Traceability Research at Packaging Logistics

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Magnus Fagerlund, Lund

September 2009

Abstract

"There is relevance in traceability! For example, people even die because they eat bad food." – Daniel Hellström, Assistant professor

Research at the division of Packaging Logistics, Lund University, has been performed in numerous areas, ranging from organisational learning and sustainability to process integration and service development. One of these is the new and complex research area of traceability.

When it comes to food scandals, from the mad cow disease at the end of the 90s to the more recent incident where glass has been found in chicken, this has increased focus on traceability research in food supply chains. A regulation within the European Union which came into force in February 2002 about procedures on food safety has articles (14-20) that treats traceability. The articles regarding traceability came into force January 2005 (EC regulation 178/2002). Article 3 defines traceability as "the ability to trace and follow a food, feed, food producing animal or substance intended to be or expected to incorporate through all stages of production, processing and distribution". The sense of the regulation is that every actor in the food supply chain has to know from whom a product, ingredient etc. comes from, when it was delivered, what was delivered, what has been sold, when it was sold and to whom it was sold. However, even though much research has focused on traceability within food supply chains, it is not restricted just to this industry or issues regarding food quality and safety.

This report presents research connected to the area of traceability which has been performed, as well as research currently being carried out at the division of Packaging Logistics in regard to research results, finished and ongoing projects as well as partner companies involved in research. Furthermore, this report will, based on problems with traceability pointed out in research and

discussions with researchers at Packaging Logistics, present recommendations on where to continue or start focusing future traceability-connected research at the division.

Research concerning traceability at Packaging Logistics has been versatile, allowing a comprehensive framework to be created. This framework includes *components* (necessary in order to achieve traceability), *research/industry perspectives*, *tools* and *added values* (showing the benefits achievable with traceability).

In addition, traceability research at the Packaging Logistics has, to a great extent, focused on the food branch or food supply chain and external and not internal traceability. External traceability means the ability to trace a product/batch and its history back through the whole supply chain in contrast to internal traceability which is the ability to trace how ingredients and raw material within a certain actor in the supply chain is mixed, split and transported between different steps in the manufacturing process. Furthermore, this research has focused on finding and evaluating methods in order to ensure food safety and quality. This research has also pointed out the importance of collaboration between the actors in the supply chain and critical contexts, which is informational, relational and physical factors which together form contexts that are the weak points in the supply chain. These critical contexts should be in focus since it is these contexts where traceability is most likely to be lost. In other industries than food, focus has been of a more technical nature, mainly the implementation and evaluation of Auto-ID technology, thereby enhancing the possibilities of tracing goods.

Suggestions for future traceability research studies include a larger project in, for example the pharmaceutical industry where traceability could be used to prevent counterfeit. The pharmaceutical industry is similar to the food industry in many ways as products need to be extremely safe since they greatly affect consumer health. Many of the tools developed in food industry-

related research could be evaluated in such a project, making it possible to generalise results as well as transfer knowledge from one industry to another. Within the frame of a larger research project like the one proposed, it would be possible to collaborate between ongoing project borders, allowing different areas of traceability to be further examined as well as knowledge to be shared between research projects. Furthermore, traceability research at Packaging Logistics should continue to focus on external traceability and the critical contexts as well as information sharing, both from a "soft" perspective and a technical one, These issues are highlighted as obstacles to achieving the benefits of external traceability.

Table of contents

1. Introduction

In this chapter, the background and purpose of this traceability project carried out on the division of Packaging Logistic at LTH, Lund University, are presented. Furthermore, the purpose, focus and target group are presented in order to guide the reader towards fully understanding the report.

1.1 Background

Started up in 1999, the division of Packaging Logistics at Lund University, Faculty of Engineering is the only academic research division at a national level fully focusing on the scientific area of packaging logistics. Both research and educational courses offered seek to integrate several theoretical fields of knowledge. They also seek to extend definitions to include both soft and hard dimensions of technical, behavioural and economic aspects within business and organisations. The vision of packaging logistics "*aims to contribute to a sustainable society as it integrates product/packaging development, innovation and supply chain management in economic, technical and environmental life cycle perspectives.*"
(http://www.plog.lth.se/about/vision)

The research at the division is symbolised by the tree in Figure 1 below. Traceability is one of the crowns, sprung from the research area (the branch) of "information and technology interactions". On the same branch, the areas of Auto-ID, connectivity and visibility are located.

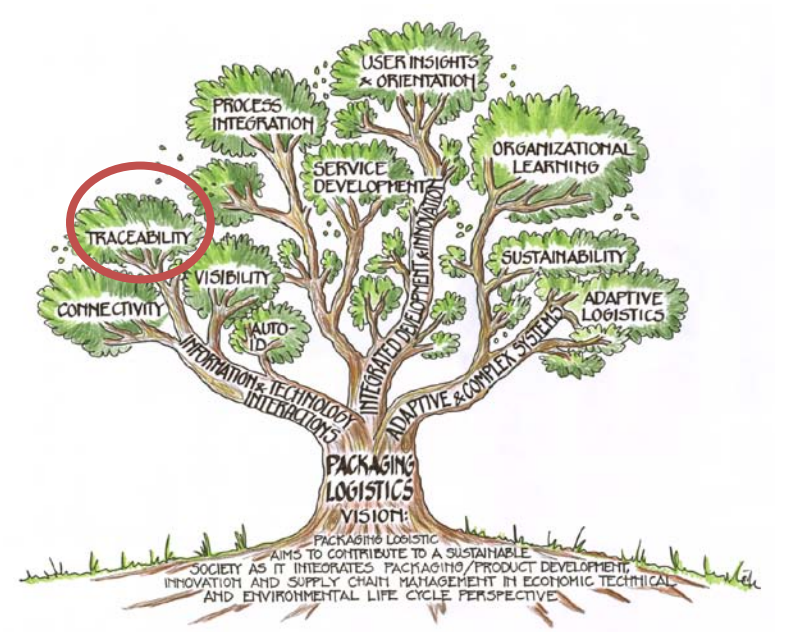

Figure 1. The different research areas at the division of Packaging Logistics (http://www.plog.lth.se/research).

Traceability is a complex and new research area, involving many different components. In literature and research there are different definitions and the researchers at the division of Packaging Logistics have been involved in numerous projects resulting in a large portfolio of articles published in the area of traceability. A number of master's-, licentiate- and doctoral theses have also been done on the subject or on subjects closely linked to traceability. As shown in Figure 2, different researchers at the division of Packaging Logistics are involved in different projects in association with different companies and with different areas of focus regarding traceability. These projects result in different publications, where the findings from the projects are presented.

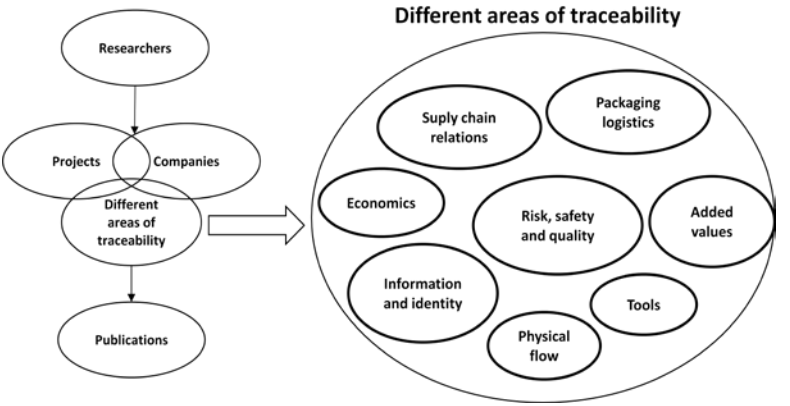

Figure 2. The research construct regarding traceability.

However, the different publications, projects and presentations in the area are diverse and it is difficult to obtain a holistic picture of what the research associated with the area of traceability has resulted in. This project, "Traceability Research at Packaging Logistics", was initiated on the behalf of the staff at Packaging Logistics in order to provide a structured framework of the research performed. Furthermore, there have been different companies, financiers and stakeholders involved in the research, so that the project aims not only to give a good overview of the different projects and their outcome, but also to connect the projects and their outcome to companies and stakeholders.

1.2 Purpose

The purpose of this project is to collect and structure the knowledge in the area of traceability in general at the division of Packaging Logistics. A structured report will give the staff a good view of the subject of interest in order to take decisions regarding future research. This report could thereby work as a basis of discussion for the staff at Packaging Logistics when deciding future research and more easily see what research has been performed.

1.3 Focus and limitations

The research area of traceability is new, containing many sub-areas. Focus will be on the areas which have been explored at the division of Packaging Logistics, both in the food industry as well as other industries, giving ideas on where to continue or where to start focusing research in the future. The project has been carried out during a period of 10 weeks and publications by others not connected to Packaging Logistics have not been taken into account.

1.4 Methodology

A comprehensive review of the publications regarding traceability at Packaging Logistics has been carried out. These publications consisted of articles (journal and conference), master's-, licentiate- and doctoral theses as well as reports and presentations and were chosen according to their relevance. In addition, interviews were held with each person working at the division and connected to the area of traceability in order to get that person's view of the subject and to make sure that no information regarding the research has been left out. The staff who have been interviewed and contributed with ideas and thoughts in this report are presented in Appendix A.

1.5 Target group

The target group is mainly the staff at the division of Packaging Logistics and partner companies interested in traceability. Fellow students interested in the subject are also welcome to read this report in order to quickly understand the issue and the problems connected to it.

1.6 List of definitions

Traceability includes a host of different components where definitions have to be made in order to fully understand the connection to the overall subject. The definition of traceability will be presented in chapter 2. Definitions used in this report are taken

from the CSMP[1] glossary (Supply Chain Management, Glossary and Terms).

Transparency: The ability to gain access to information without regard to the systems landscape or architecture. An example would be where an online customer could access a vendor's web site to place an order and receive availability information supplied by a third-party outsourced manufacturer or shipment information from a third-party logistics provider.

Visibility: The ability to access or view pertinent data or information as it relates to logistics and the supply chain, regardless of the point in the chain where the data exists.

Supply chain: 1) starting with unprocessed raw materials and ending with the final customer using the finished goods, the supply chain links many companies together. 2) The material and informational interchanges in the logistical process stretching from acquisition of raw materials to delivery of finished products to the end user. All vendors, service providers and customers are links in the supply chain.

Value chain: A series of activities, which combined, define a business process; the series of activities from manufacturers to the retail stores that define the industry supply chain.

Supply chain management: Supply Chain Management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes co-ordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies. Supply chain management is an integrating function with primary responsibility

[1] Council of Supply Chain Management Professionals

for linking major business functions and business processes within and across companies into a cohesive and high-performing business model. It includes all of the logistics management activities noted above, as well as manufacturing operations, and it drives coordination of processes and activities with and across marketing, sales, product design, finances and information technology.

Besides the definitions above, the term of *researcher* that is frequently being used in this report is defined as a person that has been involved in research at the division of Packaging Logistics. This includes PhD students, assistant professors, professors as well as master thesis writing students and project workers.

1.7 Report structure

This report will be divided into three main parts: *Research according to the construct* (where the construct refers to the authors personal view of traceability as research area at Packaging Logistics), *Research projects connected to traceability* and *Partner companies involved so far*. These different parts show research performed at the division regarding the construct (see chapter three), finished and ongoing projects (see chapter four) and company involvement (see chapter five). The overall structure is presented below.

Chapter one - Introduction
Introduces and defines the purpose of the project to the reader in order for them to understand the rest of the report.

Chapter two – What is traceability?
This chapter introduces the reader to the concept of traceability with the EU regulation as starting point and the concept is defined according to research performed at the division, both with regard to research performed in the food- as well as non-food industry.

Chapter three – The construct of traceability
In this chapter, research is roughly classified and components and perspectives associated with the traceability construct are presented.

Chapter four – Research according to the construct
This chapter presents the findings from the research according to the construct presented in the previous chapter.

Chapter five – Research projects connected to traceability
This chapter takes its starting point from the different projects which have been carried out, as well as from ongoing projects associated with traceability at the division of Packaging Logistics.

Chapter six – Partner companies involved so far
In the last of the three stand-alone parts, the companies which have been involved are briefly presented and the results regarding the companies are described.

Chapter seven – Discussion and suggestions for future research
Based on the findings in the previous chapters as well as input from interviewees, a brief discussion regarding the research until now is presented followed by suggestions for future studies.

2. What is traceability?

In this chapter, the reader is introduced to the EU regulation and to the impact the regulation has had on research in the area of traceability in the food industry. The definition of traceability with regards to food- and non-food industries is also presented in order for the subject to be fully understood.

2.1 EU regulation

The EU regulation concerning traceability in food supply chains have highly influenced research in the area. The number of BSE-(mad-cow disease) infected animals peaked the year of 1992 and four years later it was proved that people could be contaminated (Örjas & Severius, 2002). This and some other incidents led to a new regulation concerning food safety within the European Union, Regulation (EC) No 178/2002 of the European Parliament and of the council of 28 January 2002. In a number of articles the new food safety regulations are set out where article 14-20 are the ones directly describing the regulation of traceability within food supply chains. In January 2005, articles 14-20 came into effect and these can be summarised as follows:

- All involved actors within the food industry have to have a system for traceability and control one step forwards and one step backwards, to the next coming as well as the previous actor in the production chain. This means that every actor in the food supply chain has to know from whom a product, ingredient etc. comes from, when it was delivered, what was delivered, what has been sold, when it was sold and to whom it was sold. For example, this means that retailers must be able to trace goods back to their suppliers as well as forward to their customers.

- All actors are also responsible for the products they deliver to market and the products have to be labelled in a satisfactory manner (EC Regulation No 178/2002, Article 18).

- Furthermore, the regulation states that a producer is responsible for withdrawal all the products which are claimed to be unsafe for customers (Clemedtson, 2008; EC Regulation No 178/2002, Article 20).

Even though EU regulation 178/2002 is detailed, it does not say anything about how the information regarding the products should be saved or how it should be transferred to the next actor in the food chain. This responsibility is at every individual actor in the chain or is an agreement made in between all the actors in the chain (Örjas & Severius, 2002).

2.2 Definition of traceability

The definition of traceability differs in literature and depends to a high degree on individual opinion (Morén & Samuelsson, 2002). Research at the division of Packaging Logistics can be divided into two categories; one focusing on research made in food supply chains and the other focusing on non-food supply chains, and therefore two different definitions have to be provided.

The definition of traceability within food supply chains is directly taken from the EU regulation 178/2002 which states:

Traceability means the ability to trace and follow a food, feed, food-producing animal or substance intended to be, or expected to be incorporated into a food or feed, through all stages of production, processing and distribution. (EC Regulation No 178/2002, Chapter 1, Article 3, p. 8)

This definition is confirmed by publications related to traceability within food supply chains and also by information from interviews with researchers focusing on these supply chains.

Another definition of traceability related to the food industry has been stated in a network project initiated by ABB (Asea Brown Boveri Ltd) and SIK (Swedish Institute for Food and Biotechnology). In 2002, the project resulted in a comprehensive report where participants defined traceability as the following: *"Through identity, traceability is being able to track raw materials and*

products backwards and forwards in the production chain, as well as be able to retrieve information linked to that identity irrespective of the time and place in the production chain." (Stadig, Wiik., Johnsson, Berg, Bergström, Jansson & Karlsson, 2002, p. 6)

Since the EU regulation 178/2002 definition is aimed only at traceability in food supply chains, and due to the fact that there have been made research with focus on traceability in other industries than primarily food has been done, another definition has to be made. Research associated to traceability in other industries than food has not started from a clear definition as research in the food industry. However, in the master thesis "The use of track and trace system in the IKEA supply chain" (Morén & Samuelsson, 2002), traceability is defined in line with van Dorp (2001) as: *"traceability provides companies with continuous visibility of where and how activities are being performed. Because of the historical data that is registered over the products lifecycle, the product can be traced backwards in the flow, which can be done directly or afterwards."* (Morén & Samuelsson, 2002, p. 41)

2.3 Traceability vs. track and trace

Even though traceability as term has been defined and stated, the terms of track and trace should be noted since it is used by some of the researchers focusing on non-food supply chains at the division. The difference between the term of traceability and track and trace is that the latter also includes a tracking component, which is the ability to point out where something is, ideally in real time. That is, for example the ability to follow a shipment of books from Amazon on its web site. There is a time aspect linking the terms of tracking and tracing, where tracing is the ability to say where something *has* been, and tracking is to say where something is right now.

3. The construct of traceability

In this part the construct of the research area of traceability at the division of Packaging Logistics according to the author is presented. The concluding constructs are described and the findings related to these constructs are presented.

A number of areas connected to the overall issue of traceability have been identified through the author carefully reading through the published material connected to traceability and through semi-structured/open interviews with researchers working at the division. It becomes obvious that research can be divided into two distinct categories – internal/external traceability and the industries of food/non-food. Some of the research is generally about traceability, while other research deals primarily with a sub-area within a specific component. This construct represents the author's personal view of what components are included in the traceability concept (with regard to research performed at the division of Packaging Logistics), different perspectives on traceability and what added values that can be achieved by traceability.

3.1 External and internal traceability

Two kinds of traceability can be distinguished: internal and external.

External traceability (or chain traceability) refers to the possibility of tracing a product/batch and its history back through the entire supply chain, excluding the consumer, and it is more complex than internal (local) traceability. It could also include product/batch traceability between different countries (Olsson & Skjöldebrand, 2008; Lindh, Skjöldebrand & Olsson, 2008b). External traceability also refers to information which is transferred between different companies (Alklint & Göransson, 2004). Most of the research at the division of Packaging Logistics has focused on external traceability and particularly on food supply chains (see Figure 4).

Internal traceability (or local traceability) refers to the possibility of following how ingredients and raw material within a certain actor are mixed, split and transported between different steps in the manufacturing process. The system for internal traceability documents the production process at a certain step in the manufacturing chain. As with external traceability, the subject of internal traceability has focused particularly on the food industry and on how different ingredients should be monitored in order to ensure food safety. Internal traceability is not managed by the EU regulation.

