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# Factors affecting implementation of the information exchange for traceability in food supply chains

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# Contents

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## Abstract

The globalisation and intensification of food production has led to food related health incidents. These incidents range from BSE in cattle to illegally high levels of dioxins in chicken feed (Carriquiry and Babcock, 2007, Caswell, 2000, Elbers et al., 2001, Fallon, 2001, Hobbs, 2004, Madec et al., 2001, Ozawa et al., 2001, Sporleder and Goldsmith, 2001). The modern consumer is increasingly concerned with quality, sustainability and the possible health benefits related to the food that they eat (Chryssochoidis et al., 2008, Gellynck and Verbeke, 2001, Kehagia et al., 2007, van Rijswijk and Frewer, 2008). There is an increasing need for information when consumers are no longer familiar with the production attributes of their food (Carriquiry and Babcock, 2007, Kiesel et al., 2005, Pettitt, 2001). In this research features such as systematic information loss and lack of unique identification were identified as inhibitors of traceability. Standardisation of data elements for electronic information exchange and the identification of critical traceability points were identified as important activators.

# 1 Introduction and state of the art

The increasing globalisation and intensification of food production has led to, amongst other things, food related health incidents. These range from BSE in cattle to chicken given feed containing illegally high levels of dioxins (Carriquiry and Babcock, 2007, Caswell, 2000, Elbers et al., 2001, Fallon, 2001, Hobbs, 2004, Madec et al., 2001, Ozawa et al., 2001, Sporleder and Goldsmith, 2001). In addition, the modern consumer is concerned with quality, sustainability and the possible health benefits related to the food they are eating (Gellynck and Verbeke, 2001, Hobbs et al., 2005, Kehagia et al., 2007, van Rijswijk and Frewer, 2008, van Rijswijk et al., 2008). Research points to the fact that consumers need more information the further away they become from the production, processing and origin of the food. (Carriquiry and Babcock, 2007, Kiesel et al., 2005, Pettitt, 2001, Unnevehr, 2004). Hence food information has taken on much greater significance in this age of globally sourced food. According to the Food Standards Agency (FSA) such food information is not regularly available (FSA, 2002). Information is also becoming increasingly necessary to fulfil legal requirements and to meet import and export demands (Caswell, 2000, Caswell and Mojduszka, 1996, Darby and Karni, 1973, McKean, 2001, Nelson, 1970, Schwägele, 2005). Food information is also required because the complex nature of the modern food industry increases the possibility of opportunistic behaviour by members of the supply chain (Souza-Monteiro and Caswell, 2010).

Bringing product and process information about food to consumers should not, at first glance, be difficult. Most of the required information already exists within food supply chains and is used in a plethora of situations from food safety to marketing. One might therefore expect that discovering the origin of your fish fillet, for instance, would be easy. Research suggests that this is not the case. In a series of studies carried out by Randrup et al (2008) and Karlsen and Senneset (2006) it was discovered that it was only possible to find the origin (boat or boats) of just over 50 % of the fish fillets tested. Pálsen (2000) presented data that showed that only 20% of the information gathered in one individual link in a supply chain was communicated to the next link in the chain. This is in spite of the fact that according to Sporleder and Moss (2002) there is an increasing demand for this type of vertical product information flow.

## 1.1 Aims

The aims of this research were:

1. To investigate factors affecting implementation of information exchange for traceability in food supply chains.

2. To identify challenges relating to traceability through literature review and original research

3. To bridge gaps between existing theory and the application of this in practise

4. The identification and classification of the type of transformations at critical traceability points

5. To contribute to the research needed for the maintenance of information exchange between companies in the supply chain and the related areas of global electronic information exchange and standardisation.

These aims were achieved by direct work in the field carried out in individual companies, complete supply chains and food sectors. Comparison of the data obtained then led to the identification of factors affecting traceability that have transferability to other companies, supply chains and sectors.

Research which supports business to business (B2B) communication is of the utmost importance because without this any advantages gained by internal traceability are lost in a chain traceability perspective.

## 1.2 Theory

**Definition of Traceability**

The International Organisation for Standardisation (ISO) defines traceability as follows: 'Ability to trace the history, application or location of an entity by means of recorded identifications'*(ISO, 1994)*. Applied to a product it may relate to the origin of materials and parts, the product processing history and the distribution and location of the product after delivery.’ Product information consists of all that is known about the product such as origin, date of picking/slaughter/catch and anything else that has happened during the production process which has been recorded. Process information tells us about what has happened to the product during processing up to the time it reaches the consumer, for example product storage temperatures (Luning and Marcelis, 2009). Product and process information can include any of the following: information about ingredients, information about the suppliers of the ingredients, the location of any part of the food at any point during production, which store at the factory the goods were kept in, the status of the ingredients, e.g. organic or the fishing area within which the fish were caught, or the plants which the honey bees have been visiting. This is information that can be captured and used at a later date, in conjunction with techniques for verification of claims using analytical techniques. This is necessary because there could be a temptation to fake product and process information in order to get higher prices for a product (Nelson, 1970) and being able to detect such forgery is essential for consumer confidence. It is important not to confuse this “definition” of traceability with legal demands imposed by authorities such as those in the EU or USA. For instance while EU regulations discuss traceability, their definition of traceability is limited to knowing who delivered what to a company and who that company delivered finished products to, i.e the so called ‘one up one down’ system. This is somewhat different from the definition cited in the ISO standards.

**Types of Traceability**

Two types of traceability have been defined by Moe (1998) these are internal and chain. Internal traceability is defined as the ability to trace the product and process information within a company. Chain traceability is defined as the ability to trace the product and process information through all of the links in a supply chain.

Fritz (2009) however defined three different types of traceability;

1. Internal enterprise activities

2. Along a supply chain

3. Within a sector.

What Moe classifies as ‘internal traceability’ is the same as Fritz’s internal enterprise activities. Moe’s ‘chain traceability’ covers points 2 and 3 in Fritz’s scheme. Supply chains being one of the building blocks of food sectors. Furthermore, Fritz’s scheme has advantages over Moe’s because it may be appropriate to consider a series of integrated companies under the term ’internal traceability’. A series of links in a supply chain with the same owner and integrated systems will often face the same traceability challenges as a single company in a non integrated supply chain. Fritz’s schema avoids the need to distinguish between integrated and non integrated supply chains when discussing internal traceability.

Fritz (2009) recognised that there are different problems encountered when implementing traceability within each of the different levels. Implementing traceability creates a different complex of problems at each of the three levels. These interact with each other as part of a ‘scenario’ which involves policy, individual enterprises and active groups of enterprises who all have their own interests and decision making authority. The research into these three different levels needs to be carried out on an individual basis. The solution will have the most transferable value when broken down to the smallest unit for study.

**Traceable units**

GS1 (Global Solutions One) is a company that is responsible for the global administration of barcodes and related products (which can today be found on many products). They have suggested the following definitions for traceable (production) units, these are: batch, trade unit (TU) and logistic unit (LU). These definitions were applied by GS1 in 2007 in conjunction with an increased emphasis on traceability and in an attempt to define a suitable vocabulary with which to discuss traceability. A batch is defined as a quantity going through the same processes at the same time (GS1, 2007). A trade unit is defined by GS1 (2007) as; *‘Any item upon which there is a need to retrieve predefined information and that may be priced, ordered, or invoiced at any point in the supply chain’*. A trade unit is a unit which is sent from one company to the next company in a supply chain - for example a jar of honey, a bottle of water or a block of frozen fish. A logistic unit is defined by GS1 (2007) as an item of any composition established for transport and/or storage that needs to be managed through the supply chain. The logistic unit is a type of trade unit and it designates the grouping that a business creates before transportation or storage. The classic logistic unit is a pallet, but it may also be a container, a boat load or similar. A standardised globally unique identification (ID) can be used to identify trade units and logistic units (Shanahan et al., 2009). Local or non standard ID are identifiers which are only unique and meaningful within a company can also be used, but are of less help in tracing situations outside the originating company. For example in the case of one supply chain studied in paper I a company in the supply chain had recorded large amounts of internal information, however they had used only internal ID's and not linked them to any external or universally unique ID. This lack of unique ID's caused a break in the chain which in turn caused the granularity of traceability to be very coarse in this supply chain.

**Information and critical traceability points**

In a traceability system 'directly linked' means that the information about different processes or resources linked to a product is recorded in one place, e.g. on one sheet of paper and/or in a software program. Systematic information loss occurs when information about a product or process is neither directly linked to a product nor recorded systematically. When information is not recorded systematically a critical traceability point develops. The methods for detecting critical traceability points such as that used here, developed by Oslen and Aschen (in press) is one of several developed in this area, which have been well tested to identify that CTP's are an important step in enabling the implementation of traceability.

