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EFFECTS ON LOGISTIC OPERATIONS FROM RFID- AND EPCIS-ENABLED TRACEABILITY

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ABSTRACT

Purpose

The paper explores the potential effects on logistic operations of implementing the Electronic Product Code Information Service (EPCIS) standard and radio frequency identification (RFID) technology to enable food traceability. A conceptual model for analysing supply chains according to EPCIS standard is also presented.

Design/methodology/approach

A literature review was conducted to establish a theoretical framework. A case study of a Swedish fresh fish supply chain was then carried out.

Findings

Implementation of the EPCIS standard and RFID technology to enable food traceability potentially affects the following logistic operations activities: identification, monitoring, labelling, goods handling, reporting of production, identification costs and revenue changes due to sales of goods. The conceptual model was used to analyse the effects.

Research implications/limitations

The paper contributes to logistic research by studying the implementation of RFID technology and information standards to comply with food traceability requirements. The research is limited to fish supply chains; other sectors and supply chains need to be investigated for further generalisation the results.

Practical implications

Regulatory requirements on food traceability stipulate the implementation of food traceability systems, placing the responsibility on companies by authorities. The research presented can support managers in understanding the potential effects of implementing such systems.

Originality/value
The discussion about logistics and food traceability has in part revolved around implementation of RFID technology and standardised approaches for handling information to preserve food quality and safety. This paper presents potential effects on logistic operations when implementing the EPCIS standard and RFID technology as a way of enabling traceability throughout food supply chains.

Keywords *EPCIS standard, Food traceability, Logistic operations, Activities*

Paper type Research paper

1. INTRODUCTION

The general principles of food traceability in Regulation (EC) No 178/2002 (2002) entered into force on 1 January 2005 as a part of the European Union's General Food Law (Folinas et al., 2006). These principles contain rules about the withdrawal of unsafe products and about providing information to end consumers referring to all feed and foodstuffs (Banterle and Stranieri, 2008). To support the General Food Law, the European Commission has published several European regulations on labelling, control of production, handling, and preservation of food safety and quality (e.g. Regulation [EC] No 1224/2009, Regulation [EU] No 404/2011, Regulation [EC] No 1760/2000, Regulation [EC] No 1830/2003). Regulation (EC) No 1224/2009 specifies that, "*Member states shall ensure that operators have in place systems and procedures to identify any operator from whom they have been supplied with lots of fisheries and aquaculture products and to whom these products have been supplied*". It also states that information about this shall be available to authorities on demand (Regulation [EC] No 1224/2009, Article 58). These legal requirements have been further elaborated in Regulation (EU) No 404/2011, by specifying that companies shall provide information through an implemented identification device or system, before 1 January 2013 for fisheries under a developed multi-annual plan, and for other fisheries and aquaculture products, before 1January 2015 (Regulation [EC] No 404/2011, Article 67). Thus, each firm in the fish industry must very soon be able to identify all actors who produce, deliver, and refine food, feed and ingredients that are used in products.

In addition, the interest in implementing RFID (radio frequency identification and data capture) technology (Abad et al., 2009; Hsu et al., 2008; Pettitt, 2001) and information standards (Kher et al., 2010) to comply with food traceability requirements has increased among business managers. One of the information standards investigated for managing food traceability is the open Electronic Product Code Information Service (EPCIS) standard, provided by Global Standardisation One (GS1) (Myhre et al., 2009; Thakur et al., 2011; Gunnlaugsson et al., 2011). This standard was developed to integrate information from logistic processes through the creation of events in which logistic EPC data from tagged objects (i.e. a logistical unit, tagged with an RFID or barcode with an EPC identity) is linked to information from business transactions in supply chains (Harrison, 2004). Moreover, previous research shows that managing supply chains by implementing RFID has effects on logistic effectiveness and control (Bushnell, 2000). Previous research also shows that implementation of information standards and structured data lists provide benefits in managing food traceability regarding preservation of food quality and safety (Senneset et al., 2010; Donnelly et al., 2008).