The manufacturing process of foodstuff is associated with complexity from a traceability perspective. In the manufacturing process, raw material is being converted to products or services. It is very hard to know when new raw material enters the process and if it is mixed with other material when producing. Besides, a mix of different raw materials and ingredients starts a chemical process in the production of foodstuff which makes traceability even more complex. In these cases, advanced systems are required in order to control different manufacturing processes and flows (Örjas & Severius, 2002). Internal traceability is maintained through internal revisions where food safety risks within a company itself are considered. Furthermore, actors need tools which facilitate the acquisition of a commonly shared holistic approach among the actors. This value-adding approach should encompass the entire supply chain in order to gain and maintain supply chain traceability beyond basic regulatory demands (Lindh, Skjöldebrand & Olsson, 2008a).

3.2 Food supply chains

A food supply chain is defined as a framework of the actors in the steps where products are taken from raw material to consumed products (Olsson & Skjöldebrand, 2008). Food supply chains have become more and more complex during the last few decades. Previously, food was produced, transported and sold locally

through a few subsidiaries, while increasing globalisation has led to a radical change in the way food is distributed and sold around the world. This change has led to great availability, but more and more complex supply chains. A general food supply chain is illustrated in Figure 3 below. It includes different actors, from farmers to consumers (Olsson & Skjöldebrand, 2008).

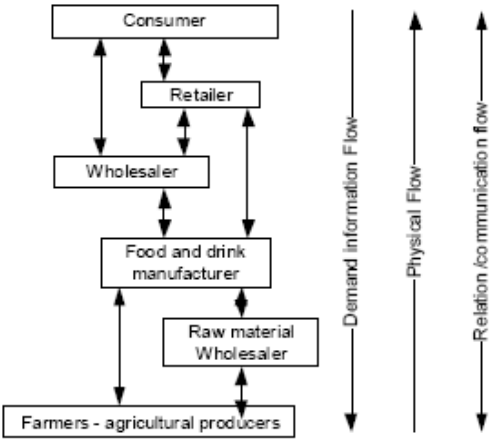

Figure 3. A common food supply chain (Olsson & Skjöldebrand, 2008, p. 51).

3.3 Classification of the published material

A large amount of research performed at Packaging Logistics related to traceability issues has been done with a focus on the food supply chain in general and within the supply chain for chilled food in Sweden. The supply chain for chilled food has been selected since this chain is more sensitive and exposed to risks than, for example the supply chain for frozen food. Chilled food requires faster and more controlled transports because of its shorter shelf-life and temperature requirements. If the temperature varies too much, shelf-life is affected leading to an uncertainty regarding quality and food safety (Olsson & Skjöldebrand, 2008). Even though research has focused on traceability within food supply chains, a number of projects have been performed in other

industries such as the automotive, paper and information technology industries.

Figure 4 below shows which areas research has been carried out in. Some of the research has not fully focused on one of the areas and is therefore placed on the dotted line. This illustrates where the research focus has been at the division of Packaging Logistics.

The numbering in Figure 4 illustrates different publications originating in the division of Packaging Logistics which have been identified as connected to the area of traceability as described in *Methodology*. These publications are shown in Table 1, 2 and 3.

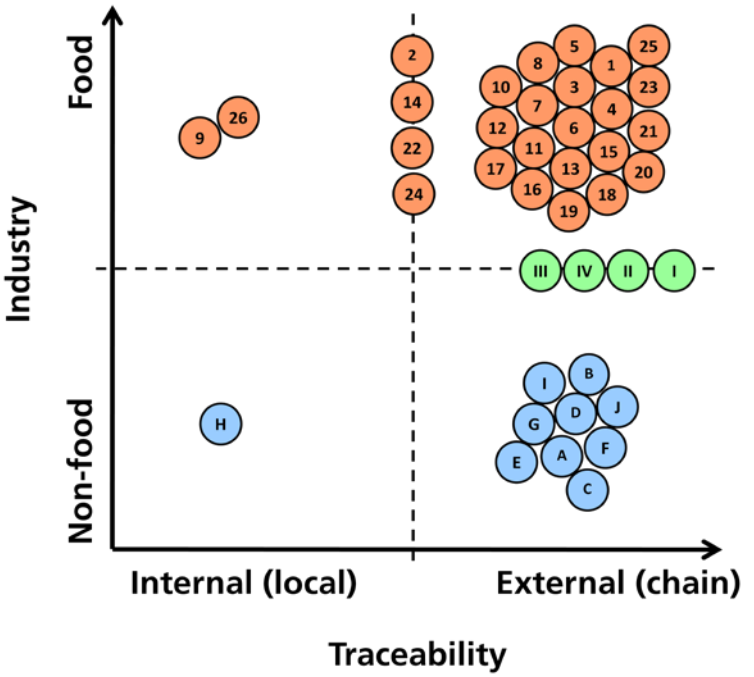

Figure 4. The research focus in the area of traceability at the division of Packaging Logistics where the numbering illustrates different publications connected to traceability.

Table 1. Publications connected to traceability associated with the division of Packaging Logistics with focus on the food industry.

Nr.	Title
1	*Risk Management and Quality Assurance through the Food Supply Chain – Case Studies in the Swedish Food Industry (2008)*
2	*Brownboard - A tool to facilitate improved supply chain traceability (2008)*
3	*Traceability in food supply chains: Towards the synchronized supply chain (2008)*
4	*Tyrannical Consumers - Initiate Value Creation in the Food Value Chain (2007)*
5	*Addera värden genom riskhantering och spårbarhet (2007)*
6	*Livsmedelssäkerhet ur ett försörjningskedjeperspektiv (2006)*
7	*Implications of interorganisational RFID implementation - A case study (2006)*
8	*Retailing Logistics and Fresh Food Packaging - Managing Change in the Supply Chain (2006)*
9	*DOSS - värderingsmodell för riskerna vid tillverkning av flytande livsmedel (2005)*
10	*Driving forces for food packaging development in Sweden- a historical perspective (2005)*
11	*Spårbarhet en väg mot transparens - Fallstudier i livsmedelskedjan (2004)*
12	*Exploring the potential of using radio frequency identification technology in retail supply chains - A Packaging Logistics perspective (2004)*
13	*Temperature controlled supply chains call for improved knowledge and shared responsibility (2004)*
14	*Intelligent packaging from a distribution perspective (2003)*
15	*Spårbarhet av dagligvaror genom den svenska livsmedelskedjan (2003)*
16	*Mobila pipelines: Slutrapport (2008)*
17	*Simulering som verktyg för mervärdesskapande av spårbarhet – exempel från livsmedelskedja (2008)*
18	*Kylkedjan för livsmedel - en kartläggning av den svenska distributionen med fokus på temperaturbrister (2001)*
19	*Distribution av temperaturkänsliga livsmedel (2002)*
20	*Säkerställande av en obruten kylkedja - vision eller verklighet (2003)*
21	*Findus Sverige AB:s distribution av frysta ärtor via cross-docking: Kartläggning och utvärdering av säsong 2008 (2009)*
22	*Food monitoring based on diode laser gas spectroscopy (2008)*

23	*Spårbarhet, transparens och visibilitet – den snabba vägen mot förbättring och effektivare produktion från ett automationsperspektiv (2003)*
24	*A Case Study In Dark (2008)*
25	*Spårbarhet i leveransnätverk skapar mervärden (2009)*
26	*A Simulation Model of A Retail Distribution Centre with RFID Technology (2003)*

Table 2. Publications connected to traceability associated with the division of Packaging Logistics with focus on other industries than food.

Letter	Title
A	*Risk and gain sharing challenges in interorganisational implementation of RFID technology (2009)*
B	*The cost and process of implementing RFID technology to manage and control returnable transport items (2009)*
C	*Using RFID technology captured data to control material flows (2008)*
D	*Towards a framework for designing logistical RFID systems (2008)*
E	*On interactions between Packaging and Logistics - Exploring implications of technological developments (2007)*
F	*The effect of asset visibility on managing returnable transport items (2007)*
G	*Konceptualisering och design av Auto-ID system för Volvo Olofström (2006)*
H	*Konceptualisering och design av Auto-ID system för Scania (2006)*
I	*Nyttan med RFID i IKEAs försörjningskedja - ett sätt för IKEA att uppnå spårbarhet (2002)*
J	*Exploring an open-loop RFID implementation in the automotive industry (2009)*

Table 3. Publications connected to traceability associated with the division of Packaging Logistics not focusing on a specific industry.

Nr.	Title
I	*Supply chain integration obtained through unique ID:s on packages and load carriers - a survey of Swedish manufacturing industries (2008)*
II	*Connectivity in Logistics and Supply Chain Management: A Framework (2008)*
III	*Demand-driven logistics from a packaging perspective (2006)*
IV	*Packaging Development – Update 2001 (2001)*

As can be seen, the research focus has been on traceability in the food industry and especially on external traceability. A more detailed illustration of the content in the different publications is shown in Appendix B.

3.4 Research construct

The identified areas of research can be seen in Figure 5. This framework represents the author's view of the research performed at the division of Packaging Logistics and the aim of this framework is to show the different areas and sub-areas and how these are connected to traceability in order to provide the reader with a comprehensive view of the research performed at the division. Figure 5 is divided into four different parts: *Components, Perspectives, Tools* and *Added values.*

Components refer to components necessary to achieve traceability from the start. Labelling and a labelling system, often in the form of Auto-ID technology such as RFID (Radio Frequency Identification) or EAN (European Article Number) are essential since when they are applied to the p*ackaging or product* provide them with a unique *product identity*. This unique identity is to be captured at different points internally or in the supply chain. The information captured and saved is thereafter to be distributed (information sharing) in order to trace the specific product. In order to share information, willingness and trust between the different actors are needed and costs, risks and gains should be shared.

The area above the supply chain in Figure 5 illustrates different research and industry *perspectives* on traceability, which means how traceability is regarded by different industries, companies and researchers. These are *Laws and regulations, Supply Chain management, Economics, Exploitation of living resources* and *Safety, quality and risks.*

- *Laws, standards and regulations* refer to companies which view traceability as meeting the demands made by governments, authorities and customers.

- *Supply chain management* is about all issues within logistics as well as relationships between different actors in the supply chain (collaboration, risk- and cost sharing) in the area of traceability.
- *Safety, quality and risks* are about looking at traceability as a means of minimising risks and achieving safer and higher-quality products.
- *Exploitation or ending of living resources* refers to the use of traceability from an environmental perspective as a controlling tool when, for example, applied to fishing or harvesting. In fishing, traceability can be used to make sure that the location for placing the net is not the same as the previous time. This information can ensure the ocean is not being overfished.

The area on the right of the figure illustrates some of the benefits in the form of added values which could be achieved with traceability. The area in the lower part of the figure illustrates tools which have been developed/evaluated/tested in the research area of traceability at the division.

It should be noted that this construct only takes in consideration components and issues which can be related to research at the division of Packaging and Logistics. Therefore, it has to be pointed out that there might be other areas related to traceability which exist and that this construct might be expanded in order to accommodate them.

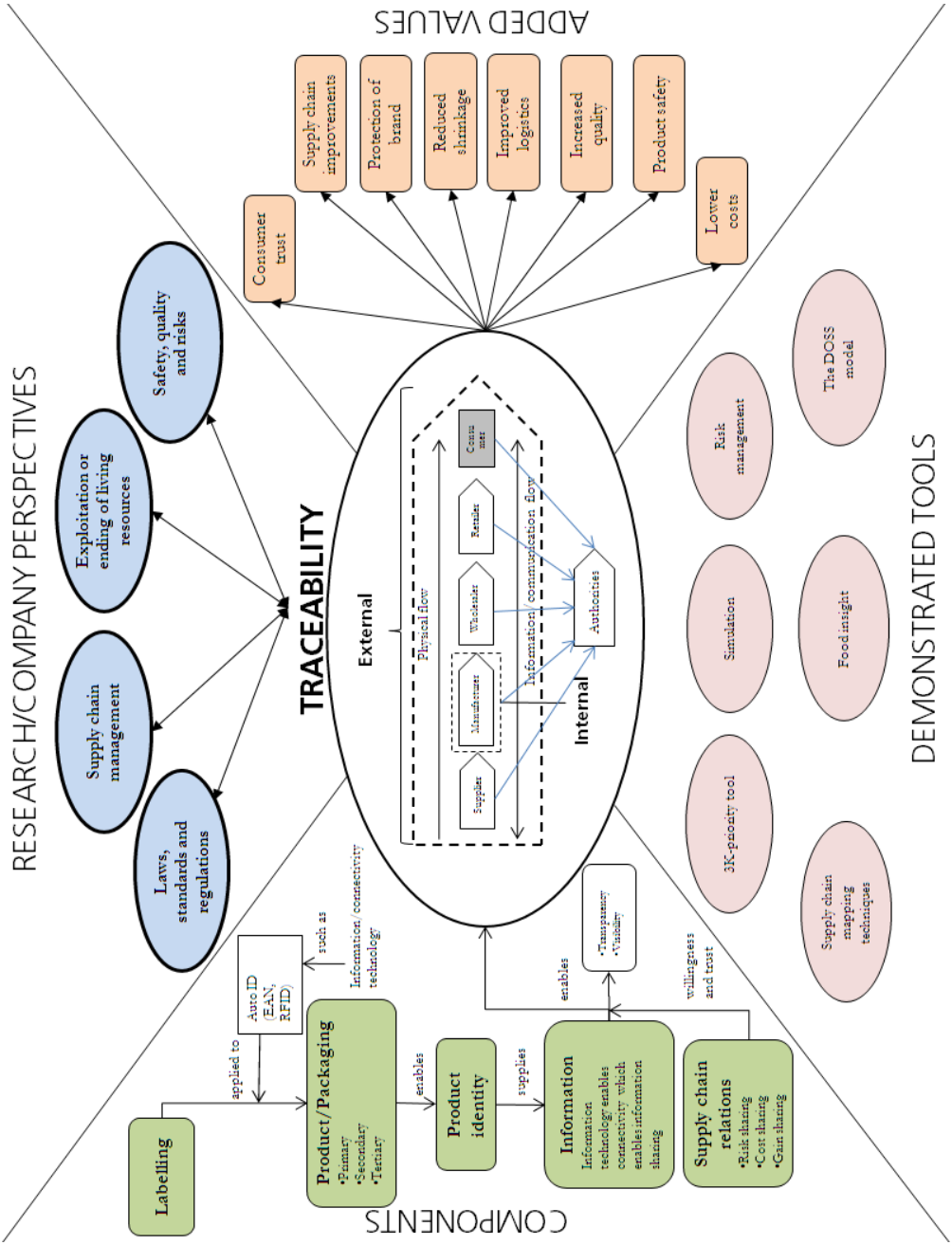

Figure 5. The author's view of the construct of traceability at the division of Packaging Logistics.

4. Research according to the construct

The construct showed the author's personal view in which traceability related areas research has been carried out in. In this chapter research according to this construct is presented.

4.1 Labelling and the benefits of Auto-ID technology

Labelling (put) on packaging is one of the components needed in order to achieve traceability (Örjas & Severius, 2002). The labelling could be a batch number, an EAN code or an RFID tag containing an appropriate amount of information. This is further stated by Morén and Samuelsson (2002), where the authors point out that one of the basic requirements for traceability is the existence of a labelling system combined with appropriate equipment in order to capture information at different control points. Labelling should contain specific information designed according to what kind of traceability a company strives for. A simple way of putting it is that the more control points there are, the better the traceability (Morén & Samuelsson, 2002). Örjas and Severius (2002) state that the way products are labelled is of great importance for traceability for two reasons. Labelling contains product-specific information stored directly on the packaging, and information connected to the product which could be stored in information systems. Furthermore, in Örjas and Severius' (2002) research, conducted in the Swedish food industry, the authors found that it is vital that the entire industry uses the same labelling system in order to trace foodstuffs throughout the whole food supply chain.

In a study done in the Swedish dairy and meat industries it is confirmed that labelling is extremely varied (Alklint & Göransson, 2004). Different systems are being used (everything from EAN to

manually written labels) and the systems are not connected internally between different divisions. Identities are not electronically connected. Furthermore, the lack of a standardised labelling system throughout the supply chain is pointed out, something which prevents effective information management and thereby a traceability system (Alklint & Göransson, 2004).

Auto-ID technology and RFID in particular are areas which have been thoroughly examined in several case studies and publications. The use of Auto-ID technology represents an easier way of collecting product-specific data, which could be used for traceability purposes. A typical RFID system consists of tags, readers and a computer. Via radio waves it captures data from an object without needing visual contact, which means that tagged objects may be tracked and traced in real time (Pålsson, 2008b).

EAN codes are the most frequently used Auto-ID technology today. The problem is that the information kept cannot be changed after printing. From that aspect RFID tags are preferable since the information that these tags keep can change as the product passes through the different actors in the supply chain (Örjas & Severius, 2002).

According to Örjas and Severius (2002), RFID tags and 2D bar codes have their advantages: the information in RFID tags can be changed and 2D bar codes can hold a larger amount of information. However, the strong position of EAN codes, where a global standard for labelling objects has been accepted means that they are preferable.

"RFID technology has been a 'hot' topic during the last couple of years in the logistics and supply chain management community. Compared with bar codes (EAN), the main strengths of RFID are that an RFID tag can be read through non-metallic obstructions not requiring line-of-sight, and that an RFID reader has the ability to read several tags simultaneously. Hence, RFID technology can

potentially provide real-time information to manage operations and enable supply chain visibility (Hellström, 2009, pp 1-2)".

By using RFID tags on packaging, visibility is made possible throughout the supply chain (Pålsson & Johansson, 2009). This provides more efficient and more accurate traceability of products and could facilitate exact identification if something happens which requires recalls of products. In two case studies (Hellström, 2004) it is noted that traceability is lost when pallets (tertiary packaging) are split into cases (secondary packaging) in the picking process. With RFID tags on case or item level, traceability could be maintained throughout the entire chain. Tagging products on an item level is, however, a consumer integrity issue which needs to be further investigated.

Ousbäck and Olsson (2003) describe a future scenario for the use of a Bioett tag (which can show how temperature differences have affected the product) combined with an RFID tag on primary packaging levels could increase traceability by providing an easier way of registering temperature disturbances, and time. The database where this information is being collected is continuously updated automatically which means that manual information transfer is removed. This leads to effective traceability throughout the supply chain as long as the database is available for all the actors in the chain. RFID readers should be placed at every point in the chain where the products are handled.

