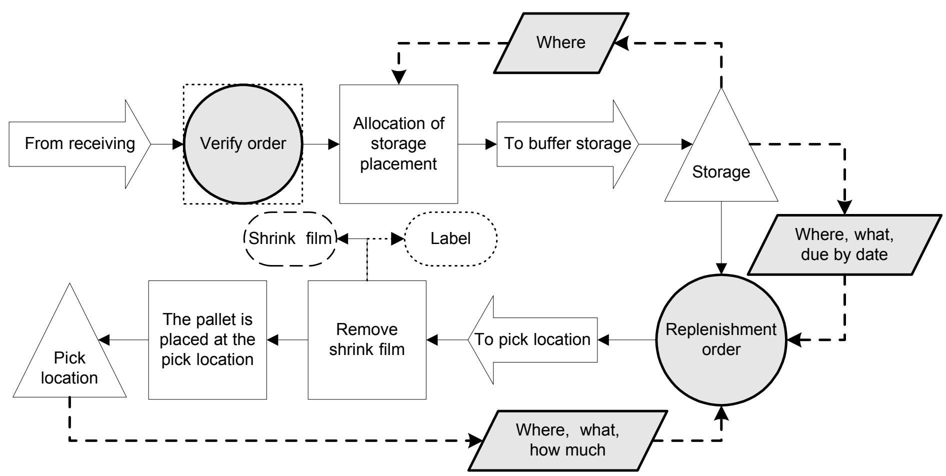

Figure 5.5. The storing process at distribution centres incorporating RFID technology

5.3.3 Picking process

Picking is one of the most important activities in a distribution centre. It is extremely labour-intensive and time-consuming. The main activities in the picking process are picking, labelling and stacking cases into roll containers and/or pallets. When stacking cases, the order picker has to make sure that the products are not damaged and that the picking labels are properly placed on each case, since additional verification activities are sometimes required downstream e.g. in the shipping process. In addition to incorrect labelling and stacking there are several opportunities for errors to occur in the picking process, such as picking the wrong products and quantity of products.

With tagged cases the picking process would become faster and more accurate. The activity of labelling cases would not be needed, making the picking process faster and getting rid of the problem of incorrect labelling. Not having to label cases also makes the stacking activity faster because the picker does not have to make sure that the picking labels need to be properly displayed. Furthermore, as described in the storing process, order pickers would not have to wait for pick locations to be replenished, which also speeds up the picking process. One should bear in mind that the Dutch distribution centre alone processed an average of over 350 000 cases each week. Eliminating any of the manual activities in the picking process would greatly benefit efficiency in the distribution centre.

In Figure 5.6 there are two verification activities. The first verification activity verifies each case when it is picked, whereas the second verification activity verifies a roll container or pallet with picked cases. The first verification activity prevents picking errors just as they occur, while the second alternative requires the picker to bring back products which were picked wrongly and that he/she has to re-pick products that were forgotten. Both of the verification activities are achievable through using RFID tags on cases. Tagging on a case level would then provide an RFID system with the ability to automatically verify cases and quantities that are picked, against what is supposed to be picked. Errors associated with picking would be virtually eliminated and pickers or other employees would not have to spend time and energy on checking what they have or not have picked. In conclusion, tagging on a case level would ensure that the picking is done more efficiently and in accordance with what has been ordered. This increases shipping accuracy and the customer service levels which in turn lead to increased shelf availability in the retail outlets.

When roll containers or pallets are full, they are closed or fixed with shrink film, labelled with the retail outlet number and transported to the front of the destination column. The label is used to organise the shipment in the destination column and is used by the truck driver to identify which roll containers and pallets are intended for every retail outlet. This means that the visibility of the label is important but does not mean that the destination label cannot be replaced by an RFID tag. Once roll containers and pallets are tagged, the truck driver would be able to use a handheld reader to identify which roll containers and pallets are intended for each retail outlet.

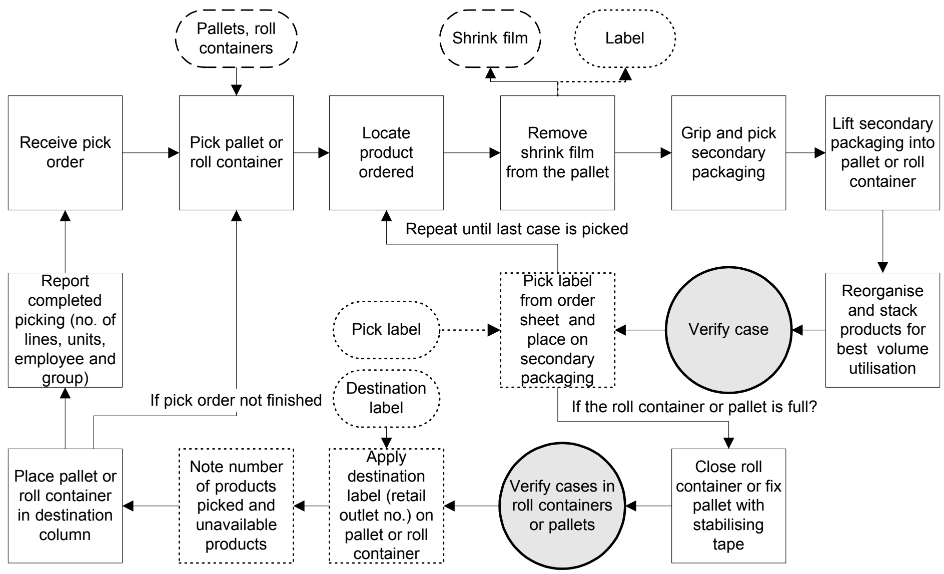

Figure 5.6. The picking process at distribution centres incorporating RFID technology