**Information exchange models**

There are three basic types of information exchange to be found in food supply chains. These have been outlined by researchers in this field and are represented in fig. 1. In system A information is held within the individual companies and the information is exchanged on a one up and one down basis. This is effective as it means that the final product does not need to carry large amounts of information. As with all of the systems, System A is dependent on the correct use of unique ID's and identification of CTP's for storing and connecting information to enable future retrieval, for instance in the case of a food safety incident. Without this information tracing the 'paper' trail forwards or backwards can be challenging as shown in paper I. In System B in fig.1 the information is transported either physically or electronically directly with the food stuff. This has the drawback that when a product reaches the consumer it may have a block of paper similar in size to a small novel if it is a complex foodstuff. This is, of course, easily overcome with electronic solutions and it can provide a complete history of a product which is instantly accessible. However System B does not provide feedback to the primary ends of the supply chain; this means that there will be drawbacks with regards to the benefits of improved information flow for individual businesses. The businesses at the primary producer end of a supply chain will not necessarily be able to receive feedback regarding their products, i.e. what was thought about a particular quality of their products. Finally System C can be described as a database system where each company reports the information about products to a central data base. This system has the advantages that the information does not have to be transported with the product, is not stored at any one company in the food chain and in the event of a food safety incident the information may be quickly and easily retrieved.

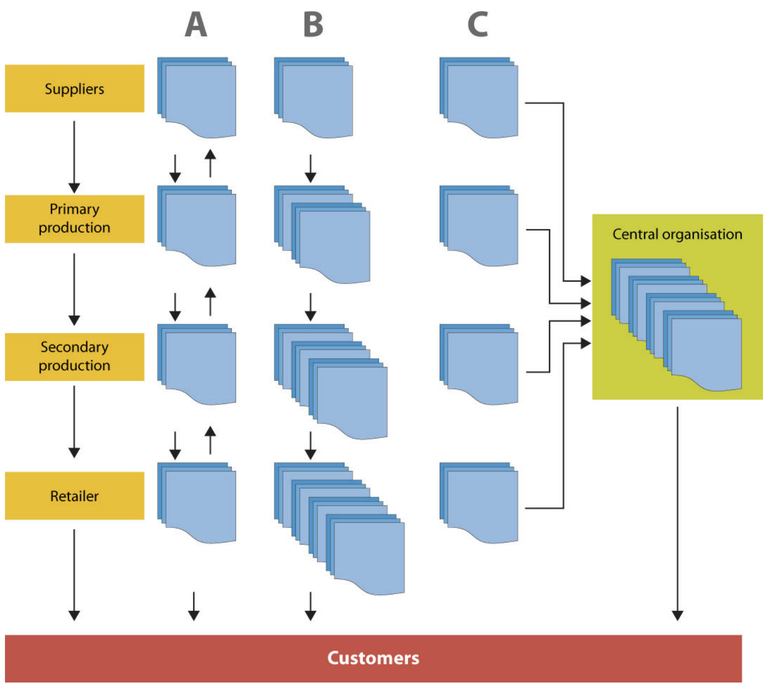


Figure 1. Traceability system information exchange modified from Meuwissen et al., (2003).

System C has the disadvantage that in non integrated supply chains it may be difficult for companies to agree an appropriate level of information sharing when compared to System A.

Systems A or C have the most advantages particularly with regard to confidentiality of information, reduction of the need for detailed information to follow each individual product and combining both integrated and non integrated supply chain sections which are to be found in the food webs for most food products.

**Motivational factors for traceability**

The drivers for traceability are many and various. Some are required by legislation e.g. those regarding food safety, some driven by consumer preferences and some are seen to give a product a competitive edge. The following figure outlines all the drivers,

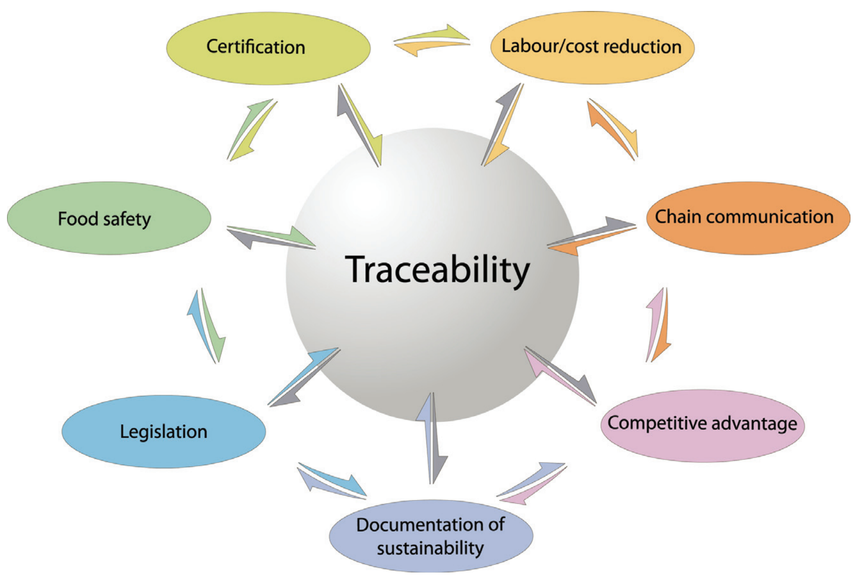


Figure 2. The driving forces for traceability in the EU modified from Olsen (2009).

The main driving forces for food traceability in the EU were outlined by Olsen (2009). They include certification for environmental and sustainability purposes in order to combat illegal, unreported or unregulated (IUU) fish from entering the supply chain. An example of labour and cost reduction is to be found in the following: just as electronic messages imported into a company's system saves time in terms of retyping, re-formatting and so preventing unnecessary errors, likewise traceability can also enable companies to improve logistics and efficiency, by knowing with greater precision what resources are required from which suppliers, so improving knowledge management. A traceability system in itself can provide a company with a competitive advantage by securing a greater market share. Legislation and compliance is a major driving force and for this reason it is addressed in its own section below. The most obvious driving force for traceability is often cited as being ‘food safety’. However, it is important to remember that being traceable does not automatically confer a ‘safe’ status. Traceable food can be very unsafe to eat and conversely non traceable food can be very safe. Nevertheless in the event of a food safety incident a traceability system will enable a precise recall hopefully limiting the effects of such a recall. A traceability system can also be used to check and verify claims about the safety and sustainability of food stuffs.

**Legal dimensions of traceability**

In the European Union (EU) the Common Food Law 178/2002, applies to all feed and foodstuffs. Each Food Business Operator must be able identify all those who delivered food, feed or ingredients that were used in their products. A mechanism must exist to make this information available to the authorities on request. Food or feed items that will or might be sold in the EU must be labelled in accordance with sector specific requirements and the code on the label should facilitate identification and enable (targeted) recall. Without prejudice to more detailed rules, the Regulation does not compel operators to establish a link (i.e. internal traceability) between incoming and outgoing products. Neither is there any requirement for records to be kept identifying how batches are split and combined within a business to create particular products or new batches. Food Business Operators are only encouraged to develop systems of internal traceability designed in relation to the nature of their activities (food processing, storage, distribution etc). The decision on the level of detail of internal traceability is left to the business operator, commensurate with the nature and size of the food business. Charlier and Valceshini (2008) argue that the EU regulation 178/2002 introduced following various food safety scandals will only provide a minimal level of granularity. Granularity is the detail which a traceability systems contains, for example can you trace back all of brand X, to 2 factories that produce food for brand X or the production line in the factory which produced the product. Another term which might be used instead of granularity is the resolution of a traceability system. For traceability to have the greatest effect a greater level of granularity than is demanded by EU regulations is needed. However, more research is required to define the appropriate level of granularity.

In the United States of America (USA), legislation relating to traceability has only been enacted relatively recently. It is mainly aimed at the need to protect the country from perceived bioterrorism threats. Two new food safety bills have been introduced in the USA; the Food Safety Enhancement Act and the Food Safety Modernisation Act. The Food Safety Enhancement Act was introduced in June 2009 and has been passed in the House of Representatives. The bill will now be voted on in the Senate. The Food Safety Modernisation Act was introduced in February 2009 and is the first step of the legislative process. Both of these Acts will enhance the authority of the Food and Drug Administration (FDA) to access records from food production facilities. The legislation also requires the food facilities to evaluate their hazards and to implement preventative controls. These acts will also provide the FDA with mandatory food recall authority as well as establishing mandatory inspection frequencies for food facilities. These regulations will also apply to the food businesses outside of the USA that wish to export their goods for consumption in the USA (FDA, 2009). If this new food safety legislations is passed, it would put the USA on the track of implementing sophisticated electronic traceability systems; both for internal and chain traceability.