Pålsson (2008b) states that RFID technology is identified as having the potential to enable supply chain integration through improved tracking and tracing of goods. In addition, Pålsson provides guidelines for how to design a logistical RFID system where implementation leads to supply chain integration.

The implementation of RFID has been explored in several case studies. Hellström (2007, 2009) performed case studies in the two Swedish companies Arla Foods and IKEA to explore and describe the costs and process of implementing RFID technology to manage

and control the rotation of returnable transport items. At IKEA, the purpose of an RFID trial was to gain insights into RFID technology and see whether the technology could be used in tracking steel containers to improve the process of managing and controlling the rotation of steel containers. Results from the IKEA study showed that an RFID implementation could be used for tracking steel containers. The system proposed showed 100% reading rate. At Arla Foods, the purpose of the implementation was to tag roll containers (for dairy products) and thereby be able to track and trace them. The purpose was to decrease the numbers lost annually; one in five before implementation. Approximately one year after implementation, the number of lost roll containers was close to zero. This shows the potential of RFID systems. Mentioned in the article is that cost should not be regarded as a barrier for implementing RFID on returnable transport items. In a recent case study (Pålsson, 2008a), containers at the paper company Stora Enso have been provided with RFID tags. The study showed that for tracking reasons, it is most important to report the position of a product when it leaves, or arrives at, a geographical location.

In Johansson and Hellström, (2007), the use of RFID on returnable transport items (RTIs) (roll containers) shows that a tracking system itself does not provide any benefits. It has to be coupled with a data analysing and reporting capable system in order to provide visibility. This study was combined with a discrete-simulation model where different scenarios were built, showing the potential of the system. It has been suggested that tracking systems are needed to manage and control RTI systems. However, tracking systems do not in themselves provide any benefits. The case study showed that a tracking system with inadequate data analysis and reporting capabilities provides limited visibility. Furthermore, asset visibility does not guarantee that firms are able to use the increased information gathered, or, more importantly, to use it efficiently. The study also illustrates that when tracking data are used to take action, shrinkage can be controlled, but it is pointed out that these tracking data require continues management attention. The case

study furthermore points out the difficulty in determining fleet size, especially in the introduction phase. Arla Foods purchased the initial roll container fleet based on conservative estimates. As tracking data become available, fleet sizing can be refined and abundant roll containers can be transferred to other distribution centres (DCs).

In one of the latest articles published, a case study regarding interorganisational RFID implementation shows the risks, gains and challenges associated with such a change in the supply chain. The framework conducted could be of great help in identifying the risks and gains in collaborative initiatives (Hellström, Johnsson & Norrman, 2009). In Johansson and Hellström, (2006) and Hellström, (2006), the conceptualisation and design of an Auto-ID system (RFID) in the automotive industry with focus on traceability has been carried out. The results show that the effect of an Auto-ID system could increase effectiveness, but it is essential to point out is that it has to be integrated with other information systems in order to provide information to the right people. The combined components will ensure effective management of the traceability and physical flow of the products.

Most RFID studies have focused on closed-loop settings (where tagged products are supposed to be transferred back to the point of origin). One recent study by Wiberg (2009) investigated one of the biggest open-loop RFID implementations in the Nordic region at the automotive supplier's; Plastal. One of the reasons for the RFID implementation project was to increase traceability. Results showed that the main problems were that the readers read too much or too little. Recommendations were to increase the technical knowledge among all actors involved in the project before implementing RFID as well as to define roles and goals in advance for actors involved.

When other RFID studies have focused on hard issues such as technological demands, Pålsson (2006) looks at the organisational issues when RFID is implemented in a German retail supply chain.

It was found that there have to be clear motives and a well-planned structure for the implementation process. Clear motives and structure are found to be particularly necessary in the interorganisational context as they determine the ability of involved organisations to keep their focus during an implementation process.

Morén & Samuelsson (2002) state, that in order to get the most out of a labelling system, there have to be common standards. The lack of a standardised RFID system is a big problem because different actors then will use different systems which are unable to communicate. Furthermore, if a standard is to be accepted, competition will increase and prices will fall.

Sparks, Gustafsson, Jönsson and Smith (2006) state that the potential of RFID, which will impact on both packaging design and data capture, could increase food security and safety.

4.2 Packaging

Packaging is the ideal bearer of information, since it adheres to the product throughout the entire chain (Beckeman & Olsson, 2005) and it is vital that packaging supports the logistical process in order to achieve traceability (Örjas & Severius, 2002). In order to achieve effective enough traceability, company focus should be on secondary packaging. In the food industry there is no interest in tracing on primary packaging. Traceability on primary packaging would be too expensive and create a complex information flow which is not required by consumers today (Örjas & Severius, 2002).

Information technology and its interface with packaging are of importance when examining secondary effects of packaging in the logistics context. Packaging may be regarded as an information link between the physical flow and the IT system. The validity and reliability of parts of the logistical information in the IT systems are based on information gained from product flows, which are usually based on the actual movement and registration of packages, e.g. POS (Point Of Sale) data, inventory in- and out checkpoints etc.

Consequently, packaging provides information functions which are crucial (Nilsson & Pålsson, 2006).

Packaging innovation is a subject connected to traceability and food safety. A recent study presented a new technique to ensure the quality of foodstuffs without having to break the packaging (Lewander, Guan, Persson, Olsson & Svanberg, 2008).

Intelligent packaging (e.g. packaging which can indirectly interact with those operations and handling resources it comes into contact with) will create new possibilities to combine supply chain requirements with customer requirements in order to offer a safe environment for products and customers (Johnsson, Hellström & Sanders, 2003). Jönsson (2001) continues on the same track by declaring that intelligent packaging is interesting for safety reasons. Intelligent packaging allows possibilities to trace products if there is something wrong with them and to pick up additional loads in order to fill the vehicles on the road. Furthermore, intelligent packaging can provide customer service in terms of product arrival. However, work remains to be done to establish common standards for transferring information and also to reduce production costs (Johnsson, Hellström & Sanders, 2003).

In several industries bar codes have become compulsory, however, from a demand-oriented perspective there is a call for Auto-ID, e.g. RFID technology and other information-enriching facilities which can be integrated with the product or its package. In these cases packaging should be designed in order to function in any situation, whether the demand is for information in order to track and trace, to follow the temperature of a package in a chill chain or to inform a customer of containment and handling tips. Furthermore, with this up-to-date information, logistical flows are able to perform more effectively, which is of interest as supply chains are differentiated. Knowing where each item of transport packaging is located facilitates a rapid response and efficient handling, and fewer

out-of stock situations are likely to occur (Nilsson & Pålsson, 2006).

Sparks et al. (2006) found in their research that the increasing use of reusable and returnable packaging systems raises the issue of traceability. In such cases there is a need to track the returnable system components.

4.3 Product identity and batch size

In order to accomplish traceability through the supply chain it is required that products have unique identities which could be read through the entire chain (Clemedtson, 2008). Product identity refers to the least traceable volume in a system. This size depends on process layout and the layout of the traceability system, and could be everything from one single item of packaging to a year's production. Many companies choose to work with daily production volumes in a traceability context, even though these volumes vary. This means that the least traceable unit for these companies is what has been produced during a specific day. Product identity could also refer to batch size and is essential when recalls have to be made. The search for the "golden batch size", which means the batch size which is small enough for decent traceability purposes but still economically feasible, is one of the big questions where many aspects have to be taken into consideration (Skjöldebrand & Samuelsson, 2003; Alklint & Göransson, 2004; Örjas & Severius, 2002). In the food industry, one common way of tracing food products is through the use of best-before date. If withdrawal of a product has to be carried out, all products with the same best-before date can be identified and recalled. The question of product identity refers to what level the identity should be on. Örjas and Severius (2002) imply that an identification number on a batch level is needed because the best-before date provides too little information in order to achieve satisfactory traceability. In a recent study by Pålsson and Johansson (2009) in the Swedish manufacturing industry, the use of unique product identities has

been investigated. The results showed that increased traceability was the most important driver for the companies investigated for having unique identities on packaging and load carriers.

4.4 Information

It is information which provides a company with visibility in the supply chain and therefore also traceability. An integrated, developed information system and its management are consequently required for traceability to be achieved. The information system has to be integrated with company-specific systems (Morén & Samuelsson, 2002). The technical aspects are essential in order to make traceability simple and it is in this area that many problems are found, especially when it comes to using a common system throughout the chain. For every step in the chain the product passes through, the more complex the history of the product becomes. This puts high demands on the systems which store the information. Some kind of computer-based system is needed (Örjas & Severius, 2002). Lindh, Skjöldebrand and Olsson (2008b) have elaborated on what challenges need to be overcome for full chain traceability to be achieved. One of the challenges refers to informational issues such as the data collection, information sharing and the management of appropriate information. All these issues have to be solved for supply chain traceability to be achieved.

It is found by Skjöldebrand and Lindh (2007) that the risk of losing information increases if it is manually captured. Manual information is hard to handle and to search through. Furthermore, manual information could easily be manipulated and incorrectly registered, intentionally or unintentionally which makes it harder to achieve full-chain traceability (Eken & Karlsson, 2006). A computer-based information system is also attached to some risks, but makes it easier to search through and identify appropriate information. However, information handling is about how many

resources companies are willing to put into it (Skjöldebrand & Lindh, 2007).

Eken and Karlsson (2006) state that the main problem in the food supply chain they examined, from a traceability perspective, is that different actors have different information systems which are unable to communicate with each other. Instead of automatic information transfer by the use of different actors' information systems; procedures and individual people make transfer possible through e-mail and phone calls. However, traceability is regarded as somewhat well functioning, but not because of the help provide by systems, but in spite of the systems drawback. Companies have the technical potential to be able to trace products on a pallet level in real time, a potential which is currently not fulfilled.

Alkint and Göransson (2005) state that the work of constructing a common traceability system should be of high importance for the food industry. A system which could manage information throughout the whole supply chain where a system standard should apply to the entire food industry. One idea is, in the future, to have external companies working with information management, following the product through the supply chain.

Skjöldebrand and Samuelsson (2003) describe information-related traceability problems. The problem is not that traceability-related information does not exist; the problem is that the information is spread out over different premises, in the form of document files, data files, automation reports and in various modules of business, warehouse and laboratory systems. These can be regarded as pockets of information, which at every unwanted production incident create stress and time-consuming investigation when someone is trying to trace the source of a production fault or institute a recall. The challenge is about linking these pockets of information, internally and externally, thereby creating a visible information flow. The authors continue to point out this is what traceability is about – collecting relevant information and making it

visible in order to improve and optimise operative processes. Effective traceability is therefore the result of a structured information gathering, that the collected information is reachable and searchable and can be presented in an understandable manner.

4.4.1 Connectivity

Connectivity has been examined by Hoffman and Hellström (2008). The findings show that the connectivity construct can be used as a bridge between information technology and information sharing where information technology enables connectivity and connectivity enables information sharing. This means that the feature of connectivity indirectly enables visibility and traceability since information sharing is a critical component in these constructs. However, their study showed that there is no uniform definition of the concept and that it requires willingness and trust among the supply chain actors in order to enable sharing of information throughout the supply chain. The connectivity problem among actors in the supply chain is also noted by Olsson and Skjöldebrand (2008) where they state that one of the biggest problems is that different actors use different systems which do not communicate automatically and cannot be connected to each other.

4.4.2 Transparency

According to Olsson and Skjöldebrand (2008), the presence of traceability contributes to increased transparency throughout the food supply chain. The traceability system can be considered as one part of a quality assurance system in which for example HACCP[2] and risk assessment are included. That traceability leads to transparency is also acknowledged by Skjöldebrand and Samuelsson (2003) who claim that transparency in the value chain is a significant result of traceability, particularly in the long run when all the pockets of information are connected. This means that consumers, distributors and producers and suppliers of raw

[2] Hazard Analysis and Critical Control Points, a method of working in order to find, evaluate and control all the risks in food manufacturing.

materials can show critical data to each other, which in turn will lead to better products, better prognoses, better services and higher quality for all participants in the added-value chain. This can increase the security around store inventories, determine more precisely the volumes of incoming and outgoing goods, and reduce costs for storage and control of goods.

4.5 Tools

Different tools have been created and/or evaluated in research concerning traceability in the food industry. Skjöldebrand and Lindh (2007) present tools with a focus of adding value through traceability and risk management, illustrating how small companies could work with food safety. These tools end protecting a brand based on risk management and through companies adapting a value-adding, pro-active approach towards traceability. The tools are described in this chapter as are other tools developed and/or evaluated in other traceability-related research at Packaging Logistics.

4.5.1 Simulation

A simulation model, based on complexity theory (agent-based modelling), was built and evaluated with focus on the internal flow of products, information, competences as well as the external logistic flows. The object of developing such a model is to picture reality as it is (Skjöldebrand & Lindh, 2007). This simulation model was focused on the critical points between the different actors in the food supply chain and the temperature disturbances which occurred as well as the aspect of combined loading (Nilsson & Lundin, 2008). In Wikström (2009), the model is described in more detail where three different levels have been included: the physical, informational and relational flows which involve information, knowledge and attitudes. The holistic thinking in the model can show how the weather, different residence times and guiding of the physical flow affect food safety and quality.

4.5.2 Supply-chain mapping techniques

A tool within process mapping with a focus on traceability has been developed by the company Good Solutions and evaluated by researchers at Packaging Logistics. The results from these studies are presented in the article "Brownboard - A tool to facilitate improved supply chain traceability" by Lindh, Skjöldebrand and Olsson (2008) as well as the report "Adding value through risk management and traceability" by Lindh and Skjöldebrand (2007). With the brownboard tool, focus is placed on the question of where in the supply chain risks occur, risks which can lead to loss of traceability. The difference between brownboard and traditional process mapping is that, while process mapping considers macro or micro levels, brownboard focuses on bringing in all relevant information from a traceability perspective while still maintaining a useful overview. The name brownboard comes from the actual tool, which is simple brown wrapping paper, allowing the people using the tool the chance to be creative. Different symbols are used in order to capture traceability-related aspects such as *split* and *mix*. The symbols are easy to understand and in combination with discussions among the supply chain actors, awareness regarding risks connected to loss of traceability can be achieved. The case studies presented in the article showed that the tool enables identification of potential traceability improvements by its visualisation of a flow transcending functional, as well as organisational, boundaries and makes potential risks of losing traceability visible to supply chain actors. Furthermore, the tool can facilitate the identification of critical issues connected to overall safety and quality aspects which would have not been addressed (Lindh, Skjöldebrand & Olsson, 2008a).

4.5.3 3-K priority tool

The 3-K priority tool was developed and evaluated by Eken and Karlsson (2006) as a means of finding and handling critical contexts in the supply chain from food safety and traceability aspects. Critical contexts can, according to the authors, be of three kinds –

physical, informational or relational. The tool works by the user going through a checklist where the criticality of each critical factor (K) is estimated according to the impact the factor would have on food safety and the probability that the critical factor is to occur. After the steps are gone through, the user will have a table of which critical contexts are to be prioritised with regards to food safety. The tool takes a holistic view of the supply chain.

4.5.4 Food insight

Food insight is a tool developed by the company Good Solutions and evaluated by Lindh and Skjöldebrand (2007) in a workshop at the companies Pipersglace and Engelholms Glass. The tool means a possibility of going through with a new way of working in the production in order to make the flow more effective, increase traceability and thereby add values. The tool works in a structured way where data is collected objectively. This collected information could thereafter be used for online-surveillance and is searchable. (Lindh & Skjöldebrand, 2007)

4.5.5 Risk management

Risk management was developed in collaboration with consultant Pia Lundberg from the company CAPE. The tool focused on appreciation and estimation of risks and evaluation criterions and a risk matrix was developed and further on tested on the case companies Pipersglace and Engelholmsglass. The matrix and the working methodology is a supporting tool when choosing which risks that are most important to work with in preventive measures. (Lindh & Skjöldebrand, 2007)

4.5.6 The DOSS[3] model

The DOSS model was developed to estimate the costs of internal operative risks, with special focus on companies' brands, and two case studies were performed in order to validate the model created.

[3] The researchers named the model after their initials, Dagmar Ohlsson and Sofia Svensson.

The model is built as a classic risk evaluation matrix, but it adds a time aspect which varies the effect and the impact of the risks on brand. The results show that contamination is a major source of risk. If contamination actually occurs, it is vital that directed recalls can be made and that there is a high level of traceability throughout the supply chain. Furthermore, the study shows that quality assurance is of the utmost importance and the DOSS model can be an essential basis for the decision concerning quality assurance. Even though the model was validated in two case companies producing liquid food, the authors feel that the model can be used in different manufacturing companies (Ohlsson & Svensson, 2005).

4.6 Laws, standards and regulations

It has been shown in a great deal of research within food supply chains that companies fulfil the regulations on traceability required by the European Union, but that does not mean that the regulation is well functioning; instead it means that the regulation is put at a minimum demand. It is important to point out is that this is true for internal traceability, and not for the chain perspective (Olsson & Skjöldebrand, 2008; Eken & Karlsson, 2006). In a study carried out in the dairy and meat industry it is pointed out that the companies regard regulatory demands as secondary to the demands made by customers: the standards. Laws and regulations are put at a minimum demand which almost every company can meet. This means that regulations do not lead the way for increased traceability development. Instead, it is the demands put by customers which lead development. (Alklint & Göransson, 2004).

4.7 Safety, quality and risks: Re-active vs. pro-active thinking

Ousbäck and Olsson (2003) point out that products in the Swedish cold food chain go through many different quality assurance systems such as ISO (International Organisation for Standardisation) 9000, EFSIS (European Safety Inspection Scheme)

and HACCP. These quality assurance systems are, however, often bound to company boundaries which mean that products will have to be screened whenever they reach a new quality assurance system. With the Bioett system it is possible to create a quality system which goes all the way from producer to end-consumer.