5.3.4 Shipping process

In the shipping process certain shipments are manually verified on a case level. In the Dutch distribution centre, for example, the shipments to retail outlets with different owners from that of the distribution centre were verified on a case level to reduce returns and claims. The complexity of numerous product types, quantities and deliveries makes it unrealistic to manually check all shipments on a case level. Case-level verifications consume time, space and labour. Furthermore, there is no guarantee that the shipment is correct since the opportunity for errors is always present when shipments are manually verified. As described above, the picking process would be more accurate if RFID tags on a case level were used, ensuring that the right products and quantity are picked according to what retail outlets ordered. This would eliminate the need for manual case-level verification, increase the order accuracy for all retail outlets, and would result in increased customer service, at the same time reducing returns, claims and labour associated with the manual verification activity.

Tagging roll containers and pallets would provide the ability to increase the efficiency of planning the shipping process. In the Dutch distribution centre, for example, an outgoing goods planner decides which destination column orders are to be shipped from. When a shipment is picked the o utgoing goods planner controls the amount of roll containers and pallets each order is composed of. This is done to inform the truck drivers of the exact quantity of roll containers and pallets that is going to be delivered and to verify that there is sufficient truck capacity for the shipment. If roll containers and pallets are tagged with RFID, readers would be able to automatically identify the number of roll containers and pallets located at the destination column, see Figure 5.7. This would enable the distribution centre to identify unoccupied destination columns and automatically verify the amount of roll containers each shipment is composed of. A system could generate an alarm indicating when a shipment is composed of too many roll containers and pallets, or when roll containers and pallets are placed in the wrong scheduled destination column. Tagged roll containers and pallets would also make it possible to automatically track pallets and roll containers among retail outlets, making it possible to find out where roll containers have been damaged or stolen.

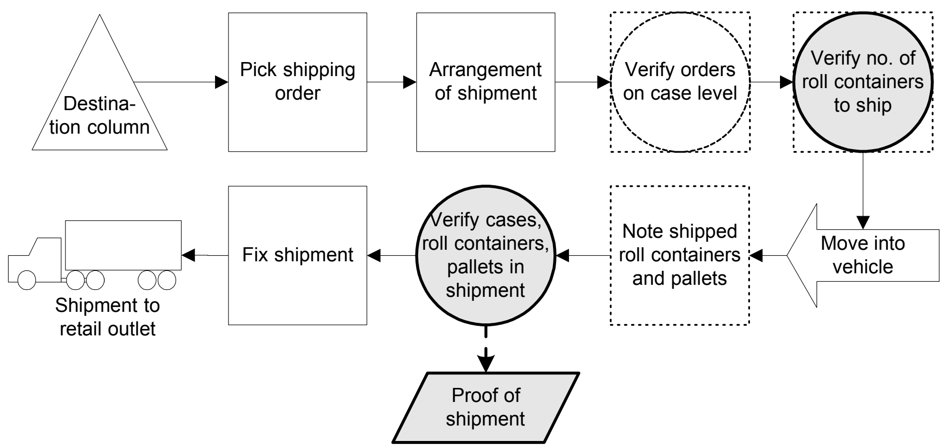

Figure 5.7. The shipping process at distribution centres incorporating RFID technology

With readers by shipping doors, tagged pallets, roll containers and cases would be automatically identified and verified when loaded into the delivery trucks. Based on this information a system could generate an alarm when an incorrect or incomplete shipment is loaded into the delivery truck; this would then increase shipping accuracy. In addition, an ASN could automatically be generated to provide retail outlets, carriers and the distribution centre with detailed information of what quantities and products are being shipped. This would eliminate the need for transport documents to be signed and could be used by the retail outlet to prepare reception and replenishment. In conclusion, an RFID system would increase the accuracy of the shipping process. The process would also use less labour and become faster, which will increase chances of delivering on time and maximise the utilisation of shipping door and shipping space.

The option of automatically identifying tagged pallets and cases can be used for increasing the security and integrity of the distribution centre. With readers by all dock-doors, doorways, windows etc. the distribution centre would be able to automatically detect unauthorised movement of tagged pallets and cases. This would prevent thefts of pallets and cases, which currently means the loss of products which have been stolen, incorrect stock levels and errors in deliveries. The Dutch distribution centre used special procedures and storage areas to reduce the internal theft of "attractive" products e.g. tobacco. With an RFID system the distribution centre could be able to process some these "attractive" products with the same procedures and people as for ordinary products.

In the Dutch distribution centre, incorrect inventory levels were one of the major reasons for out-of-stock problems. Incorrect inventory levels mainly originate from errors in receiving and picking processes, which in turn means that the wrong products or quantities are shipped. These errors corrupt the data in the WMS, which then shows the wrong inventory levels. With incorrect inventory levels the distribution centre could be unaware of current or potential out-of-stock situations and might therefore not place orders in time. The opposite might also be true; the distribution centre staff thought that they did not have the product in stock and place an unnecessary order, resulting in excess inventory. Even if an RFID system is capable of automatically locating and quantifying all cases in storage and in pick locations at the distribution centre, which eliminates the problem of incorrect inventory levels, the sources causing the problem of incorrect inventory levels are eliminated by an RFID system. With an RFID system the accuracy of receiving, storing, picking and shipping is increased and this results in increased accuracy of inventory levels in the distribution centre. Decreasing the number of out-of-stock situation increases product availability in the distribution centre, which in turn increases customer service.