It is important to realise that the EU and the USA are major trading partners for many companies in the global economy, therefore their legislation will be decisive for countries wishing to export to them.

**Information exchange in the European Fisheries sector**

The nature of the seafood industry is characterised by a high degree of international trade making it is very difficult to transmit all information physically with the products (Denton, 2003). This makes the seafood industry an interesting area in which to study inhibitors and activators for traceability. Traceability can be seen to be of greatest benefit in areas of international trade where the benefits a traceability system can confer are most easily seen.

The TraceFish European Committee for standardisation (CEN) standards are made up of all the possible individual businesses which form the 'building blocks' in a fish supply chain together with a 'block' for ingredients coming from outside the industry where the standards are not used. At the conclusion of this project it was realised that there were only standards for this type of information exchange in this particular sector and following it's success it seemed logical to develop similar standards for other food sectors in order to see whether the research could be applied elsewhere.

The CEN TraceFish standards are specifications as agreed upon by the industry (in this context the industry is defined as a ‘sector’) these are

1. the information to be held in captured fish distribution chains

2. the information to be held in farmed fish chains

3. how this information should be encoded.

Basically, this is a list of terms relevant to either captured or farmed fish production and distribution chains. This includes a specific way of identifying these terms which would mean that exchanging information is easier as there is an internationally agreed vocabulary and set of standards.

Standards developed to meet the ISO definition of traceability need to relate to both the physical traceability of the product and also information about the product. The TraceFish CEN standards are the basis for the research carried out in paper V. Three different specifications were made: two sector specific standards (wild caught and farmed fish) and one technical specification for the encoding of data in both standards.

By encoding data elements in a standardised manner the data can remain under the control of the entity who ‘owns’ the data elements whilst still being easily accessible should the need arise.

**TraceFood framework**

The TraceFood framework is a tool that was developed in response to the need for traceability identified by both research and industry. The framework was informed by the TraceFish CEN standards. It includes several generic guidelines which are meant for use in the industry together with the generic TraceCore language and the sector specific language.

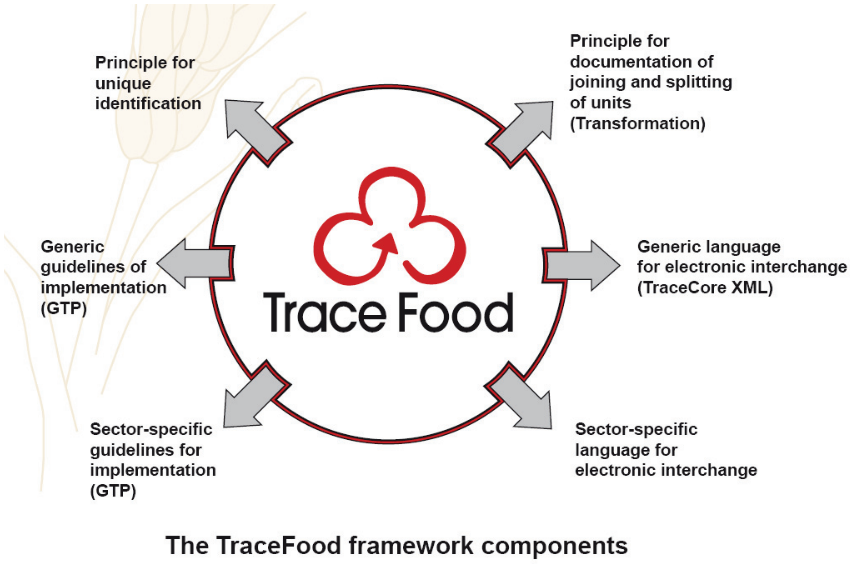


Figure 3. A depiction of the TraceFood framework. (GTP - Good Traceability Practice) (TRACE, 2007).

These components are intended to aid the flow of information within food sectors.

**International traceability implementation initiatives**

In response to the need for traceability systems outlined in the introduction governments and other regulatory bodies acknowledged that both sector and cross sector schemes were necessary. These schemes date from early 2000 (Smith et al., 2008). It is clear from the short review presented below that the schemes are still in the planning and testing stages for many countries. It would seem that export to important markets is the main driving forces behind such schemes (H Darling pers. comm). An overview of Traceability from a European perspective can be found in Schwagele et al. (2005).

The actual experience from around the world gives a good indication of the status of traceability at the present time.

*Canada*

The national traceability initiative in Canada, 'CAN-TRACE,' identified needs for both identification standards and also for non proprietary standardised sets of traceability data (CAN-TRACE, 2008). The Canadian Food Traceability Data Standard (CFTDS) 'encourages' the use of EAN.UCC (now known as GS1) for product, party and location identification. The

Canadian Food Traceability Data Standard suggests that existing identification schemes can be linked to the GS1 standards further along the supply chain, thereby solving the problems related to the lack of consistency in the use of GS1 standards throughout the supply chain.

*Japan*

In Japan there are no identification strategies which cover all sectors. There are no integrated national traceability databases. However, there are some sector specific national databases such as those described for cattle in the EU (NBLC, 2009). With regards to unique ID systems there are reported to be two competing organisations GS1 Japan and the uID center (Sakai pers. com 2009).

*Norway*

A survey carried out in Norway concluded that few standardised identifications were used to identify food items (paper I). The survey was carried out as part of the Norwegian electronic traceability initiative which is called 'eSporing'. This initiative, started in 2008, had the intention to have implemented electronic traceability within Norway for all foodstuffs by 2010.

*Korea*

The Korean government has introduced the possibility for all producers to be involved in a national traceability scheme. In the Korean system nationally unique ID's are used (not GS1). The reported experience from Korea highlighted the need for continuous support and training when carrying out implementation of traceability (Lee and Park, 2008).

*United Kingdom (UK)*

In the United Kingdom (UK) there is one well developed traceability system and that is for livestock. This system is mandatory and involves registration and identification of all cattle. This system followed legislation resulting from the BSE scare (FSA 2009). In the UK the numbering system for health/identification marks for meat, fish and dairy products differs between establishments, the system is approved by Local Authorities and those establishments approved by the Food Standards Agency (slaughterhouse, cutting plants etc) (B.Drennan pers.comm).

*United States of America (USA)*

The United States Department of Agriculture (USDA) emphasises the need to have 'separate traceability ID systems' both between states and sectors. They also highlight the need for these systems in different sectors to be able to 'speak' to each other when necessary (USDA, 2009). This allows existing databases to be incorporated into each other and promotes the saving of time and money since implementation of an entirely new system is not required. The United States Department of Agriculture states that this decision also allows them to maintain a certain degree of flexibility. The USDA also emphasise the need to standardise the data elements (registered in the various animal databases) in existing disease control programmes as they believe that this will improve emergency response capabilities. An Open Source approach will also ensure compatibility between different regions and contexts. For further reading see Smith et al. (Smith et al., 2005).

**Sector specific schemes**

There are numerous examples of sector specific, nationally operated ID systems. In some countries these have been established for many years while in others, such as New Zealand, detailed implementation is just beginning. These schemes are mostly directed at food products which have been identified as problematic such as beef and other meat sectors see (Fearne, 1998a, Fearne, 1998b, Calder and Marr, 1998) and the schemes aim for a much finer granularity than is observed in other sector specific schemes. Other schemes are directed at markets where the product may be very valuable or one which is traded across many countries. In these cases the importance of cross sector and cross border traceability work becomes clear. For example some of the first work which recognised the need for sector specific traceability systems was the 'TraceFish' work.

The TraceFish work has been described in detail by Denton (2003). The TraceFish (CEN14659, 2003, CEN14660, 2003) projects involved industries and researchers from across the EU and the Nordic countries. The aim was to develop standards for the fishing industry which is a large sector involving a lot of international trade. The standard should enable IT based schemes for traceability throughout the fishing and fish processing industries. The reason for the IT focus was that it would become practically impossible to transport all of the information about a product with it. Some years after the TraceFish work was completed this choice was shown to be highly appropriate in light of the new ‘bio terrorism’ laws in the USA. This requires that for imported foodstuffs information about the food tuff is received within the USA 4 hours before the food. This means that electronic transmission of information is a necessity (Anon, 2002).

In this research both what traceability is, the research carried out on it and the initiatives created by the observed need for it, have been outlined/examined. It can be seen that international research providing bodies such as the EU, international standardisation bodies such as ISO and national governments around the world see traceability or improved information flow as extremely important.