According to Alklint and Göransson (2004), traceability should not be seen as a new quality certification system which would meet resistance at the company, but rather as a system for connecting the different quality systems in order to increase quality and ease the production process. To a wider extent, traceability should be regarded as a component in a quality assurance system where hygiene and product safety should be included, as well as control of the different systems. Risk analysis should also be included in the quality assurance system and run simultaneously with traceability work.

Furthermore, the traceability system can be seen as a part of a quality assurance system where traceability can be regarded as adding value to the quality assurance system. This is accomplished by traceability providing the communication linkage for identifying, verifying and isolating sources and products which deal with quality aspects (Olsson & Skjöldebrand, 2008).

It is important that if contamination (which is a risk in food supply chains) occurs, the producer has an effective traceability system to be able to institute recalls if directed. In this sense, it is essential to have a quality assurance system. All risks in the food supply chain originate from the functional risk which puts pressure on a quality assurance system and means that full chain traceability has to exist (Ohlsson & Svensson, 2005).

According to Lareke (2007), food companies often have a re-active focus when it comes to traceability. The focus is on recalls when something occurs, strictly following regulations without having the customer in mind and focusing on internal traceability, not taking action *before* something occurs. On the other hand, there could be a

pro-active strategy. Pro-activity in this sense means adding value based on traceability and risk sharing, which in turn make it necessary to add the consumer as a part of the food value chain (Olsson & Skjöldebrand, 2008). Pro-active thinking is mentioned as a key objective in order to assure quality and product safety, something that is currently lacking in the cold food chain (Karlberg & Klevås, 2002). It is regarded as an advantage to implement systems which exceed EU regulation 178/2002 to be more pro-active and which have both the trademark and customers in mind. Since a food scandal not only affects the consumer, but also companies' trademarks through bad will, traceability should be used pro-actively (Lareke, 2007). Some supply chains for food have, however, in the last years started to focus on a more pro-active perspective, where traceability is regarded as a part of the advertising machine, that it can protect the brand and is thereby also a factor which can be used in order to make more money.

This is also noted by Alklint and Göransson (2004) who state that it is essential to see the use of a traceability system not only with regards to product recalls, but also from an economic aspect, from "good will" and protection of the brand. The use of a pro-active traceability system is especially significant for companies which invest in strong brands, where bad will could hurt the company even more than it could affect companies without a strong brand. Traceability cannot prevent mistakes from happening, but it can say *where* and *how* the problems occurred in order to avoid those mistakes from happening in the future (Örjas & Severius, 2002).

4.8 Supply chain management

According to Örjas and Severius (2002), the biggest traceability issues in the supply chain occur at the producer's, the wholesaler's and in the interfaces between the different actors (critical points). At the wholesaler's, unit loads are split. Regardless of the level of labelling at the producer's, traceability will be lost if this part of the chain cannot control where products are being transported.

However, a more recent study by Eken and Karlsson (2006) shows that the most critical traceability issues occur at the reception and unloading of products.

4.8.1 Supply chain relations

Research made in cold food chains in Sweden show that different actors have limited knowledge about what is happening in the interfaces between different actors and that it is essential to study these interfaces from connectivity and risk-sharing points of view. Furthermore, the studies in these chains show that there is no holistic responsibility, and sub-optimisation is therefore likely to occur, not to mention the fact that temperature regulations are hard to fulfil, causing risks for consumer safety (Eken & Karlsson, 2006; Karlberg & Klevås, 2002; Björklund, 2002; Olsson & Skjöldebrand, 2008). Communication between the different actors is poorly functioning, which leads to misunderstanding (Karlberg & Klevås, 2002). When it comes to power relationships in the chain, it is found that the retailer is the one with the control by, for example, having their own labels and standards. In order for the producer to be able to supply the retailer, the demand for using specific labels and standards cause this power relationship (Olsson & Skjöldebrand, 2008). Lindh, Skjöldebrand and Olsson (2008b) state that full chain traceability demands supply chain collaboration which is not yet a reality. There has to be an overall understanding among the supply chain actors of the importance of traceability. The study indicates that the supply chain perspective and the supply chain collaboration needed, which has been elaborated on in literature, are not yet a reality for companies studied (Lindh, Skjöldebrand & Olsson, 2008b).

Information sharing, integration in terms of supply chain collaboration and incentive alignment in terms of shared goals, risks and benefits gained through supply chain traceability, are also found in literature as requirements for a synchronised supply chain (Lindh, Skjöldebrand & Olsson, 2008b). Supply chain traceability can therefore be regarded as an enabler for supply chain

synchronisation. According to Beckeman and Olsson (2005), a holistic perspective on the supply chain and collective responsibility on the part of the different actors are required to achieve traceability.

In a case study in the Swedish food supply chain, actors in the chain are competitors as well as co-operating partners and the competitive situation plus the changing surrounding determines long-lasting trust relationships and co-operating company culture. This increases the resistance among certain companies to share both information and competence. It is also pointed out that poor supply chain relations and the willingness to share information are hard to correct. It is therefore vital to work on trust which could be achieved through transparency and through smooth interactions between the actors. First then can a complete integrated supply chain, which can lead to supply chain traceability, be reached (Eken & Karlsson, 2006).

4.8.2 Risk, cost and gain sharing

When it comes to risk- benefit- and cost sharing among supply chain actors, this is done to a limited extent according to Eken and Karlsson (2006). This can depend on the fact that there are no incentives for companies to share risks, costs and benefits among the actors in the supply chains because in some cases they could be competitors.

Lindh, Skjöldebrand and Olsson (2008b) discussed risk sharing during a workshop with the actors involved in the case study. The companies studied had little faith in being able to share the risks with other supply chain actors due to their small company size compared to, for instance, their customers. Possible effects on the ability to share risks due to implementation of supply chain traceability are hard to find in literature according to the literature review performed.

4.8.3 Critical points and contexts

Critical points in the cold food chain for food in Sweden have been examined in several studies (Olsson & Skjöldebrand, 2008; Eken & Karlsson, 2006; Olsson, 2004; Karlberg & Klevås, 2002; Ousbäck & Olsson, 2003). The interchanges between the different actors in a food supply chain should be considered as contexts with several critical parameters involved, based on the physical, informational and relational flows (Eken & Karlsson, 2006). Furthermore, it is the connectivity in terms of all these flows between actors which are identified as the weak points in the supply chain. One aim of the entire traceability research project is thus to develop methods and systems to identify and evaluate different critical control points – Chain Traceability Critical Control Points (CTCCPs) along the whole food value chain from fork to farm. These points are the basis for quality assurance/quality control in the entire value chain. However, connecting the points throughout the entire chain and achieving transparency between the actors require more than just identifying the critical points. They require the context of integrating physical information as well as the relational flow between all actors in the supply chain or network (Olsson & Skjöldebrand, 2008). One of the problems is that most of the methods available to achieve food safety manage the critical points when food is produced and do not take into account all the critical points throughout the whole supply chain. Results from the studies in the Swedish cold food chain show that in order to solve temperature-related problems, monitoring and mapping of the supply chain are essential as first steps. Furthermore, to increase the safety and quality, some steps should be taken, where increased knowledge about food technology in the companies, an increased supply chain thinking (in order to minimise sub-optimisation), collaboration in the supply chain and focus on quality rather than economy are some suggestions. By securing and increasing the quality of food, demand will increase and economic investments are therefore feasible (Olsson, 2004).

Ousbäck and Olsson (2003) point out in their master's thesis that the Bioett tag (which can show temperature disturbance) is one way of visualising critical points in the supply chain. Eken and Karlsson (2006) expand the discussion regarding critical points to critical contexts, claiming that there are informational, relational and physical factors which together form these critical contexts. It is in the interface between the different actors that the weak points or contexts exist in the supply chain and it is these that should be in focus.

4.8.4 Distribution

Distributors are also significant for traceability from food safety and quality perspectives. It is noted that most of the damage to products occurs when they are being moved and transported. At loading, pallets of goods can both be damaged and mixed, something which affects both safety of the products and their traceability. One way of decreasing such mistakes would be to make the drivers more involved and make them assume responsibility in order to perform a good job. In that way, their performance and product safety could be increased (Eken and Karlsson, 2006).

4.9 The consumer

The EU regulation 178/2002 has been formulated as a "from- soil-to-table" perspective, but it should instead take its starting point at the consumer and have a "from-consumer-to-soil" perspective. There has to be a holistic value perspective from the whole food value chain in order to meet the demands of the consumer (Lareke, 2007). The consumer thinks of food safety differently from what is usually regarded in science and at the food manufacturers'. The consumer's relationship to food safety means a "trust-in" relationship to the quality assurance system (Lareke, 2007).

Studies made in the Swedish cold food chain show that much of the focus on traceability, food safety and risk management lacks the consumer perspective (Olsson & Skjöldebrand, 2008). Through

efficient traceability there are potential savings to be made in terms of increased customer value (Lindh, Skjöldebrand & Olsson, 2008a). According to Lareke (2007), consumers have been more tyrannical through unlimited information access; the transparency era. This means that consumers place higher demands on the food value chain than before. Traceability is therefore increasing in importance in securing food quality and protection of the brand as a way to add value to the consumer. Even though a traceability system can be costly, it is essential to state that if the consumer can choose a super-safe product, they will certainly pay for it (Skjöldebrand & Samuelsson, 2003).

4.10 Exploitation or ending of living resources

The use of traceability as a controlling tool in order to ensure that food production is secured from an environmentally sustainable way is a new perspective being examined at Packaging Logistics. Henrik Ringsberg, PhD student claims that if you have information about where the latest place of fishing was, then it is possible to avoid fishing at that location next time. In the end, this means that it is possible to avoid the sea from being overfished. At the same time, this information could be communicated to consumers, allowing them to read on primary packages in stores the exact location of where the fish was caught.

4.11 Added values

As the alert reader has already noted, traceability can mean achieving a host of benefits and added values.

Lindh, Skjöldebrand and Olsson (2008b) show in their study that challenges in achieving supply chain traceability refers partially to the economic investments which have to be feasible. However, as stated by Alklint and Göransson (2004), it is costly to achieve traceability, but costly not to do it. It is said that the costs for

recalling a product is five times greater than to send it out (Alklint & Göransson, 2004). In addition to that, the cost of "bad will" has to be taken into consideration (Skjöldebrand & Samuelsson, 2003). According to Örjas and Severius (2002) there have to be economic advantages for the companies involved with regards to implementing a traceability system. Therefore, it is important to make sure that companies focus on the savings such a system could represent, and not on the cost.

Cost is often mentioned as one of the main barriers for a supply chain mass adoption of RFID technology. However, for the application of RFID to track returnable transport items, cost is not generally considered a barrier. Hellström (2009) has performed a cost analysis of the implementation of an RFID system at two large Swedish retailers. The results show that the payback time for the implementation is less than 2 years for IKEA and about 14 months for Arla Foods.

Some other added values that traceability could give are:

- By introducing a well-functioning traceability system, it is easier to have control of in-deliveries, storing and out-deliveries which could lead to lower stock levels and safety stocks (Örjas & Severius, 2002).
- If a system deals with different processes, profits can be made through time savings. This could also be achieved if manual handling operations are done automatically (Örjas & Severius, 2002).
- Profits in the form of decreased wastage could be realised through increased control of products (Örjas & Severius, 2002).
- In daily work, updated real-time information can be visible thereby enabling redirecting transports if needed, re-planned deliveries and dynamic additional services.

- With information about deviations and disturbances, logistical issues such as redirected transports and re-planned deliveries could be handled faster. Traceability provides visibility.
- When it comes to products which have reached the market, traceability could enable better service when spare parts could be directly replaced with a correct part without the old one having to be sent in.
- When recalls have to be made, these could be done in a directed way, meaning that only "bad" products have to be recalled (for example, if someone becomes ill after eating a contaminated foodstuff). This is also true when the media are informed whenever anything unpredictable occurs. For example, when consumers found glass in chicken recently, the producer could not guarantee that the glass found was limited to a specific batch. This meant they were forced to throw away several tonnes of perfectly good food as well as endure a bad reputation. Quickly showing that bad products are limited (and specifying this) and being able to recall them rapidly create an increased feeling of product safety.
- In collaboration between companies, traceability is of high value since it could increase the possibility of showing where mistakes and shortcomings happen. This could reduce possible risks, such as where in the supply chain products are being wrongly handled, between companies.
- This risk-reducing aspect has a pro-active side to it by being able to identify and follow up critical points where product safety could be lost. A great number of possible risks (from risks in production to risks in distribution) could be prevented and management skills can be developed and used cost-effectively.
- If product safety and consumer security increase, this could lead to higher levels of consumer trust thereby benefiting sales and marketing possibilities (Clemedtson, 2008).

5. Research projects connected to traceability

In this part of the report, the various projects initiated at the division of Packaging Logistics are presented and the results are described. A summary of the results of each project is presented after the outcome of each project.

As previously stated, several projects connected to the area of traceability have been carried out at the division of Packaging Logistics over the years. Some of the projects have been carried out only at Packaging Logistics, while others have been done at different locations where researchers from Packaging Logistics have been involved, but not have acted as project managers. In addition, the projects have been initiated by different financiers, with different purposes and with different outcomes. In this section, the different projects are thoroughly reviewed and the connection to the subject of traceability is made. Some of the projects are finished while others are still ongoing, and the presentation is divided accordingly. The figures in this section present the projects and the outcomes so far.

5.1 Finished research projects

Some of the projects carried out are finished. In this part, these are presented:

- *Traceability - a way to achieve transparency in the food chain.*
- *Added value through risk management and traceability.*
- *Modelling of traceability and risk analysis for safe and sustainable food manufacturing.*
- *Mobile Pipelines.*
- *Traceability in Logistics and Transport Systems - An Innovative Approach.*

- *SCA[4] project.*

5.1.1 Traceability: a way to achieve transparency in the food chain

Focusing on traceability in the food supply chain the project "Traceability: a way to achieve transparency in the food chain" was initiated in 2003. The initiation had much to do with the new EU regulation 178/2002 about traceability in food supply chains and by using different methods and models, the aim of the project was to develop and examine not only which costs, but also which advantages could be created with effective traceability and a transparent value chain. Within the overall project, several studies were performed as shown in Figure 6. These studies resulted in two master's theses, one licentiate thesis and one conference article as well as the main report. As with many other projects concerning traceability, the studies conducted within the overall project were initiated mainly due to the consequences of new regulations on traceability of food and due to limited knowledge of how consumers regarded trust relationships with the food industry as value adding. The questions the project aimed to answer were, for example, how to create a golden batch production, how accurate a traceability system should be, and how to go from re-active to pro-active traceability (Alklint & Göransson, 2004; Olsson & Skjöldebrand, 2008).

[4] SCA (Svenska Cellulosa Aktiebolaget), Swedish developer and manufacturer of care products, tissue, packaging, publication papers and solid wood products.

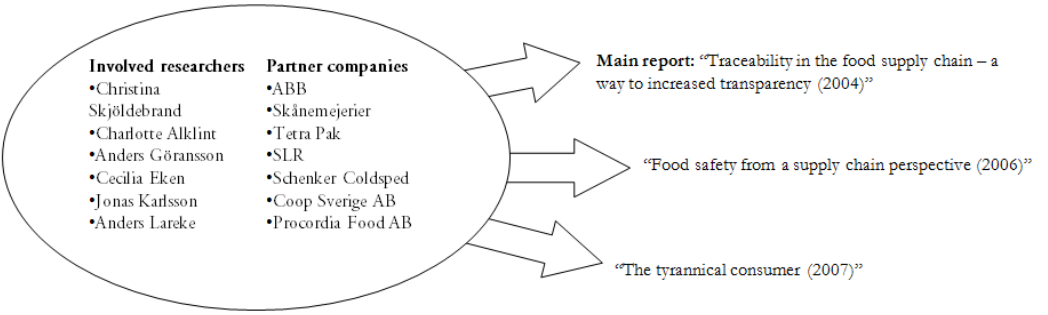

Figure 6. Traceability – a way to achieve transparency.

In the following section, the different studies are described and their results are presented in chronological order. Finally, overall results are presented.

In 2004, the report "Traceability in the food supply chain – a way to increased transparency" (Alklint & Göransson, 2004) was published. In it two case studies in the Swedish food industry were performed, one in the dairy industry and one in the meat industry. The conclusions drawn from the study was that the EU regulation is so vague that most companies can meet its requirements. The areas lacking are an active, documented control of how traceability is working at companies, and systems enabling the companies to transfer the information to authorities. Furthermore, the authors point out that the different information systems in the supply chain are not capable of communicating with each other, which makes traceability much harder. At the same time, it is stated that many registrations of ingredients and products are done by hand. Even though a manual traceability system could work for smaller companies, the authors highlight the need for a computer-based system in order to achieve a full-scale traceability system. Internal traceability is lacking at the dairy producing company studied where they fill and empty tanks of ingredients and silos at the same time. This means that ingredients from different batches are constantly being mixed, making it hard to trace the exact ingredients in each batch. Finally, the authors highlight the fact that in order to adopt

an effective traceability system, companies have to know what it should be used for and why it has to be established in the company's overall strategy. There also has to be a driving force behind the change towards a functional traceability system (Alklint & Göransson, 2004).

Focusing on the food supply for frozen products, the purpose of the master's thesis "Food safety from a supply chain perspective" (Eken & Karlsson, 2006) was to expand the concept of critical points in the supply chain, not only to include product safety, but also to include traceability aspects and the relationship between the different companies. The results of the studies conducted in the master's thesis show that the critical factors for food safety in a supply chain can be divided into three levels, physical, informational and relational, and used with a tool, a 3K priority tool, in order to be able to prioritise the most significant critical factors and see where in the supply chain these occur. Regarding traceability, the study shows that there are several problems in the supply chain, where the biggest problem is that the different actors use different information systems which do not automatically communicate. In addition, there is a great deal of information which is being manually transferred; a problem which increases the risk of information loss. However, the study points out that traceability is to some degree satisfactory, despite the lacking informational aspects and the fact the companies involved say that they are able to fulfil the demands of the EU regulation even though the technical conditions are available to trace products in real time, something which is not realised today.