With an RFID system, the distribution centre will have the opportunity to expand its range of customers. In the Dutch case, for example, the retail outlets that did not have the same owner as the distribution centre, often verified its deliveries on a case level, which resulted in returns and claims. This forced the distribution centre to manually verify their shipments on a case level, making such retail outlets less economically viable. With an RFID system, the distribution centre is able to assure customers a high degree of order accuracy, resulting in a situation where the distribution centre would find customers with high demands on accuracy more profitable to serve.

5.4 Retail Outlet

5.4.1 Receiving and shipping processes

The activities in the receiving and shipping processes at retail outlets include all levels of the packaging system. Just as in the receiving and shipping processes at the distribution centre, an RFID system would be able to automatically identify tagged pallets, roll containers and cases when they pass by readers on/by the receiving doors of the retail outlet (Figure 5.8). Currently, retail outlets verify the amount of pallets and roll containers they receive against the number of roll containers shipped from the distribution centre to make sure that no roll containers or pallets are missing. As described in the shipping process at the distribution centre, some retail outlets verify the shipment on a case level to make sure that the shipment corresponds to what was ordered, whereas the other outlets assume all ordered products and quantities have been delivered. If discrepancies such as missing products appear between quantities ordered and quantities received, the truck driver and employees of the retail outlet have to spend time on verifying and making a note of discrepancies in the transport documents. With an RFID system which utilises tagged cases, shipments would automatically be verified to ensure that the shipments correspond to the quantities and products ordered. Manual verification activities would not be needed, reducing the labour and time required for receiving. Furthermore, proof of delivery and invoices would automatically be generated, increasing invoice accuracy and eliminating administration work associated with incorrect invoices.

When a shipment is unloaded at the retail outlet, roll containers, pallets, product returns, reusable, and returnable packaging are loaded on the truck and transported back to the distribution centre. If these were tagged with RFID technology they would automatically be identified when moved through the receiving doors at the retail outlet. This would eliminate the need for the truck driver to verify which, and how many, roll containers, pallets, returns, reusable and returnable packaging are returned from each retail outlet.

An RFID system where every item (product) is tagged would make it feasible to have automated checkout stations. Letting every item in the consumer's shopping basket be identified by readers would make the checkout activity faster, decreasing the time end consumers have to spend at the checkout stations. This would also mean less retail staff would be needed since the checkout personnel would not have to scan and locate bar codes and solve problems such as damaged bar codes etc.

An RFID system where every item is tagged would also reduce the theft of products in retail outlets. With readers at the checkouts stations, dock-doors and in doorways the retail outlet would be able to automatically detect unauthorised movement of tagged items, preventing both shoplifting and employee theft. Currently, retail outlets use EAS[41] systems to reduce shoplifting by attaching EAS labels to products. By using RFID tags, which incorporate the EAS function, the retail outlet would not need to apply EAS labels to products. RFID tags are also able to relate to the specific product, so if products are stolen, the stolen products could be identified through the RFID tag and returned to the correct owner.

In conclusion, an RFID system would facilitate faster and more accurate receiving and shipping processes. When products are being received, the verification activity could be eliminated, resulting in less labour and reduced receiving time. This would increase the utilisation of delivery truck and truck driver, and enable retail outlets to redirect their employees from receiving to more consumer-interactive activities, or reduce cost by having less staff. Furthermore, an RFID system where every item is tagged facilitates automated checkout stations, which reduces labour and increases consumer satisfaction.

[41] Electronic article surveillance, see chapter 3.2.1 The components of RFID systems – Tag programmable options