## 1.3 Literature review

The literature in the relatively new field of traceability is spread across a wide spectrum of journals that range from legal to engineering. This can hamper identification and classification of relevant literature. The spread of literature shows that the area makes an important contribution to many areas of science relevant to the modern world. Contributions to the area are clearly significant to the scientific discourse and the ability to see it from a multi disciplinary perspective is important. In my opinion literature can be broken down into the four following main areas: food production engineering including IT and standardisation, economic, legal, and consumer together with market research. The important research perspective within the engineering field relates to process re-engineering or the re-engineering of information management.

Skoglund and Dejmek (2007) highlighted in particular the need for a definition of batches particularly in systems where there is a liquid involved in the production process or in the case of products which are often mixed such as grains e.g. soya beans. Thakur and Hurburgh (2009) also highlighted the challenges related to continuous process and the need for appropriate internal identification which pointed to the need for further research regarding internal traceability. Opara and Mazaud (2001) noted the need to analyse both internal and chain traceability with flow diagrams. Manikas and Manos (2008) identified that a traceability system should address the identification registration and elaboration of information. They also noted the need for transformations to be studied and recorded particularly in the case of processed products.

Steinsträter and Jensen (2001) demonstrated an elaborate system for beef traceability. However what is apparent from their paper is that the systems must be engineered in such a way that they are suitable for application across many actors in a food sector and not just specialist producers. The need for investment in hardware such as new scanning systems for both traceability purposes and systems reengineering is highlighted by Regattieri et al. (2007)

Frederiksen and Bremner (2001) noted that the optimisation improvements that can be achieved as a result of traceability and the need for easily implemented electronic systems. Authors including Børresen et al.(2003) also commented on the need for information technology solutions in order to handle the amount of data generated by a traceability system. Riden and Bollen (2007) highlighted the need for framework concepts and terminology to enable discussion of ideas about traceability in the agricultural sector.

Senneset et al. (2007) and the FSA (2002) reported on the need for electronic traceability with Seneset et al. (2007) addressing the possible implementation in the fisheries sector. Their results show that standards such as the TraceFish CEN (CEN14659, 2003, CEN14660, 2003, Denton, 2003) agreement are suitable for the implementation of electronic chain traceability. This literature showed that there are possible and appropriate methods for electronic traceability but papers IV, V and IV showed how the research can be implemented at a sector specific level. The need for considerable technological inputs has been identified by (Opara and Mazaud, 2001) together with the fact that such demands can actually impede free trade. This barrier could be addressed when carrying out traceability research. For example open source solutions should be investigated for their appropriateness as part of solutions for traceability implementation. Shanahan et al. (2009) identified the need to implement electronic traceability throughout the supply chain particularly the primary producers end. The need for standardised sector specific business vocabularies that can be used for traceability has also been highlighted by several authors including, Folinas et al. (2006, Folinas et al., 2003) Manikas and Manos (2008), Frosch et al. (2008), (Jansen-Vullers et al., 2003), (Bechini et al., 2008). All of whom identify the need for xml based technologies for information exchange. Smith et al. (2008) together with many others has identified the need for unique identification.

Bollen (2006) notes that improvements in traceability will allow improvements in supply chain management systems. Previous research has also identified that further study of agricultural supply system traceability can serve as a useful paradigm for other complex processing systems (Bollen et al., 2007).

Jansen-Vullers et al. (2003) concluded that there was a need to focus not only on traceability for production management and increased food information but also for recalls. This is interesting because most of the literature with two notable exceptions (Karlsen and Senneset, 2006, Randrup et al., 2008) focuses upon production improvement and product information while the consciousness of the general public relates traceability to food safety and product recalls.

In conclusion many authors identify that there is a need for further research in terms of internal traceability, chain traceability and sector wide information exchange.

## 1.4 Methods

Food related problems, are characterised by both technical and human challenges (Lyons, 2005). Food industry engineering research challenges are therefore best investigated by using a combination of techniques from the science disciplines. One technique used in this research is that of the case study together with extensive use of industry wide structured questionnaires. Lyons (2005) stated that in food industry related research, case studies are a relevant vehicle for research. Case studies can be used not only in meta-analysis, i.e. comparing multiple case studies, but can also be used to build, test and further develop theories. The aim being to learn rather than attempt to construct universal truths about the subject (Flyvbjerg, 2007)

In the research undertaken the aim was not to make generalisations which ‘can be applied universally and which are context free’ (Lincoln and Guba, 2000), but generalisations which can be applied to a similar situation or as Blaikie (2000) puts it ’generalising from one research site to another’. Flyvbjerg (2007) goes so far as to state that formal generalisation is overvalued and the force of example (which is observed in paper IV) is underestimated. I agree that these views are valid and in this research both the force of individual studies is valued, to be held up as an example for other companies and perhaps more importantly taking the site specific generalisations and transferring them to other companies by taking into account site differences. Comparing and contrasting the experiences will provide a greater insight into how to improve traceability in the food sector. However some findings will by their nature be specific to the case in question.

The method developed by Olsen and Aschen, described at length in their paper (in press) has also been used. Briefly, the method consists of a series of structured interviews designed to identify critical traceability points. These are studied in the flow of one food product followed back through the production process. The method can also be adapted and used throughout a supply chain. The method is outlined in fig. 4.

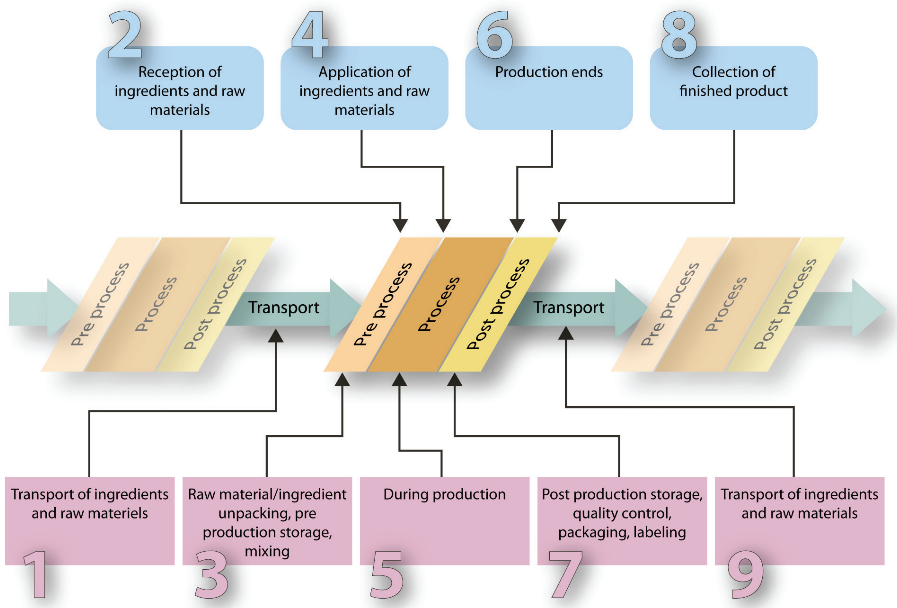


Figure 4. A modified visual description of the process mapping method developed by Olsen and Aschen (in press).

# 2 The research

Paper I is an investigation into the traceability of thirty foodstuffs. The foodstuffs were purchased in Norway and sourced from across the European Union (EU). Just over half the food products could be traced both internally and through their supply chains.

Paper II investigates the importance of transformations for traceability. There are critical points where information is systematically lost and these are frequently encountered in the transformations of the resources. For instance, at one company 60% of the resource transformations were shown to be additions, mixing and splitting. These factors produce the highest number of critical traceability points and are also those which concern consumers the most (Gellynck and Verbeke, 2001).

Paper III is a study of critical traceability points at a mineral water producer.

In Paper IV two companies, typical of those that could form links in a supply chain, (one a producer of wet salted cod the other of dried salted cod) were systematically investigated. The production of dried salted fish is challenging due to the many transformations during production. Use of the basic technique of applying and recording unique identifiers could have provided a traceability system from delivery of wet fish through to final dried product.

Papers V-VII present research into information exchange in the specific food supply chains of honey, chicken and soya beans. In food supply chains, there are numerous measurements, properties and parameters that must be recorded. This documentation is already necessary for legal reasons, labelling, traceability, profiling desirable characteristics, showing compliance and for meeting customer requirements. Standards for the name and content of each of these data elements would improve information exchange between buyers, sellers, authorities, consumers and other interested parties. To establish what could form such a list of standard data elements a multi-stage survey was carried out.

Paper VIII examines the differences in the motivational factors between the EU and the USA.