The last outcome of the project is the licentiate thesis "The tyrannical consumer" by Anders Lareke (2007). In the thesis, the author looks at food safety with regards to transparency and traceability from a consumer perspective; a research area which had previously been missing. In the thesis, the need for trust between consumers and the food value chain in order to achieve value creation is pinpointed through literature review and field studies

where consumers were asked to answer questions regarding their food habits. The results show that consumers are tyrannical in their behaviour regarding food through the new informational era and Internet, where information is available at all times. Consumers seek a trust relationship regarding food safety; on which includes the retail store and the food manufacturer brand. In the research, a value creation model has been developed where strategies for value creation are shown. One of the conclusions drawn from the studies was that there has to be a holistic value perspective from the whole food value chain in order to meet the demands of the consumer.

Summing up the results from the project:

- Results show that traceability, which requires information and communication exchange, is a "transparency enabler".
- The identification of critical points and contexts is critical in order to achieve traceability and product safety. A tool for prioritising among these critical points has been developed.
- The consumer must not be forgotten in the food value chain. A key issue for the food industry to focus on is trust relationships with the consumer.

5.1.2 Adding value through risk management and traceability

As a part of a bigger project at Kristianstad University, financed by Nutek[5], the "Adding value through risk management and traceability" project aimed at finding methods, tools and models in order to help companies obtain profitable production, and protection of their brand through risk management and traceability. Researchers from the division of Packaging Logistics involved in the project were Christina Skjöldebrand and Helena Lindh as can be seen in Figure 7.

[5] Nutek/Tillväxtverket is the Swedish Agency for Economic and Regional Growth. The aim is to work to achieve more enterprises, growing enterprises and sustainable, competitive business and industry throughout Sweden. (http://www.tillvaxtverket.se)

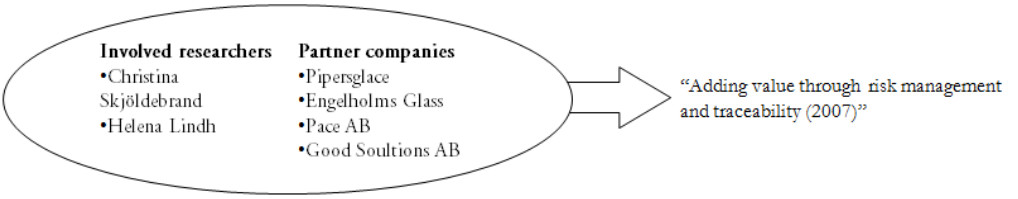

Figure 7. Adding value through risk management and traceability.

The project was reported in the eponymous publication in 2007 (Skjöldebrand & Lindh, 2007). To achieve the purpose of the project, which was to find methods for companies to achieve a profitable production and protected brand, this was done by working pro-actively with traceability and risk management/risk analysis. Furthermore, the goal was to have a "toolbox" and strategies in order to help the companies involved achieve the purpose of the project. A case study was performed at the ice cream manufacturer Pipersglace and Engelholms Glass in two steps. The first one was to examine internal processes and the other step was to examine all of the actors in the value chain. The result of the project was that a number of areas were identified, where improvements could be made. These were process surveillance, goods handling (physical), information handling, competence and funds. Also within the frame of the project, some direct tools have been developed. These are brownboard (see Lindh, Skjöldebrand & Olsson, 2008a), risk management (in order to identify and evaluate risks with the help of a certain matrix), food insight (a way to implement new methodology in production) and simulation.

Summing up the results of the project:

- A toolbox has been developed in order to help companies find strategies that can provide long-term profitability. This results in protection of the brand based on risk management and traceability.
- With the results of the project, it is possible to measure the companies' competitiveness, with consumer needs and demands as starting points.

- There are a number of techniques which can be used to transfer knowledge regarding traceability and risk management from university to industry, where brownboard is one technique which has been illustrated.

5.1.3 Modelling of traceability and risk analysis for safe and sustainable food manufacturing

In collaboration between SIK[6], the division of Packaging Logistics, School of Economy and Foodtechnology at Lund University and the companies Tetra Pak processing systems, Vin & Sprit AB and Brämhults Juice, the project "Modelling of traceability and risk analysis for safe and sustainable food manufacturing" was carried out over three and a half years between 2004 and 2008. The purpose of this SIK project was to develop a general methodology and tools which can be used in order to analyse a production system in a structured way with regards to safety, quality and economic values. SIK and the companies involved financed the project (Östergren et al. 2008). From Packaging Logistics, Christina Skjöldebrand was involved in the project, together with the two authors of the master's thesis; Dagmar Ohlsson and Sofia Svensson. However, Christina Skjöldebrand was not involved in the project as employed at Packaging Logistics but as external food technologist. The only publication sprung from this project and connected to Packaging Logistic is therefore the master thesis "DOSS – model for evaluating the risks in manufacturing of liquid food" as illustrated in Figure 8. SIK took an early decision to focus on internal traceability, while the food related research at Packaging Logistics focused on the external traceability. The main publication is, despite this fact, briefly described for the interested reader to take part of the results from the overall project.

[6] SIK stands for the Institute for Food and Biotechnology and is a Swedish industry research institute (http://www.sik.se).

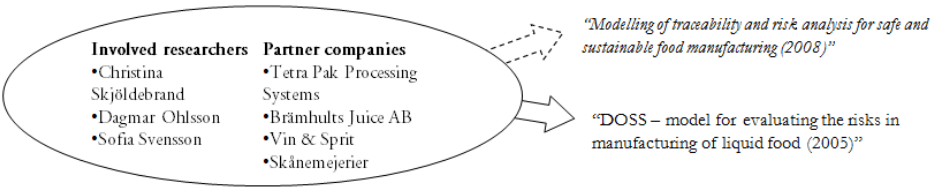

Figure 8. Modelling of traceability and risk analysis for safe, sustainable food manufacturing.

In the main report, the overall objectives and results of the project are presented. The focus throughout the project was on the producer and who he can work pro-actively with in his manufacturing process from risk and traceability perspectives in a supply chain context. The two case studies were performed at Brämhults Juice, a Swedish juice producer and Blossa Glögg, a mulled wine producer, where new tools were tested and evaluated. The tools evaluated in the project are the DRISC model (Disruption Risks In Supply Chains) and dynamic simulations for fuzzy traceability. In addition, a static simulation strategy has been developed in order to evaluate traceability in a production line. The DRISC model is a holistic, generic model which can be used in order to deal with the possible risks in the supply chain in a structured way; its focus is on the financial risks. These models were tested and evaluated in the case studies, where results showed that the models were valuable to the companies in order for them to identify, structure and estimate the risks in the supply chain and to provide a full view of the risks companies are exposed to. Dynamic simulation for fuzzy traceability is a tool for simulating how different events affect a certain product. In the report, this model was demonstrated for Blossa Glögg (Östergren et al. 2008).

Within the frame of the project, the master's thesis "DOSS – model for evaluating the risks in the manufacture liquid food" was performed which focused on internal operative risks. A model was developed to estimate the costs of risks, with special focus on the company's brand, and two case studies were performed in order to validate the model created. The results show that contamination is a

major source of risk. If contamination actually occurs, it is vital that directed recalls can be made and that there is a high level of traceability throughout the supply chain. Furthermore, the study shows that quality assurance is of the utmost importance and the DOSS model can be an essential basis for a decision concerning quality assurance. Even though the model was validated in two case companies producing liquid food, the authors consider the model can be used in different manufacturing companies. Studies should, however, be done in order to confirm this.

Results from the project showed that:

- The demand on traceability placed by the EU regulation is managed by all the actors in the supply chain.
- An evaluation model for the internal, operative risks has been developed.
- The future challenge is about managing the supply chain and the information flow between the actors. There is great potential in the existing technical systems that companies work with which not are being currently realised.
- In the future, the focus should be on finding actors willing to take a holistic perspective on the supply chain and to develop common standards.
- Traceability should focus on the consumer's need of safe food stuff instead of technical systems (Östergren et al. 2008).

5.1.4 Mobile Pipelines

The project "Mobile pipelines" was carried out over two and a half years and aimed to improve the competitiveness within the Swedish food and transport industries by implementing modern technology and by promoting collaboration between the different actors in the supply chain. Involved partners were the faculty of Engineering at Blekinge University, the Transport research group in Borlänge, Volvo Technology, the faculty of Engineering at Lund University and SIK, the Swedish Institute for Food and Biotechnology as can be seen in Figure 9. Representing the faculty of Engineering at

Lund University were Packaging Logistics resources Christina Skjöldebrand and Fredrik Nilsson, which is why the "Mobile Pipelines" project ended up in this report. The project was financed by Vinnova and by the actors involved. The project resulted in four partial reports and a final report. The first partial report was a literature study, done by Christina Skjöldebrand and Fredrik Nilsson, which started the project. Even though the only involvement from Packaging Logistics in this project was the literature review that started the project, the results of the overall project is also presented in this part.

The term of mobile pipelines means the transport chain which deals with unpackaged food in external transports between the different actors in the food supply chain. These transports are often done through pipes internally, within a company, but by containers, trucks, railroad carriages or ships externally between the different actors in the supply chain. The task of the project was to make these "mobile pipelines" work in an integrated system with high safety and traceability demands (Clemedtson, 2008).

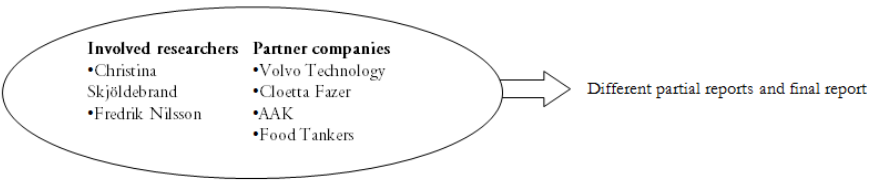

Figure 9. Mobile Pipelines.

The literature study examined traceability with a focus on logistics and supporting systems in supply chains. Results of the study showed that the research area still is quite unexplored. Europe and USA have different perspectives on the area of traceability even though Europe is ahead in research (Clemedtson, 2008). Since the BSE scandal, the focus in Europe within the area of traceability has been on food supply chains in order to ensure food safety. It was also noted that a sophisticated traceability system within food supply chains could minimise withdrawals and recalls of defect

products. In USA, the focus has been on the risks of bioterrorism and sabotage due to the events of 9-11 (Clemedtson, 2008).

The results of the total "Mobile Pipelines" project, with a focus on traceability, was a demonstrated solution where three different components were needed in order to secure the handling of unpackaged food at three of the involved companies (AAK, FoodTankers and Cloetta Fazer). These three components were:

- RFID technology
- Mobile data communication
- The load carrier is central and carries most of the cost and technology

The demonstrated solution has been verified practically and it has been affirmed that the solution improves the effects of risk, quality and traceability, even though there is potential for further improvements. The suggested solution gave the involved companies not only the possibility to trace products on a batch level, but also equipment such as load carriers and tanks. These were labelled and connected to the common information system through RFID technology. In addition, the solution proves that it is possible to integrate three actors in the food supply chain and to trace products within this chain. It has also been affirmed that, through the method for washing the load carriers, increased traceability has been developed which is much better than what is required by the EU regulation. Practically, this means that it is possible to trace the need for washing the load carriers in order to minimise risks by preventing unwashed or incorrectly washed load carriers. The solution presented also had substantial effects on finances. A full-scale implementation is costly, but the system solution Mobile Pipelines suggests positively affects cost, revenue and efficiency to a higher degree than the companies involved had counted on (Clemedtson, 2008).

5.1.5 Traceability in logistics and transport systems - an innovative approach

With focus on practical and industrial applications of Auto-ID in the automotive industry, the purpose of the project "Traceability in logistics and transport systems" was to identify measure, analyse and implement RFID in closed-loop settings. The products to be tagged were of high value and large volumes, including loading units, racks and other packaging systems critical to production efficiency. Tracking and tracing of these individual loading units and racks enables a substantial increase in efficiency and performance of logistics and transport systems. Furthermore, by using RFID-based traceability systems it will be possible to design a supply network for the loading units, racks and the other packaging systems which could lead to a much more effective operating supply network (VINNOVA research application, 2005).

The project was executed in collaboration with Blekinge Institute of Technology, Odette Sweden AB (an organisation working on the behalf of the Swedish automotive industry) and the industrial companies Scania, Volvo Cars Body Components and Volvo Logistics. Involved in the project from the division of Packaging Logistics were Mats Johnson (project manager), Daniel Hellström and Ola Johansson (VINNOVA research application, 2005).

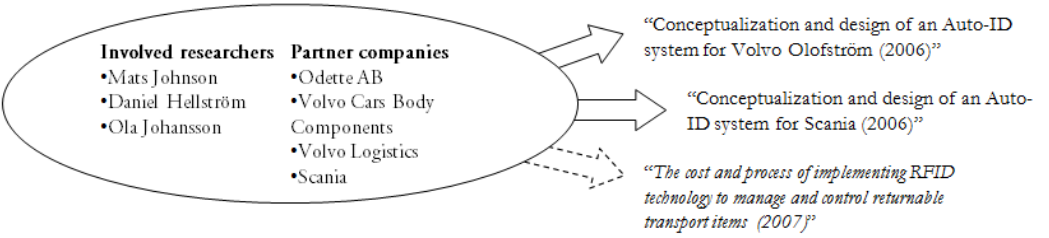

Figure 10. Traceability in logistics and transport systems - an innovative approach.

The project ended late in 2007, with the two reports in Figure 10 above as the outcome. A part of the draft of the article "The cost

of implementing RFID technology to manage and control returnable transport items" (Hellström, 2009) was also included in the other two articles in the project. Consequently, this publication is also regarded as one of the outcomes even though only some of the content is connected to the project

The two reports describe the results of the project, where the conceptualisation of an Auto-ID (RFID) system had been done at Volvo Olofström and Scania. The studies at the two different companies followed the same methodology. In the studies, a mapping of the current material flow was performed first. In Scania's case this flow was mainly internal, while for Volvo, the flow was fully external, reaching different customers. The approach used in the two case studies followed the methodology been defined by Hellström (2009) where implementation of RFID at two different companies (Arla and IKEA) had been done. The steps were as follows:

1. *Problem identification*
2. *Conceptualisation and system design*
3. *Return of investment analysis*
4. *RFID trial/pilot*
5. *Choice of system provider*
6. *Implementation*
7. *Improvements*
8. *Expansion of the implementation and the area for applications*

In the project, only the three first steps were included. Conclusions drawn from the two studies were that the RFID system described provides opportunities for automatically identifying incoming and outgoing containers (in the Volvo case) making it possible to ensure and rationalise internal container management. However, the authors point out that automatic identification is only one of the components in the system. It has to be connected to, and integrated with, a current information system in order to take advantage of improved traceability information. It is the combined

result of these traceability improvements which increases efficiency (Johansson & Hellström, 2006; Hellström, 2006).

5.1.6 SCA project

In a joint venture between SCA Packaging[7], Philips Semiconductors and the division of Packaging Logistics, a traceability project was carried out with a focus on how RFID could increase the efficiency of the handling of goods in a distribution centre. In this project, Mats Johnson and Daniel Hellström were involved (see Figure 11), and Daniel Hellström was partly financed by SCA in his studies towards his licentiate in Engineering. Another company involved was the Dutch van Eerd Group, owner of the JUMBO Supermarket, a big Dutch retail chain. The case study for this project was done at one of their distribution centres (Johnsson, Hellström & Sanders, 2003).

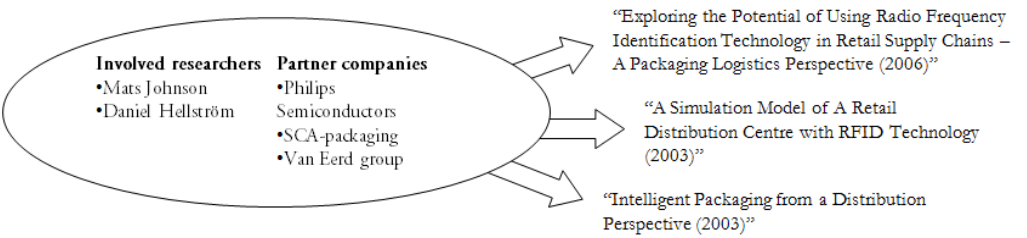

Figure 11. SCA project.

The Hellström licentiate thesis (2004) looked at the effects of introducing RFID technology in a retail supply chain from a packaging logistics perspective, all the way through the chain 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. The method used was a single case study and a modelling and simulation model (Hellström, 2003). The case study showed packaging logistics activities in the retail supply chain while the model showed how RFID in packaging could benefits.

[7] SCA is a big Swedish company in the paper industry producing hygiene products and packaging.

Furthermore, the simulation model showed how the efficiency from a time perspective could increase at the distribution centre due to the introduction of RFID tags. This meant that fewer resources were needed in order to perform the goods handling activities which meant a great cost saving for the company studied (Hellström, 2003).

5.2 Ongoing projects

There are a lot of ongoing projects at the division of Packaging Logistics related to traceability. In this part, these are presented:

- *Risk sharing through supply chain traceability*
- *100 % connectivity – the potential impact of on-line solutions on next-generation supply/demand chains*
- *Packaging innovation - a supply chain issue*
- *New technology for food safety control – innovative methods for increased safety in food supply chains*
- *Innovative food logistics*

5.2.1 Risk sharing through supply chain traceability

With the aim of developing innovative business models with increased profitability in the next generation of food supply chains, the NGiL[8] project "Risk sharing through supply chain traceability" was initiated in 2006. Because of the increasing distances food products travel, it is essential to implement systems for product safety. Besides, it has been shown (Skjöldebrand & Lindh, 2007) that there is a need for different tools to show the potential of risk sharing and traceability in the food supply chain. Based on this, the overall purpose of the project was to explore, evaluate and increase the knowledge of the actors in food supply chains regarding handling and minimisation of risks in the supply chain, and to

[8] Next Generation Innovative Logistics, NGIL, is a VINN Excellence Centre based at Lund Institute of Technology, Lund University.

develop business models based on risk sharing and traceability through the next generation food supply chain in order to obtain increased profitability and protection of brand.

The researchers at Packaging Logistics involved in this project are Christina Skjöldebrand (Project manager and assistant scientific supervisor to Helena Lindh), Helena Lindh (PhD student) and Annika Olsson (Assistant professor and assistant scientific supervisor to Helena Lindh). Figure 12 below illustrates the outcome of the project so far.