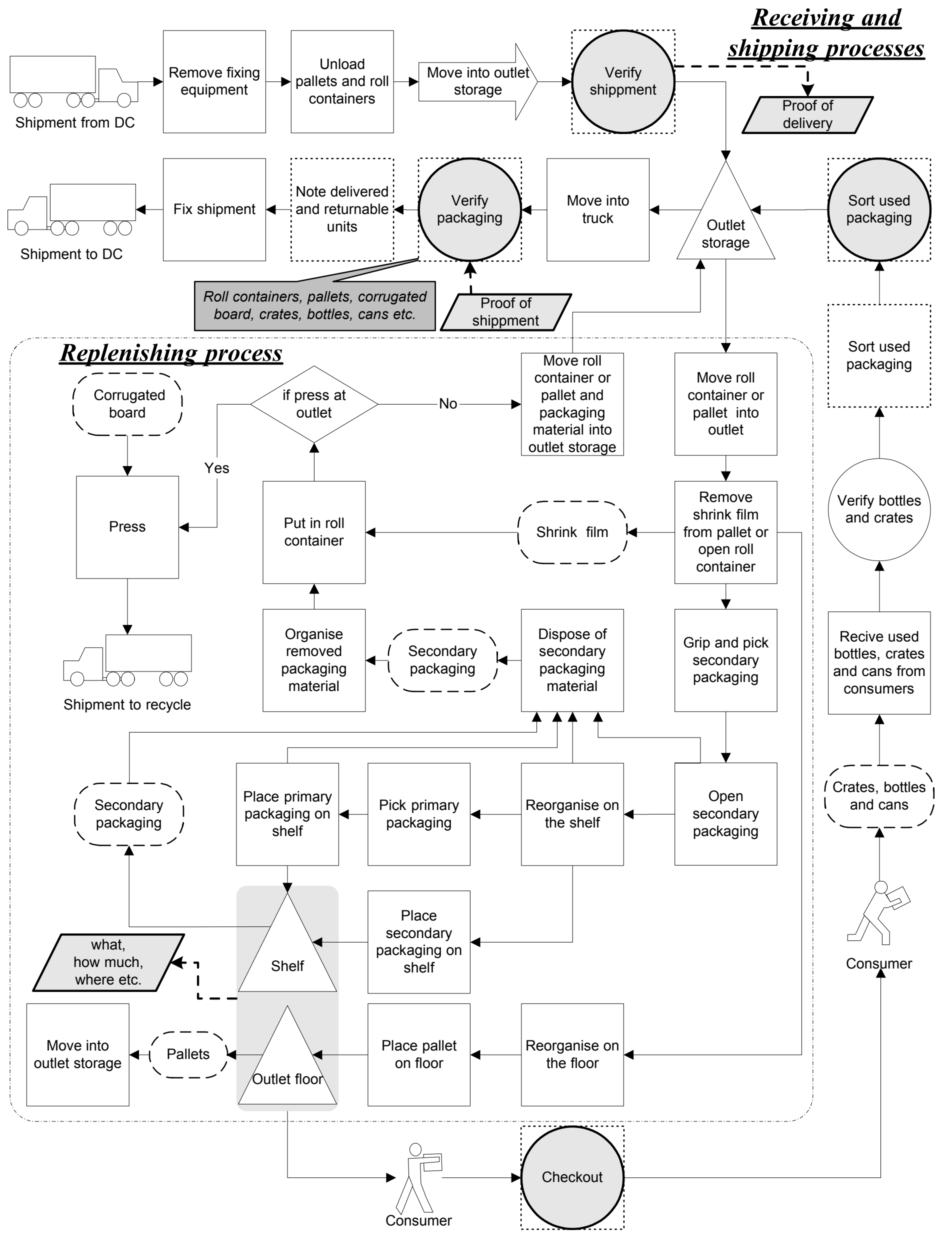

Figure 5.8. The receiving, shipping and replenishing processes at retail outlets incorporating RFID technology.

5.4.2 Replenishing process

The replenishment process at retail outlets depend on the specific product and on the concept of the specific retail outlet. Some outlets prioritise consumer perception of the retail outlet and replenish single products (primary packaging) on the shelf. Others focus on replenishing cases (secondary packaging) on the shelf or whole pallets on the floor. The activities performed in the replenishing process are not affected by RFID technology in packaging, see Figure 5.8. However, RFID technology in packaging facilitates visibility of what products and quantities located on the retail shelves and in the storage, which increases product availability and the efficiency of the replenishment process at retail outlets.

The visibility of what is moving off the retail shelves is a key factor in accomplishing an efficient replenishment process at the retail outlets. Just as in distribution centres, the storage at retail outlets could be equipped with readers to monitor tagged pallets and cases, providing employees with information on what products they have in the back-room inventory and where they are located. Furthermore, retail shelves equipped with readers would also monitor the tagged items and cases, updating the inventory system dynamically. With item-level tagging the inventory system would be continuously updated, providing information on quantities and which products are available on the retail shelves. It would also be possible to update the inventory system by walking with a reader along the shopping aisles to identify which products are on the shelves.

Item-level tagging supports the three ways of replenishing products since every single product picked from the retail shelves would be identified by readers. An RFID system with case-level tagging would provide the inventory system with the location and quantity of cases of each product, located on the retail shelves. This means that when a case is empty, the readers would still identify the case as being on the shelf but the inventory system would not have been updated with the products that had been picked from the shelf. This means that retail outlet employees would have to manually remove secondary packaging material from the retail shelf in order to update the inventory system, which then specifies how many cases there are with products on the retail shelf. Replenishing single products on shelves with case-level tagging would take away the opportunity of establishing the quantity of cases located on the retail shelves. Case-level tagging would not provide the same levels of details and accuracy as item level tagging, but would still be able to provide a limited visibility of what is moving off the shelves at retail outlets.

Currently, retail outlet employees can be unaware of a current or potential out-of-stock situation and are unable to identify an unexpected increase or decrease in demand caused by e.g. weather, promotions and holidays. With readers monitoring tagged items and cases, a system would inform employees when to replenish shelves when the inventory level of a product falls below a predefined level. This would increase product availability, which increases sales and improves consumer service. With the visibility of what is moving off the retail shelf, changes in demand could be identified. By identifying the demand before the retail shelf is empty or when the inventory level is too high, decisions could be made to adapt supply and demand. Monitoring the contents of retail shelves and the back-room inventory would also enable the retail outlets to locate mislaid products, cases and pallets. As described in the next chapter, the visibility facilitated by an RFID system also increases the precision of the ordering process e.g. by taking into account mislaid products.