**Summary of the research**

Paper I analyses the state of traceability as it is in 2008 in the European Union. The results concur with many areas already identified in the literature reinforcing the fact that it is relatively simple factors which it is necessary to resolve in order to implement traceability. These factors being unique identification, standards for both information exchange and storage and a full awareness of these things.

Papers II, III and IV address the research areas related to implementation of traceability both internally and within supply chains.

Papers V, VI and VII address the research problems related to sector specific data lists and open xml standards in order to enable information exchange in supply chains.

Paper VIII summarises some experience from research and examines it in the perspective of a comparison between policies and observations from the EU and USA. The paper also looks at future perspectives in light of the previous research. Paper VIII also looked to the future of traceability research with regards to international trade. This is a clear driver for traceability and often one of the prime reasons a company will decide to invest in traceability.

Paper I highlights the areas where there are improvements possible and what research is needed in terms of traceability for the purposes of food recalls. This paper presents new evidence involving a cross section of European food stuffs showing that factors such as recording information systematically, standardisation and an awareness of CTP's are essential for a successful recall of food products from all food sectors. This had previously only been demonstrated in the fisheries sector in the European Union. Papers II-IV Investigate further the factors highlighted in paper I. Traceability is investigated in detail both internally within a mineral water bottling company and a sausage producing company and through a supply chain for salted and dried salted fish.

In paper II the types of transformations which are found at the CTP's is analysed for the first time. Previous research has shown that consumers are most concerned with mixing transformations and in this paper it is shown that the majority of CTP's are composed of these transformations. In addition the paper highlighted the need to ensure that the systematic information recording, which was identified as a problem in paper I must be maintained both for the main ingredients as well as the smaller addition ingredients, such as the salt in paper IV. In paper I and paper IV the need for supply chains to know what information they should record when they receive products was highlighted. Additionally the need for a method to easily recognise and retrieve data was identified. This need had already been foreseen in the Tracecore work, however extension of this work had not been identified prior to the work presented in papers V – VII. These papers present a frame work of possible data elements and appropriate models for traceability.

In the light of the research presented in papers I- VII paper VIII discusses what the motivational factors for traceability are and why it is being implemented in the US and EU.

# 3 Discussion

The research presented here addressed some of the challenges of traceability through entire food sectors. The research focused specifically on the effective exchange of product and process information and aimed to maximise the ability to make generalisations. Studying different food sectors allowed comparisons of the differing experiences to be made.

First an examination of internal traceability in the selected companies needed to be carried out. This was followed by an examination of solutions for traceability within the selected food supply chains and finally an examination of traceability in a sector wide context together with solutions. The implications for this field of science will be discussed.

Paper I showed, that despite the current state of the art regarding research into traceability, still only a little over half of the products tested for this paper could be traced back through their supply chains. Factors such as lack of registration of unique ID's, lack of employee awareness and motivation were identified as inhibitors of traceability across several food sectors for the first time. Factors such as 'pride' in a product, market share and knowledge of both legislation and the specific requirements for traceability were identified as activating factors.

## 3.1 Internal Traceability

Previous research has shown that with regards to information flow no supply chain can be more effective than its weakest link (Bechini et al., 2008, Randrup et al., 2008). The research presented in Paper I showed that the weakest link, with regards to traceability can be the smallest unit in the supply chain. It is also worth noting that supply chains are in fact often webs rather than chains. This is because the food industry is characterised by short term unstable relationships between suppliers and their customers.

In their paper from 1991 Petroff and Hill presented a framework for so called 'lot tracing' and one of their specifications was that in order to capture the history of a lot, the system must record all details on all 'material movements' (Petroff and Hill, 1991). This principle has been carried further in the current research. It has been shown that the types of transformations at critical traceability points are important (paper II) to internal traceability.

Previously published research has, I believe, only pointed to the fact that CTP's are important not that the type of transformation combined with the CTP could give a greater insight into the traceability challenges. By analysing these points and assuring that at joining, splitting and addition transformations the ID's of ingredients are recorded and carried forward you could enable a company to implement internal traceability. Another necessary action is for the company to make a decision on the desired level of granularity of their system. This decision may be affected by the type and number of transformations in the process. This may prove to be too many for an individual company to take into account and therefore the company will have to make a strategic decision based on the information available in their particular case.

Table 1. Descriptions of the different types of transformations taken from paper II.

| Type of transformation | Relationship | Synonymous expression used in other texts. | Definition |
|---|---|---|---|
| Joining of resources | Many to one | Joining, addition, merging, mixing, blending, pooling, aggregated, mincing and assembling. | Joining together of different units of a main resource |
| Transfer of resource | One to one | Transfer | Transferral of a resource without it being split up or mixed |
| Addition of resource | Many to one | Addition, joining, merging, mixing and blending. | One main resource being mixed with other resources in lesser quantities |
| Splitting of resource | One to many | Splitting, segregation, disaggregated and disassembling. | A resource being split up into multiple units |

From the research in paper II companies would be well advised that they should be aware of the type of transformation and the importance this may have had for their traceability system. For example, mixing transformations where two different ingredients are mixed are more important than those where one ingredient is transferred because transferral will often not involve the mixing of two ingredients from an external source. It could be said to double the amount of information that will be lost when compared to transferral where essentially there is only one set of information that may be lost.

Interestingly the studies carried out for both papers II, III and IV highlighted that often the resource which is involved in the mixing transformations, identified in the paper as being the most important, involved the addition of apparently minor ingredients (onions, salt, pepper etc) this is an important contribution to the state of the art. This finding reflects the indication revealed in paper I that attention to small details is the key to successful traceability implementation. The research suggests that there is an awareness of traceability of the main ingredients, respectively lamb, water and fish, but a disregard for the minor ingredients. Unfortunately problems may arise with the minor or major ingredients and in the light of the principles such as those presented in the 'good traceability practice guides' (TRACE 2009) it has been shown that it is important to systematically record all transformation of which ever type (paper II).

Paper II highlights where both the traceability and the 'granularity' of the traceability at the company could be improved. The joining of other resources is a critical point at which there is a loss of traceability information and therefore loss of product and process information. The research showed that the granularity in each case could be improved. It must be noted that while the research showed, in this case, that it was possible to improve the level of granularity this will be determined in every case by the strength of the drivers for each individual company. It must be remembered that internal traceability need not be on a one to one scale meaning, for example that it is not necessary to separate each fish and handle it individually it can, of course, be mixed with other fish for processing but this mixing must be registered together with any other transformations which take place. These actions form the backbone of a traceability system.

There were many complex 'mixing' transformations at the company described in paper II. This is in contrast to the traceability challenges in paper III where, because of the nature of the product, there were no mixing transformations within the company. However, both companies had internal critical traceability points. In the case of the mineral water plant it was the lack of registration of the use of a new set of bottle caps. Whereas with the lamb meat company it was the mixing in of additional minor ingredients to the sausages. This highlights the diversity of CTP's and the fact that this diversity needed to be addressed directly when considering traceability implementation.

Paper II presented a company which was concerned with improving access to product and process information both for consumers and for internal control purposes. This paper demonstrated that it is important to be aware of the type and location of transformations to be found at each individual food producer as this is necessary in order to trace and track food through the company. This is critical when identifying traceability information. Where and what type of joining is involved is also important, because this is where consumers perceive the greatest need for traceability (Gellynck and Verbeke, 2001). A generalisation which can be made from the research presented here is that the type of joining found in many food product companies will be similar to those presented in papers II and IV. Those presented in paper III are likely to be less easily transferable to other non similar companies and therefore are less relevant for generalisation. This emphasised the need to address information flow on a case by case basis. In the example presented in paper II (company A with regard to lamb meat) there were traceability information links at each of the transformation points. This made it possible to trace a TU leaving the factory back to the farm and a set of animals used to produce it. However with the other resources used in the lamb sausage product there was no direct or indirect linking of IDs (or traceability information). This meant that all product and process information about these resources was lost.

Therefore, no matter how good traceability might have been in other parts of this supply chain the loss of this information meant that traceability would also be lost. At this point the simple action of registering ID's no matter what type of transformations are encountered would not only ensure traceability but also enable the company to identify which and how much of which ingredients need to be bought and when, thus providing two returns for one action. (Fritz and Scheifer, 2008a, Fritz and Schiefer, 2009, Meuwissen et al., 2003, Sohal, 1997)

## 3.2 Supply chain traceability

The next step following the achievement of appropriate internal traceability is the connection of several individual businesses in one supply chain (Thakur and Hurburgh, 2009). In some food supply chains the businesses are already 'vertically integrated' meaning that the whole supply chain has already agreed certain levels of cooperation. These studies have been focused on creating traceability in food supply chains that are not necessarily vertically integrated. Another focus has been supply chains which have special challenges associated with them. The inhibitors and activators associated with simple supply chain traceability were investigated in paper IV.