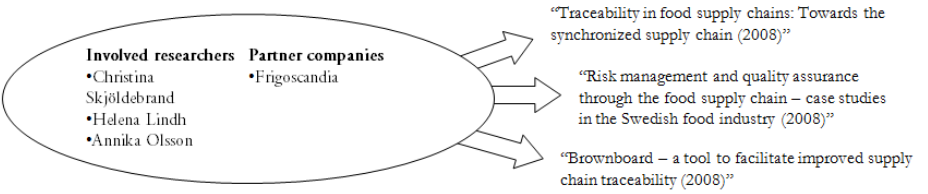

Figure 12. Risk sharing through supply chain traceability.

The different tools developed in the "Added value…" project were to be tested during workshops in 2007 and as a result of the test of the brownboard tool, the conference article "Brownboard - a tool to facilitate improved supply chain traceability" was published in 2008. In the article, the results of the brownboard workshop at Pipersglace and Engelholms Glass are presented along with the methodology for using the tool and a general description of the brownboard tool. The brownboard works as a tool within process mapping, with a focus on traceability issues, as described in the earlier "Tools" chapter. The workshop at Pipersglace showed that the brownboard tool can successfully be used in supply chains in order to address to traceability-related issues. When used at the focal company in the study, brownboard enabled identification of potential traceability improvements by visualising risks of losing traceability throughout the chain. The tool also enabled increased communication along the chain by creating a natural forum for discussions regarding supply chain issues. However, there has to be

some kind of working trust relationship between the different actors in the supply chain in order to share information; a factor which is critical when working with traceability issues (Lindh, Skjöldebrand & Olsson, 2008a).

In order to summarise the research performed in the area of traceability, with a focus on the Swedish supply chain until 2008, the journal article "Risk management and quality assurance through the food supply chain - case studies in the Swedish food industry" (Olsson & Skjöldebrand, 2008) was published. The research results show that there are five critical points in the food supply chain (see Figure 13), where problems occur between the different actors. Further on in the article different suggestions for improving the quality and safety of food in the Swedish food supply chain are presented. Some of these suggestions are to increase the knowledge of the actors in the supply chain through training, invest in quality rather than economy (right temperature rather than full trucks) and to change the attitude of the actors in the supply chain towards more holistic, supply-chain thinking where collaboration is necessary.

Figure 13. Generic food supply chain where critical points are marked (Olsson & Skjöldebrand, 2008, p. 54).

Conclusions drawn from the studies presented in the article were, for example, that the EU regulation is fulfilled by most of the actors. However, this does not mean that the regulation functions well; rather it is met to a minimum standard. Knowledge about what is happening in the critical points between actors is limited and has to be examined from risk and traceability perspectives. Olsson and Skjöldebrand (2008) also state that pro-activity means adding value based on traceability and risk sharing, and that the consumer has to be integrated as a part of the value chain. Implementing technology and systems are the factors mostly

focused on when it comes to traceability and risk management; consumer safety is not directly regarded. Finally, the authors state that their studies have shown that nobody in the supply chain has taken holistic responsibility of the supply chain (Olsson & Skjöldebrand, 2008).

The final outcome of the project to this date is the "Traceability in food supply chains: Towards the synchronised supply chain" by Lindh, Skjöldebrand and Olsson (2008b). Synchronisation means "that all supply chain functions are integrated and interact in real time; when changes are made to one area, the effect is automatically reflected throughout the supply chain" (Supply Chain Management, Glossary and Terms: *Synchronization)*. Based on a literature review and a single case study in the supply chain for frozen food in Sweden, the purpose was to examine the challenges raised by supply chain traceability and how traceability can be value-adding for the actors in the supply chain. Through the literature review, the authors found that the participation of all actors in a chain is vital in order to achieve supply chain traceability, something that was confirmed by the case study. Results further showed the challenges in order to achieve supply chain traceability which were of informational, physical, technological and economic contexts (see Figure 14).

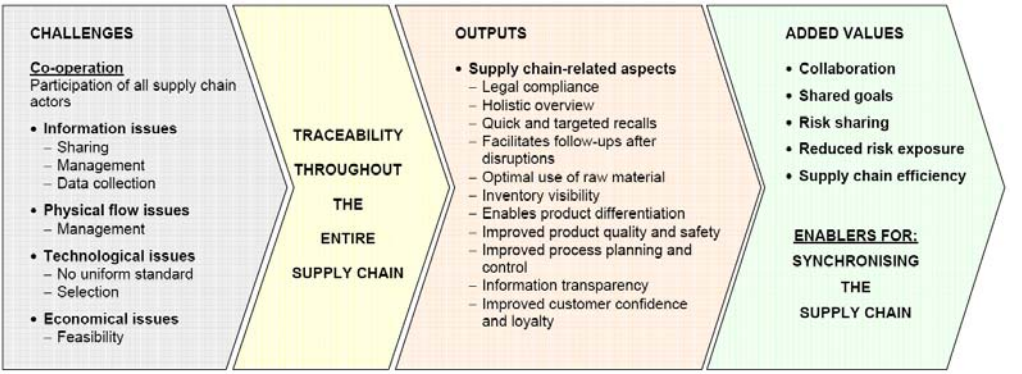

Figure 14. The challenges, possible outputs and added value of supply chain traceability (Lindh, Skjöldebrand & Olsson, 2008b, p. 5).

Even though a full supply chain perspective is not yet a reality from a traceability point of view, the study indicates that added value in terms of increased collaboration with shared goals, shared risks and benefits, reduced exposure to risks and increased supply chain efficiency can be gained through supply chain traceability. In literature, all of these components are regarded as enablers for synchronising a supply chain. Therefore, conclusions can be made from the study that supply chain traceability can enable supply chain synchronisation (Lindh, Skjöldebrand & Olsson, 2008b).

Summing up the results from the project so far:

- Tools and models have been developed and tested which are suitable for use in order to increase traceability and risk management ("Added value through risk management and traceability" and "Brownboard - a tool to facilitate improved supply chain traceability")
- Critical points in the Swedish supply chain, where food quality is likely to be affected, have been identified and some direct conclusions regarding traceability are drawn. ("Risk management and quality assurance through the food supply chain - case studies in the Swedish food industry")
- Supply chain traceability is an enabler for supply chain synchronisation, but there are a number of challenges which need to be overcome in order to achieve this. ("Traceability in food supply chains: Towards the Synchronized supply chain")

Future studies within the frame of the project are, for example, a study with a slightly more consumer-based focus. This study is about how companies can communicate to the consumer that they have traceability. For example, to communicate to the consumers that the vegetables they buy really are ecologically produced and to co-operate in the supply chain in order to achieve such a system.

5.2.2 100 % connectivity – the potential impact of on-line solutions on next-generation supply/demand chains

Started in 2007, the research project "100 % connectivity" was initiated on the behalf of the three companies, Pipechain, Volvo Cars and Volvo Logistics Corporation in order to examine if 100% connectivity could result in opportunities to establish a pipeline for electronic collaboration. The research application was written in collaboration with Andreas Norrman, Engineering Logistics, and Mats Johnson, Managing Director of NGIL, and assistant professor Daniel Hellström was assigned project manager. The term of 100 % connectivity refers to the ability of always being "on-line", being able to obtain and send information in real time. One of the aims of the project is to examine the role of information connectivity in making flexible logistics programmes successful. In order to examine how information sharing will be done, future studies and scenario planning are two of the methods used (NGiL research application, 2007b).

Examples of research questions for this project were:

- What do we mean when we talk about being completely on-line (100% connectivity)?
- What impact could connectivity- enabling technology have on supply/demand chains?
- What standards are needed?
- How will 100% connectivity affect risk management and risk analysis?
- How will these information-sharing trends in logistics impact on the supply chain in coming decades?

The project is also to be performed in close co-operation with PhD student Carina Johnsson, Engineering Logistics, who is focusing on the very closely related concept of visibility (as defined in chapter 1.6). At the division of Packaging Logistics, Karolin Grönvall is the

PhD student fully focusing on the project (NGiL research application, 2007b).

To date, the project has resulted in six different publications (2 master's theses and 4 articles) related to the area of traceability as shown in Figure 15.

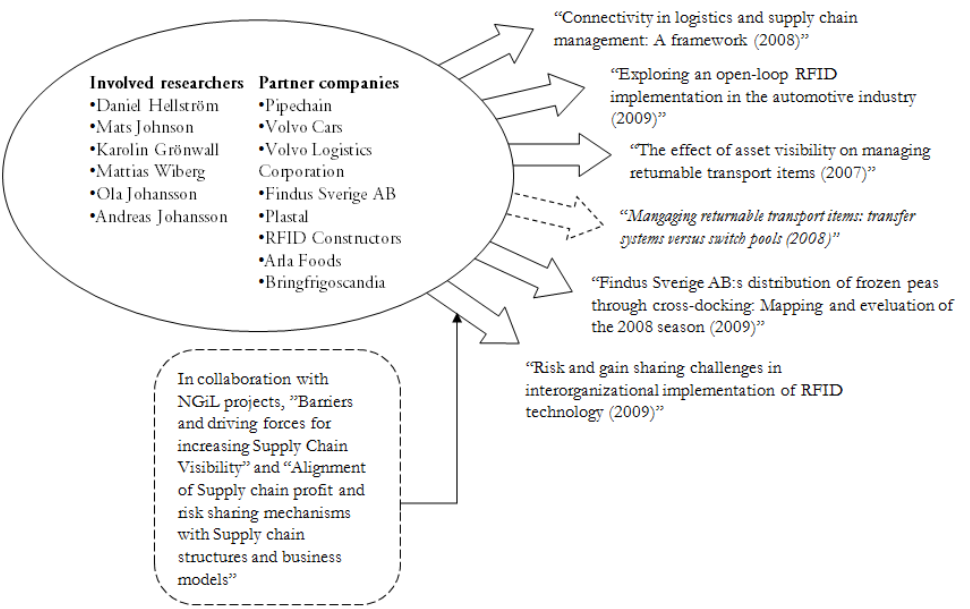

Figure 15. 100 % Connectivity - potential impact of on-line solutions on next generation supply/demand chains

In order to understand the concept of connectivity and answer the question of what connectivity actually is, a literature review was performed, resulting in the article "Connectivity in logistics and supply chain management: A framework"(Hoffman & Hellström, 2008). In Hoffman and Hellström's (2008) research they investigated the connectivity construct with regard to logistics and supply chain management and found that information technology, through standards and protocols, enables connectivity and connectivity, and through willingness and trust, enables information sharing. Traceability is closely linked to connectivity in the way that information sharing is essential to reaching traceability.

Furthermore, RFID could be seen as a "connectivity technology", providing unique product identity which is essential to establish a traceability system. Results of the research also showed that the term of connectivity in logistics and supply chain management is used in an informal manner in the sense of joining/integrating things (Hoffman & Hellström, 2008).

With the intention of examining how visibility affects the tracking of returnable transport items (RTIs), a case study was performed at Arla Foods (Johansson & Hellström, 2007). The authors looked at the existing RFID system at the case company, where tags are placed on the roll containers on which dairy products were transported. The aim of the implementation was to increase tracking capabilities thereby providing better visibility of the roll containers. From the tracking data available after running the system for some time, simulation models could be created in order examine how different scenarios could alter the behaviour of the system. The results of the different scenarios show that fleet size could be changed without having to decrease the availability of the RTIs. Another result of the case study was that a tracking system with inadequate data-analysing and reporting capabilities provides limited visibility. Furthermore, asset visibility does not guarantee that firms are able to use increased information, or, more importantly, to use it efficiently.

As a joint venture between the division of Engineering Logistics and Packaging Logistics, and between different NGiL projects ("Barriers and driving forces for increasing Supply Chain Visibility: Impact of business models and incentives" and "Alignment of Supply chain profit and risk sharing mechanisms with Supply chain structures and business models"), a paper which examines how risk and gains are shared between firms with regards to RFID implementation was published in 2009. In the research presented a case study was performed in the automotive industry resulting in a framework of the potential risk and gain sharing factors. When implementing RFID across organisational borders, the sharing of

information, technology and financial resources is critical to success, and the research provides a framework of how supply chain organisations can identify these risk- and gain-sharing challenges. According to Hellström, Johnsson and Norrman (2009), the identification of risks and gains is relevant because it allows supply chains to take steps towards the alignment of supply chain incentives which in the end could lead to increased co-ordination and integration of the whole chain (Hellström, Johnsson & Norrman, 2009).

One of two master's theses connected to the overall area of traceability originated from the "100 % connectivity" project was the "Findus Sverige AB's distribution of frozen peas through cross-docking: Mapping and evaluation of the 2008 season" by Johansson (2009) done in collaboration with the transport company Bringfrigoscandia and the cold/frozen storage provider Sydfrys. In this thesis, the author investigated the result of a change in distribution by developing a cross-docking centre and new bags and internal containers at one of Sweden's biggest food-producing companies; Findus. Before the development of this new cross-docking centre, the distribution of peas had been uncoordinated, the fill rate during transport was very low and pallets were sent randomly, making it impossible to label products according to the quality of the peas. The question the thesis aimed to answer was how the material and the information flow, with a focus on the new cross-docking centre, would be affected. Some of the results when the change of distribution was evaluated were that labelling had correct information when it left the cross-docking centre and the fill rate had increased. The author also points out the importance of a well-functioning information system in this kind of supply chain with high variations in volume. In Findus' case, the system functions well, allowing products to be traced through the chain.

The most recent outcome within the frame of the connectivity project is the master's thesis "Exploring an open-loop RFID implementation in the automotive industry" by Wiberg (2009), where a case study at one of the biggest automotive suppliers,

Plastal, has been made. Plastal's production plant in Gothenburg (PAGO) had recently constructed one of the biggest open-loop RFID implementations within the Nordic region and the thesis aimed to describe and explore *how* and *why* Plastal had implemented the RFID system. The difference between closed-loop and open-loop RFID implementation is that in open-loop implementation, the product being tagged is not necessarily transported back to the point of origin, which it is in a closed-loop setting. One of the reasons why Plastal wanted to go through with RFID implementation was to increase traceability. The results of the thesis showed the complications of the system; the system reading too much or too little are the most obvious problems. Recommendations for future RFID implementations are to increase knowledge about RFID technology (tags, readers and supporting systems) before implementation and define roles and goals of the actors involved in advance.

A summary of the outcome of the project so far:

- Literature reviews have shown that connectivity lacks a clear definition, but is described as the link between information technology and information sharing.
- Different RFID implementations have been studied. Results show that trust, and willingness to share information, technology and costs, as well as knowledge, are essential to success. Information does not automatically provide effective visibility and traceability; you have to know what to do with it.
- A case study has also shown how the development of a cross-docking centre improved both informational and physical flows.

As can be seen from the outcome of the project so far, much of the research has focused on RFID and how implementation of RFID systems functions in different settings. Since RFID can be regarded as a connectivity technology this is well in line with the overall purpose of the project. According to Daniel Hellström (in an interview), future studies within the project will, for example, be,

looking at how information sharing will be in the future where the focus will not only be on purely technical issues, it may as well be on 'softer' aspects such as willingness and trust.

5.2.3 Packaging Innovation - a supply chain issue

In order to explore and increase the knowledge of packaging innovation processes in a supply chain context, the project "Packaging Innovation – a supply chain issue" was started up in September 2008. The aim of the project is to provide guidelines to NGiL (Next Generation Innovative Logistics) companies involved on how to increase packaging innovation in the supply chain. It has been shown that integration between the different processes such as product development, supply chain/logistics development, and marketing is fairly limited and the advantages of such a holistic view have not been highlighted. With this aim, the project is guided by two main questions:

- Why is the potential of integrated packaging and product/supply chain/marketing development not realised?
- Why is the potential of collaborating with other actors in the supply chain – suppliers and customers – for new innovative product/packaging solutions not realised?

The project manager of this project is Fredrik Nilsson, Assistant professor while Malin Olander, PhD student and Bengt Järrehult, Adjunct professor are assigned to the project as shown in Figure 16. Involved companies are Sony Ericsson[9], SCA[10], Axis[11], Apoteket[12], COOP[13], ICA[14], Schenker[15] and Tetra Pak[16] (http://www.ngil.se).

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[9] A joint venture between the companies Sony and Ericsson developing, manufacturing and selling mobile phones.
[10] SCA is a big Swedish company in the paper industry producing hygiene products and packaging.
[11] Swedish company providing solution for network video surveillance.
[12] Sweden's single retailer of pharmaceuticals.

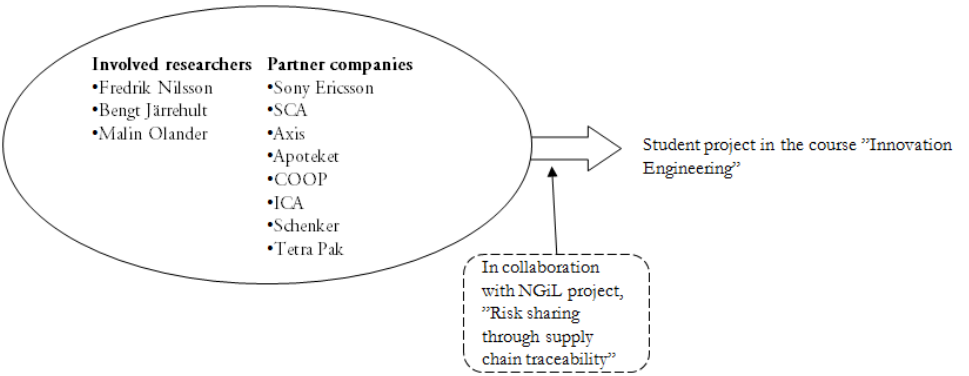

Figure 16. Packaging Innovation - a supply chain issue.

The outcome so far, connected to the area of traceability, has been a student project in the course of "Innovation Engineering", managed by Fredrik Nilsson. One of the projects in this course resulted in a new, innovative packaging solution which can tell whether food inside the packaging is fresh or not. Consequently, the consumer does not have to throw away the food even if the "best-before-date" has passed. The business plan of this innovation has proceeded to the Venture Cup[17] competition and will continue to be developed in the "Packaging Innovation" project in collaboration with the project "Risk sharing through supply chain traceability". Since the product is an object which can trace temperature, the business plan falls under the frame of traceability. The consumer will be able to look at the product and say something about its history, in this case if the product has been kept at the correct temperature or not.