This paper explores potential effects on logistic operations of implementing the EPCIS standard and RFID technology to enable traceability in fish supply chains. Section 2 describes the methodology and units of analysis. Section 3 provides a detailed literature review about the EPCIS standard and managing food traceability based on the standard's implementation and that of RFID technology, followed by a description of the case in section 4. Section 5 describes the food supply chain based on a proposed conceptual model. The model presents physical movements and information flows in food supply chains according to events specified in the EPCIS standard, emphasising effects on activities in logistic operations. The paper ends with a summary of the results, conclusions and suggestions for further research.

2. METHODOLOGY

The research covered is based on a single case study with three embedded units of analysis (Yin, 2009) and 16 companies (Table 2.1) in a Swedish fresh cod fish supply chain. This is supported by Lyons (2005) who states that the case study is a valuable and underestimated method in food industrial research, since it reveals different research aspects regarding information sharing and exchange needs. The supply chain studied was selected according to the following four criteria:

1. Increased regulatory requirements on food traceability, and sustainable production (e.g. fishery control).
2. Industrial importance of the supply chain in domestic production of fish.
3. Loss in consumer confidence due to deficiencies in the preservation of food safety, quality and living resources (e.g. sustainable fishing).
4. Use of non-automatic and manual identification, tagging, data exchange and storage techniques (e.g. delivery notes, stickers).

Table 2.1 Companies involved.

Supply chain actor	Company type	Number of companies included
Producer	Trawl fisher	2
	Net fisher	6
	Hook fisher	2
Processor	First hand receiver	1
Wholesaler	First hand receiver	1
	Wholesaler	1
Retailer	Restaurant	1
	Grocery store	1
Authority	Governmental authority	1

Data in the case study was collected from the multiple sources as proposed by Yin (2009). This included semi-structured interviews with managers at different levels in supply chain companies, participant observations at internal meetings, direct observations during site visits, internal documents and archival records. To increase validity among first and second hand data from multiple sources, a complete analysis of each interview was sent back and confirmed by the interviewees, and then triangulated with the analyses of documents, records and observations according to Yin (2009).

Potential effects on logistic operations activities when implementing the EPCIS standard and RFID technology for food traceability were analysed from temporal, economical (i.e. costs and revenues), and verification of food safety and quality aspects. These are the three embedded units of analysis presented in Table 2.2.

Table 2.2 The three embedded units of analysis and logistic operations under study.

Units of analysis	Logistic operations activity under study	Definition
Temporal (time)	Labelling	Total time for labelling of goods
	Identification	Total time for unique identification of goods
	Reporting	Total time for reporting of goods
Economical (costs and revenues)	Labelling	Total labelling costs, identification labels
	Re-labelling	Total re-labelling costs, identification labels
	Visualisation	Purchasing costs, technology for visualisation of information
	Purchase	Costs of purchasing goods
	Revenue changes	Changes in revenue due to sales of goods
Food safety and quality	Verification of food quality and safety	Food quality and safety proving capabilities

3. LITERATURE REVIEW

The EPCIS standard

The EPCIS standard is an open standard developed to enable efficient information management by collecting Electronic Product Code (EPC) data from objects (e.g. pallets and boxes) tagged with EPC numbers in supply chains (Prater et al., 2005). By scanning and reading the EPC-tagged objects, data communication between companies is made possible through EPC architecture (Bottani and Rizzi, 2008; EPCglobal, The EPCglobal Architecture Framework, 2007). The architecture includes routines for electronic registration and exchange of information by specification of four events types linked to movements of goods in supply chains (Table 3.1).

Table 3.1 The four event types included in the EPCIS standard (EPCglobal, EPC Information Services [EPCIS] Version 1.0.1 Specification, 2007).

EPCIS event type	Definition
Object event	Reports if one or several tags (labelled according to EPC) are created, clustered or destroyed.
Aggregation event	Describes if one or several tags (labelled according to EPC) are clustered or dispersed from a larger unit such as a pallet or a container.
Transaction event	Describes the relation between one or several tags (labelled according to EPC) and business transactions.
Quantity event	Reports a specified quantity of an item related to a certain action, such as report of inventory levels.