The theories developed through this research, such as the need to be aware of the fact that that even the smallest transformation (such as the addition of salt) is a CTP and the type of transformation involved in the CTP can form the basis for generalisations and knowledge transferral to other sectors.

The supply chain studied here, the wet and dried salted fish industry, was an interesting case to use in order to draw further generalisations. The fisheries sector has been studied previously in terms of sector specific information exchange, but less so regarding individual supply chain information exchange. There are particular challenges found in the seafood industry, such as sustainability and illegal fishing, and a variable abundance of a wide resource (Frederiksen and Bremner, 2001, Frosch et al., 2008, Hastein et al., 2001, Thompson et al., 2005). The case presented here is symptomatic of the individual problems found in other food sectors. This case was characterised by numerous complex transformations, adding of ingredients in small quantities and one of the particular challenges for traceability in food supply chains, an uneven supply of raw materials. The production of wet and dried salted fish involves a large amount of mixing of fish both during the curing process and in the multiple sorting processes for size and quality. This gives rise to multiple opportunities for critical traceability points or 'gaps' and consequent loss of product or process information (Bollen et al., 2007, Steinsträter and Jensen, 2001). This production process was a good model to study, as it had only one main ingredient; enabling the isolation of the problems related to the mixing of a single ingredient over long production periods. This case also provided the smallest possible example of a supply chain i.e. two companies from origin to consumer. This facilitated examination of the information flows in a supply chain together with provision of solutions to some of the problems. Improved access to information about products and processes can be used in the campaign against illegal unregulated fishing by allowing companies throughout the supply chain to accurately identify the origins of the raw products they are using.

A simple solution for traceability, suggested in this paper was to systematically record the ID's of all products No recommendations were deemed necessary about the type of recording device or preferred technology. Randrup et al. (2008) identified the need to improve the speed and precision of recalls in the fisheries sector and with all of the suggested system changes in place these companies could achieve the full chain traceability needed to achieve this. This research has shown as with previous studies that no traceability system is stronger than its weakest link.

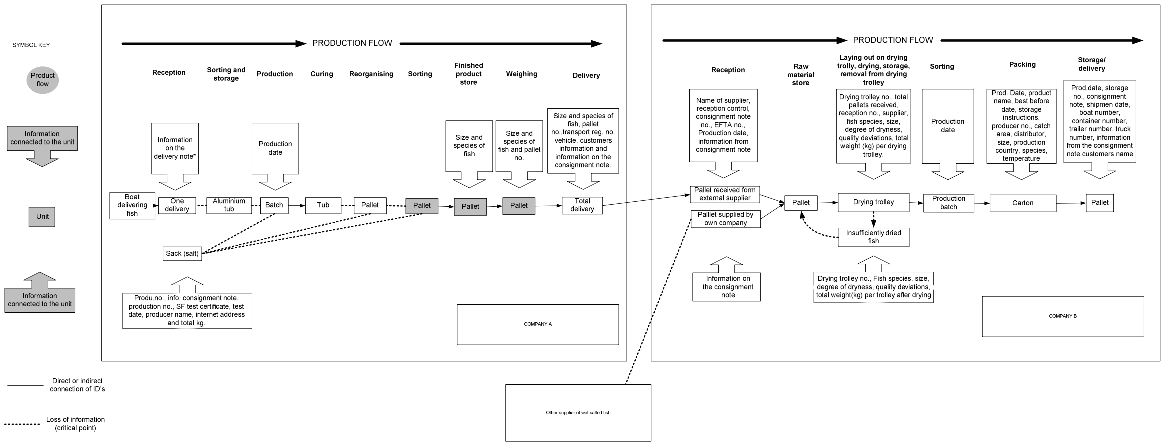


Figure 5. Diagram summarising the analysis carried out in paper IV.

The following clearly demonstrates this concept. If Company B alone used unique IDs (Steinsträter and Jensen, 2001) they could still not trace back to the delivery notes for wet fish without the equivalent actions taking place at their supplier (see fig. 5). In order to achieve full chain traceability registration of unique ID's must be carried out in both companies as shown in fig.5. This reinforces the importance of chain traceability (Senneset et al., 2007) as previous studies have documented that little information is passed on to the next link in fish supply chains (Børresen, 2003, Pálsson et al., 2000).

For Company A, implementing traceability would mean changing the production routines and registering more information during production than is the current practice. Deliveries to Company A can vary between small catches from longline boats to much larger ones from trawlers. During production it is impractical to keep these deliveries separate. This gives the company a dilemma as it has to decide on the optimal batch size that it is appropriate to trace. Optimal batch size for traceability is a clear area for further study. In addition the changing of perceptions of traceability amongst employees was an important factor for successful implementation of chain traceability (Alfaro and Rábade, 2009).

Company B had already implemented internal traceability and found that being able to keep track of the effectiveness of the production routines had become an invaluable management tool. They reported that greater knowledge of who was doing what, when and for how long actually led to greater efficiency in production. They also explained that the improved traceability system had enabled them to track the quality of a supplier's fish and allowed them to take action immediately when problems with quality were reported.

Company B was able to trace and track wet salted fish from delivery note to export of the finished product in nearly all cases apart from that of 'slack' fish.

Both companies wrestled with the need to change practices. These included re-training of staff, clarifying the degree of traceability required for themselves and for their customers, the costs involved and the cost/benefit of additional information. In these deliberations neither company seemed fully aware at the outset of the added advantages in achieving full traceability. The information a completely traceable system can provide is also needed for process control, calculation of productivity at all levels of the process, degree of re-work, compatibility with other schemes such as HACCP and Quality Assurance.

These case studies are a good example of the need to use standard procedures for thorough, systematic analysis of the processes, unique identification procedures and information flows at every step in the chain.

The research presented in paper IV documents that, with cooperation between the companies in the supply chain, it would be possible to trace one carton of dried salted fish back to a single or limited collection of delivery notes containing details of the catch region and method. This would allow companies to fulfil the demands for greater product and process information about the fish products they export to the EU. The principles shown in this research could be successfully transferred to other sectors. These principles include unique identification of all resources and the need to have a reasonable granularity of internal traceability. An important finding here is the fact that companies must be aware that that even when a resource is used in small quantities it is still essential to record the details. This paper shows that a problem with the salt would affect the finished product which would in turn have consequences for the entire supply chain. Several authors have noted that such recalls can have measurable negative effects upon the economic success of a company (Dranove and Olsen, 1994, Jarrell and Peltzman, 1985, Opara and Mazaud, 2001, Pouliot and Sumner, 2008, Skees et al., 2001, Thomsen and McKenzie, 2001).

This short supply chain highlighted one of the most important conclusions that can be drawn about supply chain traceability. This is that supply chain traceability is totally dependant on good internal traceability systems.

### 3.3 Information exchange and standardisation

A group of supply chains (such as discussed in section 3.2) are the building blocks of a sector which is the collection of supply chains involved in producing one particular range of products. The research presented in papers V, VI and VII addresses the most challenging and internationally important areas of innovation with regards to traceability.

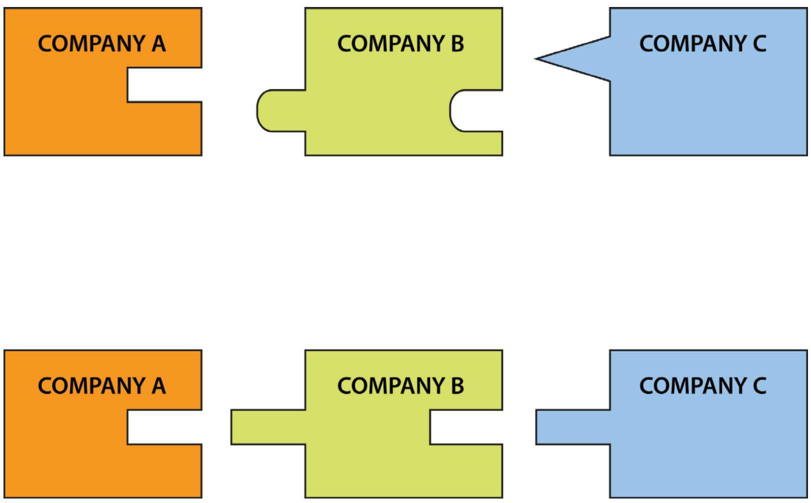


Figure. 6 Standardised information exchange modified from paper VI.