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[13] Swedish retail chain selling everyday goods.
[14] The Nordic region's biggest retail chain selling everyday goods
[15] German transport company
[16] Swedish company manufacturing machines and packaging for liquid food.
[17] Venture Cup is a Swedish competition in entrepreneurship held each year.

Future studies with a traceability connection might be the possible study of environmental aspects, how it is possible to ensure that packaging has been manufactured in an environmentally friendly way and with focus on sustainable development. In that kind of project, traceability will have a part.

5.2.4 New technology for food safety control – innovative methods for increased safety in food supply chains

"I think that this project belongs in the area of traceability, since it is about quality assurance of food and packaging. We are about to create some kind of measuring tool which in the end could be implemented in industry in order to secure the quality of the products." – Annika Olsson, Assistant Professor.

A joint venture between the division of Packaging Logistics and Atomic Physics at LTH started up in 2007. The division of Atomic Physics has developed a new laser spectroscopic technique (GASMAS (GAs in Scattering Media Absorption Spectroscopy)) which could be used for monitoring foodstuffs once packed but without having to destroy packaging, in order to ensure safe, high-quality food. Together with Packaging Logistics; different tests were to take place. As mentioned earlier in this report, avian flu, dioxin in chicken feed and mad cow disease had affected the food industry, damaging the brand owner directly and the whole supply chain indirectly, making the customer and consumer less loyal. Consequently, techniques which can ensure food safety are essential. This project aimed at testing and evaluating the GASMAS technique with an initial focus on packaged meat products in order to see if the technique could be used to ensure food quality. Another goal of the project was to identify potential scenarios for minimising recalls and risks in the food supply chain based on this laser method (NGiL research application, 2007a). The involved companies and the outcome of the project so far are illustrated in Figure 17.

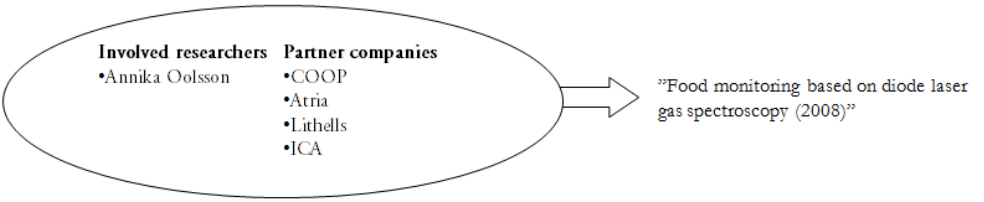

Figure 17. New technology for food safety control - innovative methods for increased safety in food supply chains.

At the time of writing (June 2009) the project has resulted in the highly technical publication "*Food monitoring based on diode laser gas spectroscopy*" (Lewander et al, 2008) where the results from the pre-study are presented. The results of the pre-study illustrate the feasibility of the technique where tests were made on minced meat packages, bake-off bread and milk cartons. The measurements of the bake-off bread are promising in the way that they indicate that the GASMAS technique is suitable for non-intrusive monitoring of the tightness of the food package. After these proof-of-principle tests the aim is to perform in-depth studies of different products in close co-operation with expertise in corresponding fields (Lewander et al. 2008).

5.2.5 Innovative food logistics

An industry-based project in collaboration with the companies Procordia, Tetra Pak, Schenker, COOP, ICA and Dagab is currently being carried out at the division of Packaging Logistics. The project aims to investigate what happens when going from internal to external traceability, which involves several actors in the food supply chain. The purpose is to look at the conditions for using traceability in order to create added value, and to lower the risks in the supply chain both for the consumer and the actors involved.

In addition, a virtual model has been created. This model can show all the actors involved in the supply chain and show how different factors, such as temperature as well as informational and relational factors, affect food. The central message is that in a distribution

network, traceability provides an opportunity to create food safety on several levels. The model can also show the links between increased traceability and more effective value chains in the food industry (Wikström, 2009).

5.3 Other activities

Besides the projects reported in this part, there are some other ongoing activities connected to traceability at the division of Packaging Logistics:

- A PhD course in quality assurance has been developed and executed. The purpose of the course is to conduct a case study to apply current regulations as well as industry and market demands in food and pharmaceutical industries in order to gain insights into the demands for quality assurance and traceability in these industries. The most recent course resulted in the report "A Case study in Dark" where the course members developed a fictional chocolate company in order to describe product development associated with risk management, quality assurance and traceability (Lindh, Nilsson, Ringsberg, Urciuoli & Wallin, 2008).
- A new project, managed by Christina Skjöldebrand and Anders Lareke called "New innovative logistic solution for small scale food processing" started in April 2009. The aim is to develop a model to transfer knowledge from academia to practical implementation dealing with issues for small-scale food processing. Two of the areas this model is to be created for are logistics and food safety.
- A new project at SLU Partnerskap Alnarp[18], a project which is a part of a big EU project called TRACEBACK, focuses on traceability and quality assurance in the food supply chain. The purpose is, over two years, to develop a new topic together with involved industrial partners, organisations and researchers

[18] Swedish Agricultural University

at SLU Alnarp and to show the usefulness of academic research, industry and society with a focus on traceability. Christina Skjöldebrand is one of the members in the support group to this project.

- A relatively new project called "Traceability for increased consumer trust, communication and logistical efficiency in the fish industry" is being carried out at the division by Henrik Ringsberg in association with Fiskeriverket (the Swedish Board of Fisheries). This project aims to develop methods to increase the informational flow in the supply chain for chilled fish (initially) and to look at informative and communicative interfaces between companies. This is strongly connected to the problem of different companies having different information systems where a great deal of information is being transferred manually. The project will not only examine ways to improve the informational flow, but also look at what information the different actors in the supply chain need to ensure traceability.

6. Partner companies involved so far

In this chapter, companies connected to traceability research at Packaging Logistics are presented. The essential outcome for the specific companies is briefly described in Appendix C in order to show how these companies benefited from being involved in the research performed.

As previously stated and briefly described in the previous chapter, several companies from different industries have been involved in the research performed at the division of Packaging Logistics. Case studies have been carried out at some of these companies, while others have acted as financiers. In Appendix C, the companies involved are listed. The publication, where results from industry-related research the different companies have been involved in, are also noted in Appendix C. The essential outcome refers to how companies have been involved and what the research resulted in.

In line with previous categorisation (see chapter 3), the companies involved are active in food and non-food industries. The companies working in the food industry include:

- Arla
- Bringfrigoscandia
- Brämhults Juice AB
- Bioett
- Cloetta Fazer
- Coop Sweden AB
- Dagab
- Engelholms Glass
- Findus
- ICA
- Karlshamn Åhus
- Karlsson & Keitsch

- Lantägg
- LRF
- Pipers Glace
- Procordia Food AB
- Skånemejerier
- Tetra Pak Processing Systems
- Vin & Sprit

Research in association with these companies has mainly focused on developing methods and tools based on both internal and external traceability in order to ensure high-quality, safer foodstuffs. The exceptions are Arla and Findus. The case study performed at Arla was intended to implement RFID in order to track roll containers carrying primary packages of milk. Findus was involved in one master's thesis where the author looked at the distribution of peas when a cross-docking centre was used. Even though these companies are working in the food industry, the primary goal of the research performed has not been to increase product safety.

Companies involved in research from industries which do not deal with food include:

- IKEA
- Philips Semiconductors
- Plastal
- SCA Packaging
- Scania
- Schenker AB
- Stora Enso
- Sydfrys
- Volvo Cars Body Components
- Volvo Logistics Cooperation
- Volvo Information Technology
- ABB

These companies work in industries ranging from transport and automotive fields to information technology. Research performed where these companies have been involved has, to a great extent, examined implementation of RFID (see Appendix C) in different contexts, and results have showed its potential. Furthermore, even though the companies do not work in the food industry, some of them have been involved in research done in said industry. Bioett, working with innovative labelling which can show temperature disturbance, was for example involved in three master's theses where the Swedish cold chain was examined. .

In addition to the companies described in Appendix C, research has been conducted where the companies involved have been anonymous.

- In the article "*Towards a framework for designing logistical RFID systems*" (Pålsson, 2008b), results of a case study at a German retail chain were presented. In this case study Pålsson examined how RFID tags attached to chocolate bars could improve supply chain performance. Findings from this case study include the identification of essential elements when implementing RFID. These include investments and information systems, as well as technical and organisational issues.

7. Discussion and suggestions for future studies

In this final chapter, a discussion regarding the research to date is presented, based on published material and with input from interviewees. Furthermore, some recommendations on where to focus research in the future are presented.

The previous chapters have described research and the outcome of research extensively and from different angles. The construct created showed which areas of traceability research has been conducted in, while the projects showed which research has been carried out and which activities are still ongoing. Chapter 6 showed the companies involved, illustrating the diversity of companies involved in traceability research at Packaging Logistics. When looking at the tree which symbolises research at Packaging Logistics (see Figure 18 below), this report has illustrated the connections to related areas of research such as visibility, connectivity and Auto-ID technology as well as other areas like transparency and packaging innovation. These connections to other areas of research are also proof of the size of traceability as a research area.

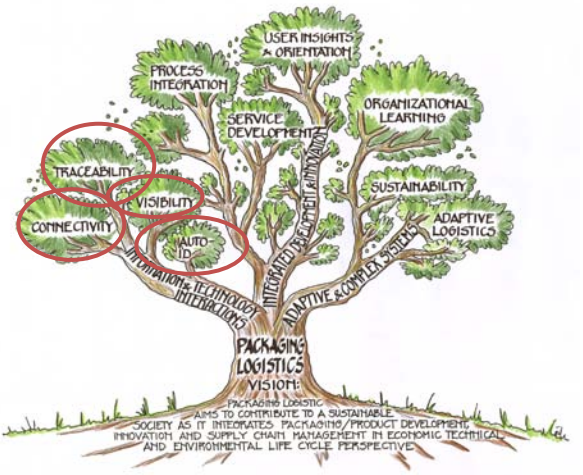

Figure 18. Research areas connected to traceability at Packaging Logistics.

Research associated with traceability performed at Packaging Logistics has been versatile, allowing a comprehensive framework to be created. As presented in previous chapters, traceability related research at the division of Packaging Logistics has been focusing on external traceability and has to a large extent been performed in the food industry and in food supply chains (see Figure 4).

By connecting the main focus in the different publications, where results from traceability research has been presented, to the identified traceability construct (see chapter 3) the result show what parts of the construct that has been in focus in research. This is illustrated in Figure 19, where the circles represent the identified traceability related publications (see table 1, 2 and 3), marked with different colours (red for food industry, blue for non-food industry and green for no specific industry). These circles have been placed at the part of the traceability construct that it is primarily dealing with, clearly showing the research focus with regard to different industries and areas of traceability research.

As can be seen in Figure 19, publications related to other industries than food (blue circles) has almost exclusively dealt with Auto-ID technology. This research has proved that Auto-ID technology in general, and particularly RFID, could be used in order to enable traceability. RFID could thereby be regarded as a "traceability-enabler".

When it comes to research performed in the food industry, the related publications have focused on more varying aspects of the traceability construct. What can be said is that this research to a large extent has been dealing with how traceability could be used as a mean of ensuring consumers that food is safe and that high quality products can be guaranteed. Furthermore, research in food-industries has allowed the development and evaluation of traceability tools. These tools can help companies in their work towards achieving full chain traceability. Furthermore, the added values have been in focus, where the potential benefits with

traceability have been pointed out – essential for companies due to the costs traceability is associated with. If companies realise that increased traceability could lead to higher-quality products and, in the end, more satisfied customers, there will most certainly be bigger investments in developing high-quality traceability systems.

"In contrast to other [research divisions], we at Packaging Logistics have had two orientations that differ from the traditional view on traceability. The first thing is that is a supply chain issue and the second thing is that it, not only, is re-active, but could be value-adding and pro-active as well. These orientations will remain." – Researcher at Packaging Logistics.

It has been said that Packaging Logistics should focus on the external traceability, because it is most important. Internal traceability must, of course, not be forgotten but it should be linked between different actors. It is in the interface between different actors where most critical points are located and where traceability could be lost. This has clearly been illustrated in publications, where only three of the related publications focus on internal traceability.

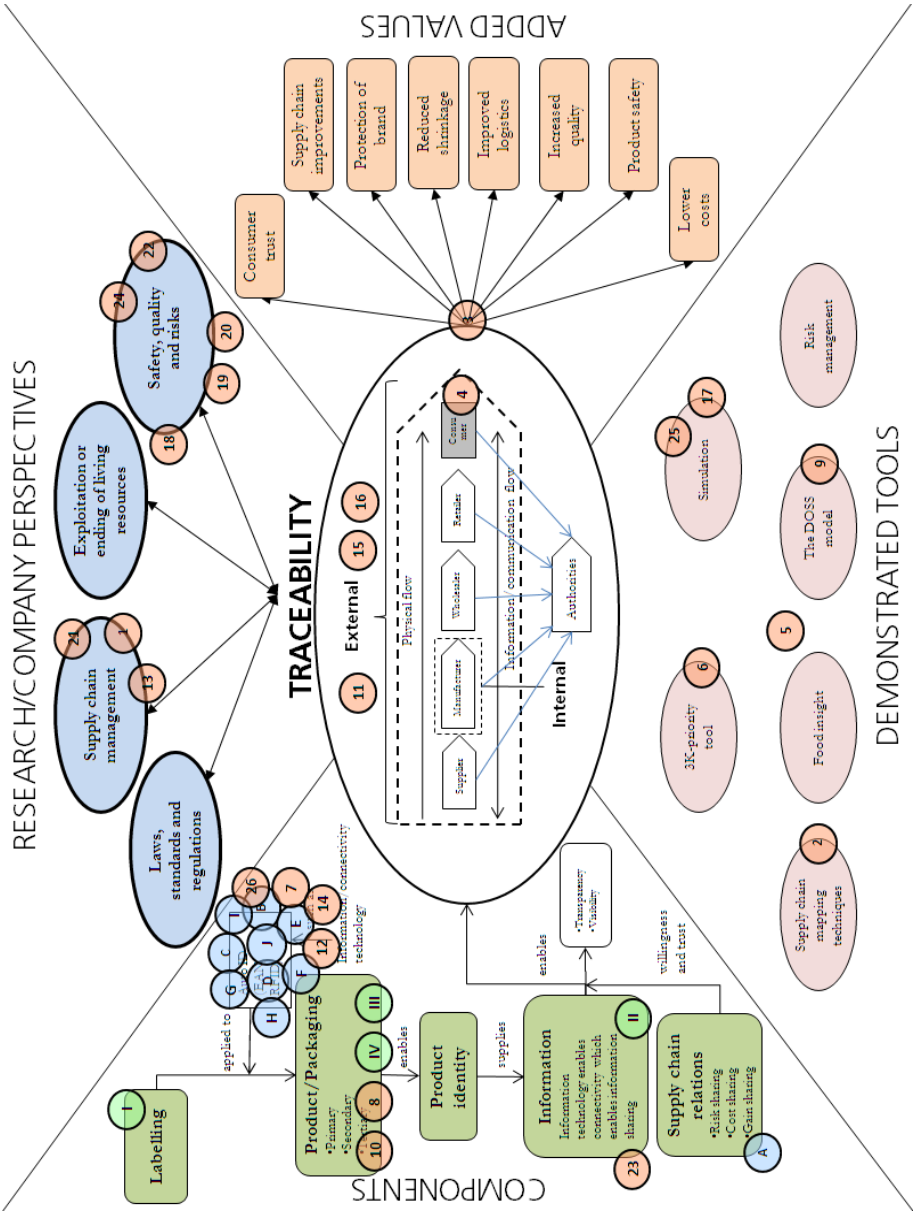

Figure 19. Research focus according to the identified traceability construct.

Explanation: Nr. 5 for example is placed in the part of *Demonstrated tools*, which means that this specific publication deals with a number of demonstrated tools within the food industry. Circles placed on a specific part illustrates that this publication mostly or exclusively deals with this specific area. The numbers 11, 15 and 16 is placed above the supply chain, illustrating that these publications generally deals with external traceability in food supply chains, and no specific part of the construct.

Another aspect which research at the division of Packaging Logistics has taken into account is the consumer's role in the area of traceability. This perspective has been a significant one to consider, especially when focusing on food, since the consumer is the one who runs the risk of getting sick from contaminated foodstuffs. Furthermore, as pointed out in relevant research (Olsson & Skjöldebrand, 2008; Lareke, 2007), the consumer is the person evaluating the added values of the product. One of the researchers at Packaging Logistics, explains: "W*e are also talking about a value-perspective for the consumer; that traceability can be used in order for the consumer to know about the history of the products in order to feel safe. In my opinion, this is the most important thing – to make sure that the product the consumers buy is safe and that the consumers feel safe about it."*

The review of traceability-related publications, projects and companies, as well as the interviews done with the staff at the division show the great knowledge found at Packaging Logistics. Research has been wide, and it is not that easy to point out specific areas where it has been lacking. However, some recommendations will be given in this part, based on interviews and problems pointed out in relevant literature.

When it comes to recommendations for future research, there are industries interesting for traceability purposes which have not been looked into in detail. From the interviews it is clear that an interesting industry to look in to is that of pharmaceuticals. One of the researchers at Packaging Logistics says: *"Traceability for me is highly linked to foodstuff, but it could also be to ensure that it is original products in packaging. I know that this is a problem in many industries, but the industry that worry me the most is the pharmaceuticals. There is no bigger harm done if I receive a malfunctioning cell-phone as if I would receive a fake medicine."* Another researcher agrees and states that *"food, care and pharmaceuticals are areas where [traceability] need to function. What I think that we are lacking is a pharmaceutical case within traceability. The pharmaceutical industry has been so much more regulated - there should be a lot to learn from this industry."*

The pharmaceutical industry is similar to the food industry in many ways, in that medicine is often something that you put in your mouth, and the need for product safety is important because of the health risks that consumers can be put at if the medicine is incorrectly composite. Consequently, much of the knowledge gained from food-related research can be transferred to this industry. At the same time, this industry is heavily regulated, and there are probably many things which can be learnt about traceability, product safety and quality which can in turn be transferred to research in other industries. A strong recommendation would be to find appropriate case studies with a full-chain traceability focus in the pharmaceutical industry. In this way, traceability could be used in order to decrease the risk of counterfeit, thereby reassuring consumer that the medication they have taken is genuine.