The visibility of what is moving off the retail shelf also provides the opportunity to reduce inventory levels at retail outlets. Reducing inventory levels at retail outlets leads to decreased inventory investments. It could also lead to other effects depending on the concept of retail outlet e.g. lowering rental costs by making retail outlets smaller, or conversely, increasing the number of product types in the retail outlets.

As described in the shipping process of the distribution centre, retail outlets would be notified of what they are going to receive from the distribution centre. This would increase the visibility of incoming shipments used for preparing, receiving and replenishing activities. Furthermore, consumers would be informed if and when products are going to be delivered to the retail outlet.

With readers monitoring expiry dates, as well as quantity and location of the tagged items and cases, a system would inform the staff when products are approaching their expiry date. This would enable retail outlets to make more informed decisions about how to handle products that are approaching their expiry date: This would then lead to an increase in consumer service and would reduce the cost of holding obsolete products that cannot be sold.

5.5 Order Processes

By incorporating an RFID system the order process at the retail outlets and the distribution centres could be greatly improved. Readers strategically placed throughout the supply chain would enable supply chain actors to automatically monitor what, how much, and where tagged pallets, cases and items are located. Inventory systems would be dynamically and automatically updated providing accurate information on what, how much, and where inventory is located. With this near real-time visibility the current inventory levels would be communicated throughout the supply chain enabling the companies within the supply chain to adjust their plans and respond to actual consumer demand, rather than to forecasts. This would reduce order variance and provide an opportunity to reduce safety stock but at the same time ensure product availability without excessive inventory.

5.5.1 Retail outlet order process

The process of generating orders is performed differently at different retail outlets. Some generate orders using a handheld terminal, while other retail outlets have a point-of-sale (PoS) system. With an RFID system, readers on the shelves and in the back-room storage could monitor each tagged pallet, case and item, continuously providing the inventory system with accurate updates on inventory levels. This means that orders could be automatically generated since the consumption of products is continuously monitored.

An order process that is facilitated by a RFID system would improve the accuracy of orders, resulting in increased product availability and improved inventory management. For example, when orders are generated using a handheld terminal, several mistakes, such as the ordering of wrong quantity and type of products, can occur. With an RFID- system-facilitated order process these mistakes would not occur, which increases the accuracy of orders. Furthermore, no resources for generating orders at the retail outlets would be required thereby resulting in less labour and increased speed when orders are generated.

An RFID-system-facilitated order process cannot be compared to one which generates orders using the information from existing PoS systems. A problem with existing PoS systems is e.g. that the system only registers the products that are sold and does not incorporate products that e.g. have been stolen. This means that existing PoS systems require continuous inventory counts/checks to maintain the accuracy of the system.

An RFID-system-facilitated order process may enable Vendor-Managed Inventory (VMI). With an ordering system that continuously updates information on what quantity and products are available, orders could automatically be generated by the distribution centre when an retail outlet order is about to be picked. This means that retail outlets do not have to rely on personnel to generate orders within specific time periods. The Dutch retail outlets, for example, send orders to the distribution centre according to an order schedule. The order schedule is designed for the distribution centre to plan and execute the picking, shipping and transport activities. The ability to generate orders just as the picking activities are initiated would increase the responsiveness of the distribution centre, since the pick orders generated correspond to actual consumer demand. This would also decrease the lead time between generating an order and the arrival of the delivery at a retail outlet. The lead time is of great importance in ensuring efficient picking in the distribution centre and in meeting the demand from the retail outlet.

Being able to automatically generate orders at the distribution centre would also increase the flexibility of distribution. Instead of processing orders to retail outlets depending on a schedule, orders could be generated, picked and shipped, for example, when a shipment is a full truck load, increasing the utilisation of trucks. Distribution could be adapted and initiated based on the number of potential out-of-stock situations at the retail outlet, where a retail outlet with several potential out-of-stock situations could be prioritised compared to a retail outlet with fewer potential out-of-stock situations.

5.5.2 Distribution centre order process

The orders generated by the Dutch distribution centre and sent to suppliers e.g. manufacturers, are managed by an ordering system. The ordering system automatically generates orders according to an ordering schedule when the inventory levels falls below a predefined point. The problem with this system is incorrect inventory levels (described in the shipping process of the distribution centre). If inventory levels indicate more than the actual quantity of products in the inventory this results in a situation where the distribution centre are sometimes unaware of current or potential out-of-stock situations and therefore do not generate orders in time. If inventory levels indicate less than the actual amount of products in stock, this would mean that an unnecessary order is generated, resulting in excess inventory levels. With an RFID system the problem of incorrect inventory levels is solved since the RFID system provides visibility of current inventory levels at the distribution centre.

Just as a distribution centre could generate orders to retail outlets facilitated by visibility of the inventory levels at the retail outlet, manufacturers could generate orders facilitated by the visibility of the inventory levels at the distribution centre and retail outlets. The visibility of inventory levels would also enable manufacturers to adapt their distribution and production in direct proportion to what is moving off the shelf, rather than by having to use forecasts. Letting manufacturers generate orders and adapt their distribution to distribution centres is a type of VMI collaboration where responsibility and service level are important issues to be determined. Furthermore, the visibility would enable manufacturers to become more responsive to fluctuations in demand, as they could continuously monitor product consumption in certain markets.