The area of research addressed in these papers is that of sector wide standardised electronic information exchange. One of the major inhibitors of traceability implementation is that of enabling communication of the product and process information independently of a particular company's or supply chains proprietary internal systems (Bechini et al., 2008).

Modern businesses are dependant upon electronic solutions throughout production and when communicating with external sources (Doukidis and Pramatari, 2005). Such communication abilities are particularly pertinent when there is a need to communicate with regulatory bodies (Folinas et al., 2006, Folinas et al., 2003).

In order to achieve effective and reliable traceability, effective 'transfer methods' (Pérez-Villarreal et al., 2008) are necessary. Standards make data transfer universal (Olsson and Sjoldebrand, 2008, Senneset et al., 2007) which is particularly important in the food sector characterised, as it is, by a network of complex companies with dynamically changing market situations (Fritz and Canavari, 2008, Fritz and Scheifer, 2008b).

Individual companies in a food supply chain, (which are not vertically integrated) will want to use their traceability system to exchange information with their suppliers and their customers. It would be more efficient to have a standardised way of exchanging the information or a model of information recorded about the goods produced (Jansen-Vullers et al., 2003). Standardised information exchange is exemplified in fig. 6. Examples of such standards are the previously mentioned TraceFish (CEN14659, 2003) that indicate which information should be recorded in caught fish supply chains.

In food supply chains, there are many data elements that, for different reasons are already be recorded. Papers V - VII have contributed to further developments in traceability whilst meeting the needs of the honey-processing, chicken-processing and soya bean processing sectors by the provision of a list of standard data elements that enable data exchange between companies in integrated supply chains. The data elements presented in the results were standardised by industry consultation and consultation with researchers. Standardisation will enable effective communication (Dreyer et al., 2004, Folinas et al., 2006). It is recognised that the standardisation described is limited, as the 'list' was devised for one particular purpose.

The results give a number of case studies which can be used when designing new electronic systems. Papers V-VII present the initial stages of data element standardisation for the honey, chicken and soya bean, food sectors. Such standardisation procedures can produce sector specific data element lists which can then be used in software development (see fig. 7.). Data elements and an xml (eXtensible Markup Language) schema that can be integrated independent of the software provider. The yellow box in the top left hand corner of this diagram represents these standardised data lists. Fig 7 represents how these lists are linked into the rest of the TraceCorexml which is the data language will which carry the information between software systems.

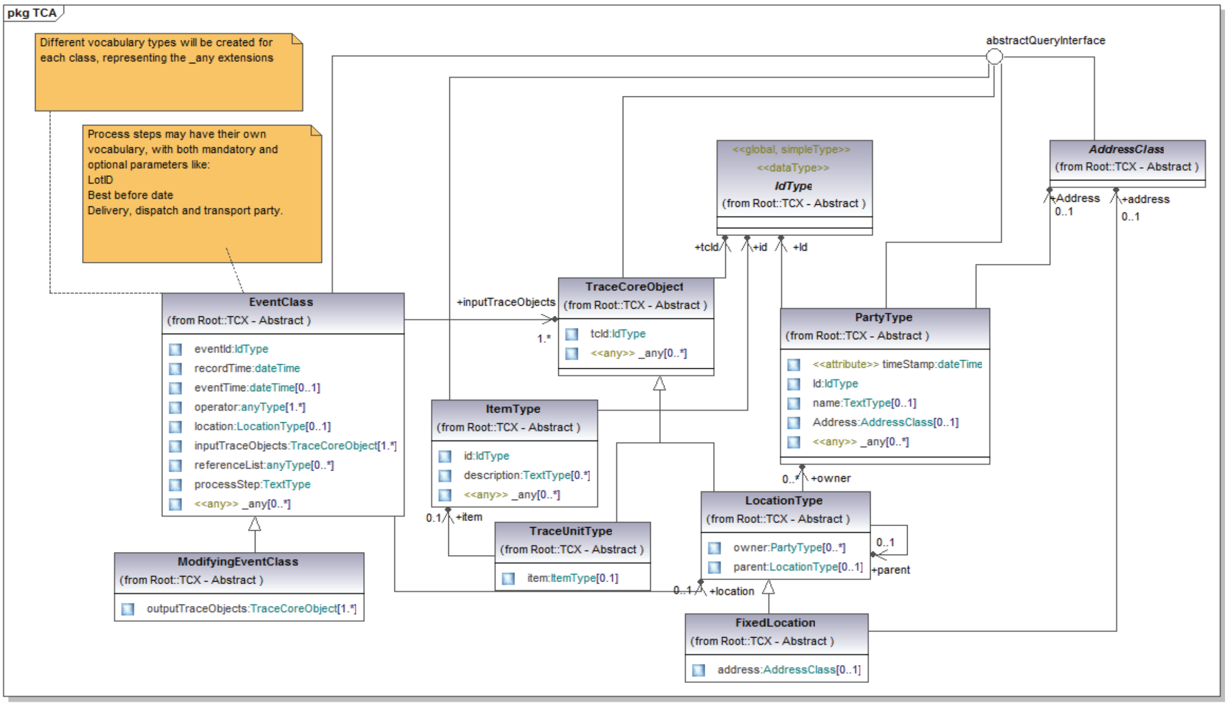


Figure 7. A graphic representation of the Tracecore xml.

A simple analogy for the use of this would be that one could send an open office, a pdf, a word or notepad document and the recipient could open it regardless of the type of text handling software they were using. Use of the Tracecore xml would bring similar ease of use benefits.

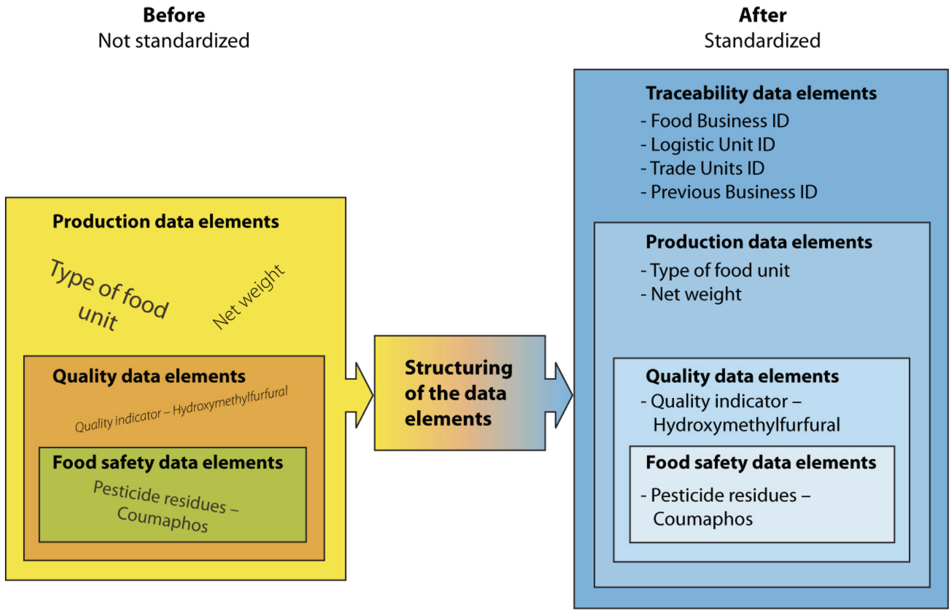


Figure 8. What information looks like before and after standardisation modified from paper V.

Fig. 8 illustrates the difference between data exchange before and after standardisation of data elements and data model construction. This standard has been intended for use in a food supply chain to exchange information effectively across multiple software solutions. Similar models can be used across multiple supply chains.

The most interesting comparison that could be made between papers V, VI and VII was the degree to which the different industries saw the need for traceability. This being expressed as a willingness to participate actively in the research. For each study companies across Europe were contacted and while they all acknowledged the need for traceability, the honey producers were shown to be the most willing to participate in the research, the grain producers the least willing and the chicken producers were somewhere in between. While this is not the main finding of papers V, VII and VI it is an important observation with regards to awareness of information flow issues. It would seem that the industries which have recently been challenged by information flow issues, e.g. soya- GMO, chicken fed on, feed containing illegally high levels of dioxins, or carrying avianflu etc. are least likely to see the value of publicly funded sector initiatives. This demonstrates the sensitive nature of traceability and access to internal information by external bodies. It also indicates that if public bodies wish to address such problems in cooperation with industry they will have to either offer incentives or legislate.