Regarding the components in the traceability construct previously presented, two things have been particularly pointed out in research as the biggest obstacles to achieving external traceability. One of these obstacles is the fact that information systems between different actors have problems communicating, and the other one is that the supply chain actors need to increase collaboration and trust in order to be willing to share information. This is stated in several publications and a recommendation would be to look deeper into this and try to understand the problems; partly from a technical perspective and partly from a "softer", non-technical, relational perspective, and comprehend what incentives supply chain actors might have for information sharing, i.e. what the drivers are.

"Another problem with the EU-regulation and traceability in general, is that no one takes responsibility for the overall traceability. Everyone looks after their own backs so to speak." – Researcher at Packaging Logistics.

"We almost have no laws in the food industry. So there should be some actor holding the chain together and that does not exist today." – Researcher at Packaging Logistics.

As pointed out in research and interviews, another issue regarding external traceability is the fact that there is no actor in the supply chain having the overall responsibility. There is a need for an actor in the supply chain having a holistic perspective, keeping the supply chain together in terms of collaboration and making sure that correct and updated information is available in order to improve the informational flow.

In addition, the focus of future research should continue to be on the critical contexts in the supply chain. These have been pointed out both in literature and in interviews as being essential to achieving the benefits offered by traceability. Besides, supply chains are becoming even more complex and consumers are becoming more and more "tyrannical" (Lareke, 2007), which increases the need to investigate these aspects.

Furthermore, research which deals with industries other than food almost exclusively concerns RFID technology (implementation/conceptualisation/design) on packaging and mostly with the purpose of tracking. The traceability aspect is a result of that, as traceability is made possible if tracking data are saved. It is pointed out that RFID is one of the enablers for achieving traceability, even though the focus, to a great extent never seems to have been traceability from the beginning. The research carried out in the food industry has looked mainly at the different aspects of traceability, where RFID technology has been one of the components. The difference is that in food-related research, research has started with traceability (in order to ensure product quality and safety, for example) which has led to RFID, while in non-food-related research it has been the other way around, in order to increase visibility, for example. Besides, the researchers focusing on food have never been involved in any research in

collaboration with the ones focusing on Auto-ID technology. There might be knowledge which could be transferred between the different researchers working at the division, and a joint case study between the researchers focusing on Auto-ID and the ones focusing on traceability in food supply chains might lead to interesting results. One of the researchers at Packaging Logistics expand the resoning: "*"My wish is that research will be of a more technical nature. More exactly; how to use different identification techniques in order to achieve traceability in food supply chains. The identification techniques have been highly reserved to supply chains for non-food products such as spare parts for cars. I think that it is time to look at the supply chain for food in this matter. [..] In this case it is important to look at standardization of metadata and information – too take it one step further."*

The recommendations suggested above could be examined in a large, new project; such as a project in the pharmaceutical industry focusing on traceability in order to reduce the risk of counterfeit. In such a project, knowledge gained from previous research could be transferred, not only from the previous research which fully focused on traceability, but also from other research areas such as connectivity. Within the frame of a large research project, collaboration between other ongoing projects would be desirable.

Below follows a summary of the recommendations connected to the framework constructed in this report:

Industries:

- Traceability research within the pharmaceutical industry could contribute to reducing the risk of counterfeit of medicine as well as evaluating tools, i.e. brownboard and the DOSS model in another industry than food. In the end this would lead to safer products. Much of the research carried out in the food industry would most certainly be applicable to case studies in the pharmaceutical industry and knowledge from such case studies could most certainly be transferred to other industry-related research.

Information:

- Keep looking at methods in order to share information more easily between different actors in the supply chain. Research has shown the difficulties which different actors have in connecting their information systems, leading to a substantial amount of manually transferred information (Eken & Karlsson, (2006); Olsson & Skjöldebrand, (2008)). This equals a risk of losing information which in the end could lead to a loss of traceability.
- Keep looking at drivers for information sharing.

Auto-ID technology:

- Collaboration between researchers focusing on Auto-ID and researchers focusing on food supply chains. Although Auto-ID has been pointed out as an enabler for external traceability, no research has been done in collaboration between Auto-ID experts at the division and researchers focusing on foodstuffs.

Safety, quality and risks:

- The critical contexts in the food supply chain are pointed out as important areas, where traceability is more likely to be lost which will continue to increase in significance. Maintaining a focus on these critical contexts is advisable.

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Appendix A – Interviews

Interviews/discussions regarding traceability and the research performed at Packaging Logistics were held with the following researchers:

- Helena Lindh, PhD student, April 16, 2009
- Caroline Grönwall, PhD student, April 20, 2009
- Henrik Ringsberg, PhD student, April 20, 2009
- Annika Olsson, Assistant professor, April 23, 2009
- Sandra Silgård Casell, PhD student, April 29, 2009
- Henrik Pålsson, PhD student, May 06, 2009
- Märit Beckeman, PhD student, May 06, 2009
- Fredrik Nilsson, Assistant professor, May 07, 2009
- Daniel Hellström, Assistant professor, May 08, 2009
- Christina Skjöldebrand, Adjunct professor, May 28, 2009
- Mats Johnson, Associate professor, June 01, 2009

Appendix B – Content of publications connected to traceability

	Industry																																									
	Non-food									Food																													Unspecified			
	Automotive				Paper	Furniture	Other/Combination			Chilled				Frozen						Liquid		Other/Combination																			
Context	Hellström et al (2009)	Wiberg (2009)	H ellström (2006)	Hellström & Johansson (2006)	Pålsson (2008a)	Morén & Samuelsson (2002)	Hellström (2009)	Hellström (2007)	Johansson & Hellström (2007)	Olsson (2004)	Olsson & Skjöldebrand (2008)	Sparks et al (2006)	Klevås & Karlberg (2001)	Skjöldebrand & Lindh (2007)	Lindh et al (2008a)	Lindh et al (2008b)	Olsson & Ousbäck (2003)	Johansson (2009)	Eiken & Karlsson (2006)	Ohlsson & Svensson (2005)	Östergren et al (2008)	Pålsson (2008b)	Lareke (2007)	Pålsson (2006)	Beckeman & Olsson (2005)	Allklint & Göransson (2004)	Hellström (2004)	Johnsson et al (2003)	Örjas & Severius (2003)	Clemedtsson et al (2008)	Lewander et al (2008)	Nilsson & Lundin (2008)	Björklund (2002)	Skjöldebrand & Samuelsson (2003)	Lindh et al (2008)	Wikström (2009)	Hellström (2003)	Hoffmann & Hellström(2008)	Pålsson & Johansson (2008)	Nilsson & Pålsson (2006)	Jönsson (2001)
Internal traceability			X											X	X					X	X					X									X		X				
External traceability	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X
Methodology																																										
Case study	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X		X		X		X		X			X				X					
Literature review	X				X	X		X	X	X	X	X	X			X						X	X	X		X			X	X			X					X		X	
Interviews/Survey						X							X				X	X					X		X				X	X			X						X		
Information																																										
Information sharing	X	X						X							X	X		X	X		X					X			X	X			X	X				X	X		
Information systems						X					X							X	X					X		X			X	X				X				X	X		
Connectivity		X																																				X			
Information technology	X	X	X	X	X	X		X				X				X			X					X				X	X	X				X			X	X			X
Visibility					X		X		X						X																			X		X		X	X		
Transparency										X	X												X											X		X					
Product identity																																										
Auto-ID (general)						X		X				X					X									X			X	X								X	X	X	X
RFID implementation	X	X			X		X	X	X			X										X		X						X											
RFID simulation/design			X	X					X																			X									X				
Packaging																																										
Innovation								X				X													X						X										
Packaging level						X		X				X												X	X	X			X					X	X				X	X	X
Labelling						X						X						X								X			X					X	X				X	X	X
Risks, safety and quality																																										
Risk management										X	X		X	X	X					X	X					X				X		X	X			X						
Quality assurance										X	X	X	X	X			X			X	X					X			X	X			X	X	X							
Product safety										X		X	X	X			X			X	X					X				X	X		X	X	X	X						X
Critical contexts										X	X	X	X	X			X		X		X					X			X	X			X			X						
SCM																																										
Distribution					X	X		X					X				X	X								X		X	X	X			X			X	X				
Risk sharing	X									X	X			X	X	X																X									
Cost sharing	X																							X																	
Collaboration	X					X				X	X		X		X	X	X					X		X	X	X			X	X			X					X	X		
Tools																																										
Simulation									X					X							X					X		X				X				X						
Brownboard														X	X						X																				
Other														X						X	X																					
Consumer																																										
Value creation										X	X			X	X						X		X							X		X	X	X		X						
Economics																																										
Cost analysis			X	X		X	X	X	X									X		X									X	X											

Appendix C – Involved companies

Name	Industry	Publication	Essential outcome
Arla Foods	Dairy	*The effect of asset visibility on managing returnable transport items (2007)*	The implementation of RFID on the companies roll containers provides asset visibility if combined with adequate informational management and data analysis.
		The cost and process of implementing RFID technology to manage and control returnable transport items (2009)	By introducing an RFID tag on roll containers, the loss of these containers went down from 1 out of 5 to nearly zero per year. Pay-back time for the system was calculated as 14 months.
Bioett	Labelling	*Kylkedjan för livsmedel – en kartläggning av den svenska distributionen med fokus på temperaturbrister (2002)*	Bioett financed the master's thesis where the authors examined temperature disturbances in the Swedish cold chain. Results showed, for example, that there is a lack of communication between the different actors in the cold food chain and that this leads to a non-existent holistic view of the cold food chain.
		Distribution av temperaturkänsliga livsmedel (2002)	Bioett financed this research as well, where the author looked at the distribution of both chilled and frozen food in Sweden.
		Säkerställande av en obruten kylkedja – vision eller verklighet (2003)	Researchers examined if the Bioett tag could assist in the securing of an unbroken cold chain in Sweden. Results showed that the Bioett tag could be used to secure product quality.
Bringfrigoscandia	Transport	*Findus Sverige AB:s distribution av frysta ärtor via cross-docking: Kartläggning och utvärdering av säsong 2008 (2009)*	Research done in collaboration with, amongst others, Bringfrigoscandia with the purpose of examining the logistical flow of peas. Results showed the importance of a well-functioning information flow and cross-dock capacity.
Brämhults Juice	Soft drinks	*DOSS - Värderingsmodell för riskerna vid tillverkningen av flytande livsmedel (2005)*	The DOSS model was developed during the writing of the master's thesis which could be used to evaluate the costs of operative risks. The model was evaluated on Brämhults' activities with results showing that two primary sources of risks existed: production stop and contamination.

Coop Sweden AB	Food retailer	*Livsmedelssäkerhet ur ett försörjningskedjeperspektiv (2006)*	Coop Sweden was the food retailer in the case study where the authors examined critical points in the food supply chain. Resulted in the priority tool 3K, which can show companies which critical points which are to be prioritised.
Engelholms Glass	Ice-cream	*Brownboard - A tool to facilitate improved supply chain traceability (2008)*	Brownboard can be used as a tool for identifying potential traceability improvements by its visualisation of flow throughout the supply chain and through highlighting potential risks connected to traceability for supply chain actors. The tool was tested with successful results at Engelholms Glass.
		Addera värden genom riskhantering och spårbarhet (2007)	Strategies have been developed which ensure profitability in the long run by protecting the brand through activities based on risk management and traceability. There are a number of techniques which can be used in order to transfer knowledge from the university to the business world. Brownboard and simulation are some of the techniques which can be used.
Findus	Food (mainly frozen)	*Findus Sverige AB:s distribution av frysta ärtor via cross-docking: Kartläggning och utvärdering av säsong 2008 (2009)*	The master's thesis was written in collaboration with Findus with the purpose of examining the logistical flow of peas. Results showed the importance of a well-functioning information flow and cross-dock capacity.
IKEA	Furniture	*The cost and process of implementing RFID technology to manage and control returnable trans port items (2009)*	RFID implementation showed that it could be used to track steel containers (increasing visibility). Pay-back time for the implementation was calculated as less than 2 years.
		Nyttan med RFID I IKEAs försörjningskedja – ett sätt för IKEA att uppnå spårbarhet (2002)	The master's thesis examined how RFID could improve traceability in the supply chain for IKEA. Important demands for successful implementation were the following: an automatic identification system, an integrated information system and an integrated supply chain.
Karlsson & Keitsch AB	Food wholesaler	*Livsmedelssäkerhet ur ett försörjningskedjeperspektiv (2006)*	Karlsson & Keitsch was the food wholesaler in the case study where the authors examined critical points in the food supply chain. This resulted in the priority tool 3K, which can show companies which critical points are to be prioritised.

Philips Semiconductors	RFID Technology	*Intelligent packaging from a distribution perspective (2003)*	Philips Semiconductors was one of the involved companies in the SCA project where an RFID simulation was carried out in a Dutch retail chain. Results showed that implementation of RFID could increase effectiveness.
Pipers Glace	Ice-cream	*Brownboard - A tool to facilitate improved supply chain traceability (2008)*	Brownboard can be used as a tool for identifying potential traceability improvements by its visualisation of flow throughout the supply chain and through highlighting potential risks connected to traceability for supply chain actors.
		Addera värden genom riskhantering och spårbarhet (2007)	Strategies have been developed which ensure profitability in the long run by protecting the brand based on risk management and traceability. There are a number of techniques which can be used in order to transfer knowledge from the university to the business world. Brownboard and simulation are some of the techniques which can be used. The techniques were evaluated at Pipers Glace with successful results.
Plastal	Automotive supplier	*Exploring an open-loop RFID implementation in the automotive industry (2009)*	The author looked at one of the biggest open-loop RFID implementations in Scandinavia. Results showed that the main problems were that the readers read too much or too little. The recommendations were to increase the involved actor's knowledge regarding RFID technology before implementing RFID in the supply chain and define roles and goals in advance.
Procordia Food AB	Food manufacturer	*Livsmedelssäkerhet ur ett försörjningskedjeperspektiv (2006)*	Procordia Food was the producer in the case study where the authors examined critical points in the food supply chain. This resulted in the priority tool 3K, which can show companies which critical points are to be prioritised.
SCA Packaging	Packaging	*Intelligent packaging from a distribution perspective (2003)*	SCA Packaging was one of the involved companies in the SCA project where an RFID simulation was carried out in a Dutch retail chain. Results showed that implementation of RFID could increase effectiveness.
Scania	Automotive	*Konceptualisering och design av Auto-ID system för Scania (2006)*	The conceptualisation of an RFID system at Scania showed that the effects of an Auto-ID system could increase effectiveness but it has to be integrated with other information systems in order to provide the right people with the right information

Schenker AB	Transport	*Livsmedelssäkerhet ur ett försörjningskedjeperspektiv (2006)*	Schenker AB was one of the distributors in the case study where the authors examined critical points in the food supply chain. This resulted in the priority tool 3K, which can show companies which critical points are to be prioritised.
Skånemejerier	Dairy	*DOSS - Värderingsmodell för riskerna vid tillverkningen av flytande livsmedel (2005)*	The DOSS model was developed during the writing of the master's thesis and was evaluated on Skånemejerier's activities and the manufacturing of their fruit drink Pro Viva. The results showing that two primary sources of risks existed: production stop and contamination.
		Spårbarhet i livsmedelskedjan – en ökad väg mot transparens (2004)	The extensive case study at Skånemejerier focused on examining external traceability for milk and cheese.
Stora Enso	Paper & packaging	*Using RFID technology captured data to control material flows (2008)*	The case study at Stora Enso shows the potential benefits of implementing RFID, where improved tracking in real time was one of them.
		Towards a framework for designing logistical RFID systems (2008)	The case study provides evidence that RFID technology has an impact on *processes*. In order to take advantage of RFID technology, the case company changed its physical processes in the distribution system.
Sydfrys	Cold and frozen storage	*Findus Sverige AB:s distribution av frysta ärtor via cross-docking: Kartläggning och utvärdering av säsong 2008 (2009)*	The master's thesis was written in collaboration with, amongst others, Sydfrys with the purpose of examining the logistical flow of peas. Results showed the importance of a well-functioning information flow and cross-dock capacity
Tetra Pak Processing systems	Packaging	*Spårbarhet i livsmedelskedjan – en ökad väg mot transparens (2004)*	Tetra Pak was involved in the case study where the authors looked at external traceability for milk and cheese. The company was involved because it provided equipment for dairy production.
van Eerd Group	Retail chain	*Intelligent packaging from a distribution perspective (2003)*	Intelligent packages (RFID) can be used to reorganise future supply chains towards more efficient and cost-effective distribution systems. The van Eerd Group was the retail chain where RFID simulation was performed successfully.

Volvo Cars Body Components	Automotive	*Risk and gain sharing challenges in interorganisational implementation of RFID technology (2009)*	An RFID implementation across a supply chain presents some challenges. In order to align supply chains, risks and gains need to be identified and shared. A framework is presented which can be used when identifying risks and gains in such collaboration.
		Konceptualisering och design av Auto-ID system för Volvo Olofström (2006)	The conceptualisation of an RFID system at Volvo showed that the effects of an Auto-ID system could increase effectiveness but it has to be integrated with other information systems in order to provide the right people with the right information.
Volvo Logistics Cooperation	Logistics	*Risk and gain sharing challenges in interorganisational implementation of RFID technology (2009)*	An RFID implementation across a supply chain presents some challenges. In order to align supply chains, risks and gains need to be identified and shared. A framework is presented which can be used when identifying risks and gains in such collaboration.
Volvo Information Technology	Information technology	*Risk and gain sharing challenges in interorganisational implementation of RFID technology (2009)*	An RFID implementation across a supply chain presents some challenges. In order to align supply chains, risks and gains need to be identified and shared. A framework is presented which can be used when identifying risks and gains in such collaboration.