By allowing variations in tertiary packaging and order size it is possible for manufacturers to adapt to the demands and conditions of both the distribution centres and the retail outlets. In the Swedish cases, for example, the manufacturers were able to deliver half pallets directly to the retail outlet, reducing handling at both distribution centres and retail outlets. If manufacturers were able to obtain information about retail outlet consumption, they would be able to customise mixed pallets for retail outlets. The value of customised pallets would be the opportunity to cross-dock. Cross-docking at the distribution centre and using an RFID system the contents of mixed pallets are automatically identified and immediately directed towards the destination column instead of going through the storing and picking processes at the distribution centre.

6 CONCLUDING DISCUSSION

As made clear in the introduction of this thesis, this research aims to:

Explore how and why the application of RFID technology to packaging could affect packaging logistics activities in retail supply chains.

From a bottom-up perspective, this chapter first explores how and why RFID technology in packaging could affect packaging logistical activities, then the processes, and finally the whole retail supply chain. The conclusions discussed in this chapter are drawn from the outcome of the analysis of the simulation model[42] and the conceptual model[43] that have been developed and presented in this research.

6.1 The Packaging Logistics Activities

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

Frequent and automated identification of pallets, cases and products enables near real-time visibility, which in turn facilitates the co-ordination of activities within and between processes. Currently, the co-ordination of activities is often performed by human communication and information systems. The ability of the information systems e.g. the WMS, to use the data collected by an RFID system facilitates more accurate co-ordination of activities. An example of a co-ordinated activity enabled by a WMS that uses the data collected by an RFID system, is the replenishment activity of empty pick-locations in distribution centres. With an RFID system continuously monitoring the quantity of cases in the pick location, reach-truck drivers could automatically receive

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[42] see appended paper 2: A Simulation Model of a Retail Distribution Centre with RFID Technology

[43] see chapter 5 Description and Analysis of the Conceptual Model

information on what product needs to be replenished. This co-ordinates the replenishment activity in the distribution centre with the quantity of cases in the pick locations. The co-ordination of activities facilitates better timing of activities, since activities are often dependent on other activities and events in the supply chain.

RFID technology in packaging allows for more frequent and automated verification of pallets, cases and products. The conceptual model indicates that additional verification activities would not be required since the increased accuracy provided by RFID technology, in identification of what is being handled and of what the inventory contains etc. would reduce discrepancies and would therefore not require additional verification activity. The former manual verification activities would be eliminated or replaced by automated verification activates that are enabled by RFID technology, which results in reduced labour and time needed to perform these activities.

6.2 The Processes

In general, 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 6.1 illustrates the possible benefits of RFID technology in packaging that can be observed in the different processes throughout the retail supply chain.

The costs of RFID technology in packaging and potential benefits will vary, depending on the packaging level that is being tagged. Figure 6.1 illustrates the extent and influence that tagging different packaging levels has on the retail supply chain processes. RFID tags on tertiary packaging may be used from the filling process to the storing process. Furthermore, the tags on tertiary packaging may be used from the shipping process of the distribution centre to the receiving and shipping process of the retail outlet. RFID tags on secondary packaging could be used further downstream in the supply chain than 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. We 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, reusing, and post-sales service and support.

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 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 primary 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. 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.

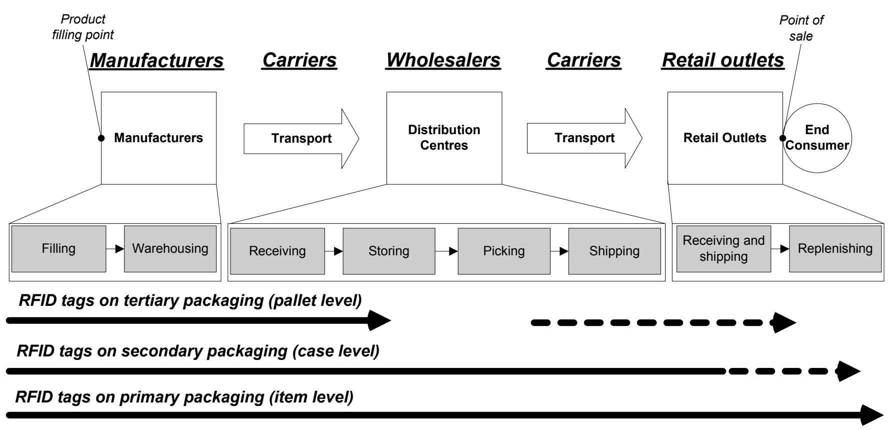

Figure 6.1. The extent and influence that tagging different packaging levels have on the retail supply chain processes.

Table 6.1. 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 ASN, proof of shipment and invoice		**X**				**X**		**X**		
Improvements in responsiveness; by better understanding of demand, trends					**X**		**X**		**X**	**X**
Utilisation improvements; space, docking doors, truck, truck driver etc.		**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**					

6.3 The Retail Supply Chain

6.3.1 Organisation

The success of implementing RFID technology in packaging along the retail supply chain will depend on the ability of manufacturers and retailers to collaborate and agree upon how they can share the costs and benefits of this technology. Figure 6.1 and Table 6.1 indicate that the processes at manufacturers' can ensure several improvements in efficiency from tagging pallets, while processes at retailers' will mainly result in improvements in efficiency from case and item level tagging. To enable manufacturers to obtain benefits from case and item level tagging, such as greater visibility of point of sales, retailers need to share their information. If retailers do not share their information the manufacturers do not benefit from case and item level tagging. Manufacturers will then only see the costs of applying RFID tags to case and item levels in their filling process, unless there are tag cost-sharing arrangements between manufacturers and retailers. However, to obtain all the benefits from RFID technology in packaging, manufacturers and retailers need to agree to share information that they may currently consider confidential.