The information gathered in surveys such as those used in these papers (V, VI & VII) may form the basis for standardised vocabularies. These would then facilitate the development of electronic information interchange in food supply chains (Folinas et al., 2003, Manikas and Manos, 2008). For instance as an extension of the Universal Business Language (UBL); UBL is a library of standard electronic XML business documents such as purchase orders and invoices developed and supported by the Organisation for the Advancement of Structured Information Standards (OASIS). Universal Business Language (UBL) is already supported by many national governments. It would be appropriate to extend this work and carry out a similar survey on all links in the honey supply chain to test the use of such standards. The same method could also be used effectively in other sectors. This research contributes significantly to the formation of international standards. These are necessary so that food business organisations and regulatory bodies in the international food market no longer have to handle multiple identification systems for data. The final link in the honey, chicken and soya supply chain is the consumer. It would be interesting to learn what product information consumers consider important and what extra value this may confer on a product.

## 3.4 Conclusion

The purpose of this research was to investigate and compare the factors affecting implementation of information exchange in the food production industry. There was also a clear intention to identify and address those research areas highlighted in the literature as being important and see if it would be possible with this research to go beyond the current state of the art. These included standardisation in electronic information exchange, identification of critical traceability points and types of transformation.

It is clear that inadequate information registration within a company will lead to the formation of critical traceability points. This, in turn, will inhibit product and process information flow and therefore traceability. A lack of awareness of the basic principles of traceability (recording ID’s etc) and a lack of information registration between companies will also inhibit effective traceability. This has been demonstrated across a variety of food sectors in this research.

Food business organisations within one sector have overlapping needs to exchange product and process information. Some or all of this information will be the same throughout a sector. However a lack of standards and agreements regarding these is inhibiting successful/full traceability implementation. This research has shown that with awareness of the types of transformation and the information that can be lost at these CTP's internal traceability can be improved. It has also been shown that successful identification and action regarding critical traceability points will enable traceability implementation. Strategic decisions related to the type of transformations will enable companies to choose an appropriate granularity of traceability.

Identifying data elements associated with product and process information, together with appropriate methods and frameworks in which to place them in is an important activator for successful traceability systems. For the sectors studied it has been shown that there is a good degree of overlap in information and that a large amount of the information which is recorded within the company is communicated outside of the company (papers V, VI & VII). The research provides a suitable framework in the form of the data lists which in combination with standardisation of electronic information exchange such as the Tracecore would enable information exchange in a non proprietary manner. Electronic information exchange is important in facilitating rapid, secure information retrieval enabling effective communication and multiuse of data.

The 'last mile' problem was highlighted by Fritz et al (Fritz and Hausen, 2009) this is what happens to food once it has been bought by the consumer and leaves the shop. Although this lies outside the scope of this research the problem is salient with regard to food recalls. Are consumers aware of what food identification is on the food that they buy and is it easy for them to identify? These questions can become particularly important in the case of food contamination recalls. This is because it is not desirable that consumers who may have been instructed to locate food which has been identified as having undesirable characteristics find that it is not easy to locate such ID's. Are clearly marked identifications which may relate to traceability ID's on food products advantageous in terms of increased consumer awareness of possible benefits from them?

## 3.5 Further work

The questions which have arisen during the course of this research show the scope of further work required. The first of these areas is the need to implement and enable cooperation throughout the supply chain and between the supply chain actors and other interested parties such as regulatory bodies. This follows on from the work presented in papers I, II, III, IV, V VI and VII. This work involves standardisation and implementation of the practice and principles related to what has been called traceability.

The second of these areas is research related to the optimal solutions from the industries' perspective (Wang and Li, 2006). For example paper II - IV showed that it was possible to trace both more and less complex production processes. These papers also present the possibilities for less or greater degrees of granularity, but not what impacts this may have for a company economically. What effect the number and type of transformations has on the costs related to implementing traceability also needs to be investigated. Work is also needed on determining the optimal levels of traceability. Work carried out by Bennet et al (2009) with regards to the cost of growing and holding separate 'Identity Protected' (IP) grain showed that there were optimal ranges of traceability that were the most profitable this is illustrated in fig. 9. Grain traceability has some of the characteristics of a production process which involves continuous liquid mixing. This process makes it difficult to find stop points for defining TU's (Skoglund and Dejmek, 2007). Wilson et al (2008) have also considered the cost and risk of conforming to EU traceability requirements (Wilson et al., 2008). Work related to the costs, benefits and granularity of traceability is another important area. Souza-Monteiro and Caswell (2010) show that the benefits of traceability may not be evenly distributed across the supply chain which may lead some companies to implement 'sub optimal' traceability. This shows the importance of research related both to traceability and the costs and benefit of this in order to avoid suboptimal traceability solutions. The hidden costs and benefits of BSE (Loader and Hobbs, 1996) have already been investigated and it would be interesting to carry out similar studies in other sectors and see if there are general non specific conclusions to be drawn.

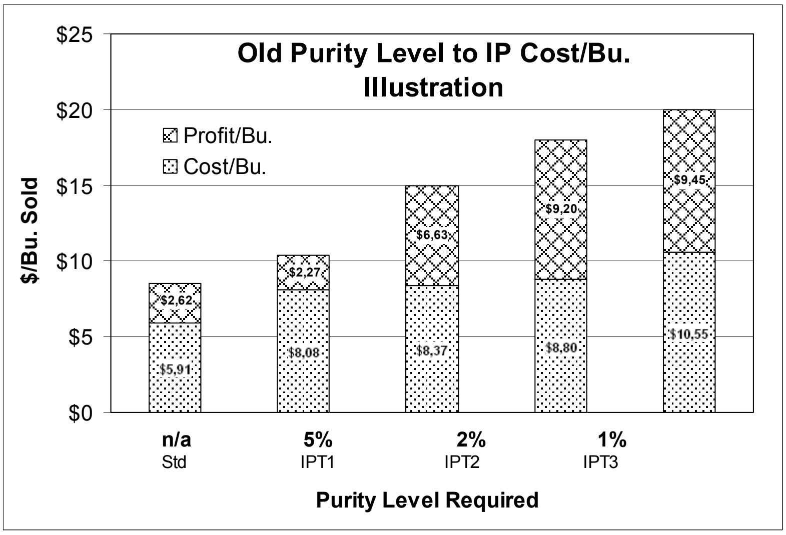


Figure 9. Illustration of the cost of the various levels of purity in grain and the resulting increase in profit (Bennet, 2009).

Work regarding the degree to which traceability can be used as an industry tool for improved internal stock management above and beyond the existing Electronic Product Code (EPC) systems is yet another area for research. If systems similar to that of 'just in time' (JIT) (Ramarapu et al., 1995) which was a system pioneered in the TOYOTA car company in Japan for maximising production capacity in on a limited production site, then it could become a widespread and useful tool. For a further discussion of this in relation to the food sector see Fritz and Hausen (2009).

The third of these areas of further work is to establish to what degree traceability is implemented and used in the real world. Authors have suggested that the EU regulation related to traceability only demands a very simple form of traceability. There must be an explanation for this. Is it that the changes are not economically viable? Is this something which is recognised at governmental levels? Or is it something else?

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## List of papers

I. Donnelly, K.A-M., Karlsen, K.M and Dreyer, B., *Simulated recalls of food products*, Food Control, submitted.

II. Donnelly, K.A-M., Karlsen, K.M. and Olsen, P. (2009) *The importance of transformations for traceability*, Meat Science, 83 pp 68–73.

III. Karlsen, K.M:, Olsen, P. and Donnelly K. A-M., (2009) *Implementing traceability: Practical challenges at a mineral water bottling plant*, British Food Journal 112 (2) pp187-197.

IV. Donnelly, K.A-M. and Karlsen, K.M. (2010) *Lessons from two case studies in implementing traceability in the dried salted fish industry*. Journal of Aquatic Food Product Technology, 19 (10) pp 38-47.

V. Donnelly, K.A-M., Karlsen, K.M., Olsen, P. and van der Roest, J. (2008) *Creating standardised data lists for traceability: a study of honey processing*, Int. J. Metadata, Semantics and Ontologies, Vol. 3, (4) pp.283–291.

VI. Donnelly, K.A-M., Roest, J. V. D., Hoskuldsson, S. T., Olsen P. and Karlsen K.M., (2009) *Improving Information Exchange in the Chicken Processing Sector using Standardised Data Lists*. Communications in Computer and Information Science, 46, 312-321.

VII. Thakur, M, and Donnelly, K.A-M, *Modelling traceability information in soyabean value chains*, Journal of Food Engineering , DOI:10.1016/j.jfoodeng.2010.02.004

VIII. Donnelly, K. A-M. and Thakur M., *Food Traceability Perspectives from the United States of America and Europe*. Okonomisk fiskeriforskning, In Press.

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