6.3.2 Physical structure

By letting manufacturers have access to information about retail outlet consumptions, manufacturers would be able to customise mixed pallets for retail outlets. The potential benefit of customised pallets would be the opportunity to use cross docking or merge in transit[44] instead of using the traditional structure of central warehousing and distribution centres carrying inventory. At the distribution centres or merge points the content of mixed pallets are automatically identified and directly directed toward the destination column instead of going through the storing and picking processes at the distribution centre. If the application of RFID technology to packaging is able to eliminate two or three processes in the distribution channel through more cross docking or merge in transit, the benefits would be great enough to justify RFID technology in packaging.

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[44] Merge in Transit is the centralised co-ordination of consumer orders where goods are delivered from several dispatch units consolidated into single consumer deliveries at merge points, free of inventory (Norelius 2002).

6.3.3 Product traceability

The supply chain visibility made possible by RFID tagging, facilitates a more accurate and efficient traceability of products. As described in the conceptual model, RFID technology in packaging facilitates the visibility of products, cases and pallets throughout the retail supply chain. This supply chain visibility, made possible by tagging, facilitates manufacturers' ability to manage the events of product recalls with surgical precision. Product recalls are costly and difficult to execute. Often, the only way to guarantee that all recalled products are removed from retail outlets is to remove every product, even intact products, from the retail shelves. This results not only in additional labour costs incurred when products are removed from the retail shelves, but also in a reduction of potential sales. In the Dutch and Swedish cases the product traceability is lost in the picking process when pallets are split into cases. With case or item level tagging the former difficult task of tracking individual products to specific retail outlets is made more accurate and efficient, using fewer man hours and means only withdrawing the defective products. Furthermore, item level tagging would also facilitate tracking of products sold all the way to end consumers, but this is a question of consumer integrity and privacy.

6.3.4 An additional step in visibility

The supply chain visibility made possible by RFID tags in packaging would not only provide the opportunity to monitor quantities, locations where pallets, cases or products are. RFID tags with integrated sensor can be used to monitor the environments they are being put through, for example, the temperatures and time at which a product is handled at throughout the supply chain can be logged in the RFID tag. These additional options have not been discussed in the conceptual model or in the simulation model since these focus on ambient FMCG which generally do not have any specific environmental constraints.

6.4 What decides the level of tagging?

There are different benefits and cost of RFID technology in packaging depending on what packaging level is being tagged. The conceptual model and the simulation model have increased the understanding of how and why the application of RFID technology to packaging could affect packaging logistics activities, the processes, and the whole retail supply chain. As a result, it is now possible to identify and discuss key aspects that influence tagging of different packaging levels. The level of RFID tagging in packaging depends on product characteristics, supply chain processes, the packaging system, end consumers, and of course the technology itself.

6.4.1 The product characteristics

Product characteristics such as, value, volume, life cycle, brand name and safety issues influence the level of tagging. FMCG, which this research focuses on, can simply be characterised as a high volume of inexpensive goods with long life cycles. This indicates that the benefits of applying RFID tags to FMCG on an item level would be limited compared to a low volume of expensive goods with short life cycles, which more often experience e.g. shrinkage, out-of-stock or excess inventory. An application of RFID tags to FMCG on a higher packaging level would be easier to motivate since it involves considerably fewer tags. In a retail supply chain that handles a variety of products, there will probably be a mix of tagging levels; this will depend to a certain extent on the product characteristic.

6.4.2 The supply chain processes

The supply chain processes influence the level of tagging, since it is here that the value is created when RFID technology is used in packaging. An important aspect is to have a total view of the benefits and not only considering one or two processes; all processes needs to be considered. Another important aspect is to consider the process uniqueness in each supply chain. For example, when the shipping processes in the different cases are compared there are different values of RFID technology in packaging: The Dutch distribution centre used lots of manual resources in verifying specific shipments on a case level to reduce returns and claims. This indicates that the benefits of applying RFID tags to a case level would be more justifiable for the shipping process in the Dutch distribution centre, than for the shipping process in the Swedish distribution centres.

The conceptual model indicate the dual relationship between the level of tagging and supply chain processes, since the level of tagging also influences the supply chain processes. For example, in the replenishing process at retail outlets, the replenishment procedure could be adapted depending on the level of tagging. With case-level tagging the replenishment could be performed by replenishing cases on shelves instead of replenishing single products on shelves, because of the opportunity to automatically identify the quantity of cases located on the retail shelves.

6.4.3 The packaging system

The function and components of the packaging system influence the level of tagging. Aspects like packaging units handled, reuse and recycling are important aspects that influence the level of tagging.

6.4.4 The end consumers

End consumers also represent an important aspect that influences the level of tagging, especially for item-level tagging. If tags are to be applied on an item level, end consumers must have confidence in the technology used so that it does not interfere with consumer integrity and privacy.

6.4.5 RFID technology

The cost of RFID technology and the potential it represents are, of course, important aspects that also influence the level of tagging. One of the most important aspects that influence the level of tagging is the cost of tags. The cost of tagging the different packaging levels varies greatly since the different packaging levels involve different quantities of tags. Another aspect that influences the level of tagging would be the functional capabilities of the technology. The different levels of tagging have different functional needs. For example, a high reading rate is more advantageous on item-level tagging compared to pallet-level tagging, because an item level often involves a higher quantity of tags to be identified during a very short time.

6.5 Generality of the Research

This research addresses packaging logistics activities related to ambient FMCG in retail supply chains. The findings of this research are therefore directed at retailing companies within the ambient FMCG sector, but the findings must not be delimitated to this retail sector or industry. I hope and believe that supply chains in other retail sectors and industries will also be able to make use of the research findings and gain an understanding of how and why RFID technology to packaging could affect their activities and processes.

6.6 Contributions

The contributions of this research have been separated into practical, theoretical and methodological contributions.

6.6.1 Practical contributions

This research presents a conceptual model and a simulation model that describes what, how and why packaging logistics activities are affected when RFID technology is applied to packaging. As described in the introduction of this thesis, the use of RFID technology in packaging is gaining acceptance throughout the retail industry. To be able to implement RFID technology to packaging throughout retail supply chains, we need to develop an understanding of how and why the technology affects activities and processes within retail supply chains. The conceptual model and the simulation model increase this understanding and illustrate the opportunities presented by using RFID technology in packaging.

RFID technology in packaging is a new phenomenon and companies, not only those in retail supply chains, might not fully realise the potential of the technology. This research increases the understanding of RFID technology in packaging, which can help companies to improve their activities and processes.

6.6.2 Theoretical contribution

The theoretical contribution to the field of packaging logistics is the framework presented in the appended paper number one. The framework provides an overall description of the packaging logistics activities in the retail supply chain. The framework demonstrates in detail the interactions and interfaces between the packaging system and the logistical system, 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 to communicate and discuss packaging logistics issues in retail supply chains.

6.6.3 Methodological contribution

The methodological contribution in this thesis is the combined use of case study and modelling and simulation study in logistic research. By combining case study and modelling and simulation study there are several synergies that are of intrinsic value to the research in this area. The main advantages of combining these two different research strategies are that of taking advantage of the ideographic aspects of case study strategy, together with the ability to explore different scenarios by using modelling and simulation strategy.

6.7 Further Research

This research has focused on ambient FMCG in retail supply chains from the filling point at the manufacturer's to the point of sale at retail outlets. The other parts of the supply chain such as the end consumers, the reusing and recycling processes, and the production planning are also of interest and are areas for further research. Another area for further research is to investigate products other than ambient FMCG in the retail supply chain. Furthermore, there is a need to investigate and explore the application of RFID technology to packaging in other industries and distribution channels rather than simply to retail supply chains.

To be able to apply RFID technology in packaging throughout retail supply chains, we need to develop an understanding of how and why the technology affects activities and processes within retail supply chains. This research has been focusing on these issues by exploring and describing how the application of RFID technology to packaging could affect packaging logistics activities in retail supply chains. The next step would be to develop a cost/benefit model where the increased performance of the supply chain and total cost of application to, and utilisation of, RFID technology in packaging throughout the retail supply chain are evaluated. The conceptual model and the simulation model developed in this research could be used for guidance in this additional research with the purpose of developing a cost/benefit model.

The validity of the simulation model developed in this research needs to be strengthened. The Dutch retail chain, which the simulation model represents, have expressed their further interest in RFID technology in packaging. Consequently, there may be an opportunity in the future to validate the simulation model, if they are going to test the use of RFID technology in packaging throughout their retail supply chain. Furthermore, the performance measures in the simulation model could be modified to better reflect ordinary performance measures used in evaluating distribution centres.

Finally, organisational aspects are also an area for further research. Aspects such as sharing of costs and data ownership will have an impact on the application of RFID technology in packaging. There is therefore a need to investigate and explore the organisational conditions in today's retail supply chain.

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Appended Papers

Paper 1

Framework of Packaging Logistics Activities in Retail Supply Chains

Presented at the 12th Annual IPSERA conference, Budapest, Hungary, 14-16 April 2003. Published in conference proceedings as a competitive paper.

Paper 2

A Simulation Model of a Retail Distribution Centre with RFID Technology

Presented at the 8th International Symposium on Logistics (ISL), Seville, Spain, 6-8 July 2003. Published in conference proceedings.

Paper 3

Using Discrete-Event Simulation in Supply Chain Planning

Presented at the 14th Annual conference for Nordic Researchers in Logistics, NOFOMA , Trondheim, Norway, 13-14 June 2002.

Paper 1

Paper 2

Paper 3

Appendix

Appendix A – List of databases, keywords and journals

Databases

ABI/Inform
Cambridge Scientific Abstracts (CSA) - Paperbase/PIRA Collection
Emerald
Elin@Lund
Ingenta Select
Sciencedirect

Keywords

Packaging, Logistics, Retail, Supply Chain, Connectivity, Information, Technology, Auto-ID, Identification, RFID, Simulation, Discrete-event Simulation, Discrete Event Simulation

Journals

European Journal of Purchasing and Supply Management
International Journal of Marketing and Logistics
International Journal of Operations and Production Management
International Journal of Physical Distribution and Logistics Management
International Journal of Retail and Distribution Management
International Journal of Supply Chain Management
Journal of Business Logistics
Journal of Intelligent Packaging
Logistics Information Management
Management science
Packaging Technology and Science
RFID Journal
Smart Label Analyst