Each of the four event types contains EPC data about the business location (i.e. where the EPC-tagged items may be found), a list of business transactions, the reading point of objects starting the event, the aggregation level of processes that have occurred, number of observed EPC codes, and the step in the business in which the event took place. Moreover, to enhance control of business processes within supply chains, the EPCIS integrates and collects supplementary data – “master data” – consisting of lifecycle information from multiple firms (Cantero et al., 2008).

Managing food traceability by implementing RFID technology and the EPCIS standard

The fundamental principle of food traceability is efficient tracking and tracing of unique logistical physical units in a way that enables monitoring of products and components to preserve food safety, quality and sustainability (Jansen-Vullers et al., 2003; Jacquet and Pauly, 2008). This requires tracing of data in information flows throughout supply chains as a product moves through it: from primary production, through all stages of processing, distribution, sales, to the final disposal at end consumers (Folinas et al., 2006). Because of this, managing food traceability entails efficient information management and data exchange with systems and applications used for business management, traceability, product detection and diversion in supply chains (Moe, 1998; Thompson et al., 2005).

Previous studies on traceability have shown benefits from implementing RFID technology in food supply chains. It reinforces consumer confidence (Abad et al., 2009; Jacquet and Pauly, 2008; Regattieri et al., 2007; Ruiz-Garcia et al., 2010), and improves monitoring of physical conditions during shipment or storage of goods to preserve safety and quality (Zhang and Wang, 2006; Abad et al., 2009; Hsu et al., 2008; Mai, Margeirsson et al., 2010). In addition, implementation of RFID technology has positive effects on inventory management and replenishment, asset visibility, reduction of labour costs, theft prevention, real time communication, and manual handling of data and errors (Prater et al., 2005; Bottani and Rizzi, 2008; Sari, 2010; Jones et al., 2005; Lumsden and Stefansson, 2007; Bushnell, 2000; Kärkkäinen, 2003). However, according to critics the benefits presented are limited to implementation costs of RFID technology (Kärkkäinen and Holmström, 2002; Prater et al., 2005; Mai, Bogason, et al., 2010).

Implementation of the EPCIS standard also provides benefits in information management and data exchange to accomplish upstream and downstream food traceability (Myhre et. al., 2009). Thakur et al. (2011) discuss implementation of the EPCIS standard in the management of food safety and quality in the processing of food products. Gunnlaugsson et al. (2011) argue that applying the standard enables food traceability in fish supply chains, especially because of the ability to extend information visibility. This is also discussed by Bottani et al. (2010) who show that real time visibility of goods based on the EPC architecture (including the EPCIS standard) decreases the bullwhip effect by lowering the costs for some actors in a fast moving consumer goods (FMCG) supply chain. The benefits of implementing the EPCIS standard is supported by previous research on food traceability, which suggests that information standards (Folinas et al., 2006; Senneset, et al., 2007) or structured data lists (Donnelly et al., 2008), should be used for managing food traceability according to requirements (Donnelly et al., 2009; Senneset, et al., 2007; Dreyer et al., 2004).

In conclusion, studies are still lacking in the literature on the effects on logistic operations of implementing RFID technology and the EPCIS standard to manage and analyse food traceability in supply chains. This paper extends previous research and knowledge about doing so to enable food traceability.

4. CASE DESCRIPTION AND ANALYSIS

The effects on logistic operations from implementing the EPCIS standard and RFID technology to enable food traceability were analysed in a six-level fresh cod supply chain, illustrated in Figure 4.1. The supply chain is strictly regulated by governmental authorities through fishery control and accounts for 60% of the domestic Baltic cod production. Non-automated techniques (i.e. handwritten stickers and documents) are used for transferring information between supply chain actors, causing difficulties in complying with legal food traceability requirements and inefficiency in logistic operations activities. Goods in the supply chain are distributed by using fish boxes (un-filleted fish), cardboard boxes (filleted fish) and wrap-up paper (fish fillets).

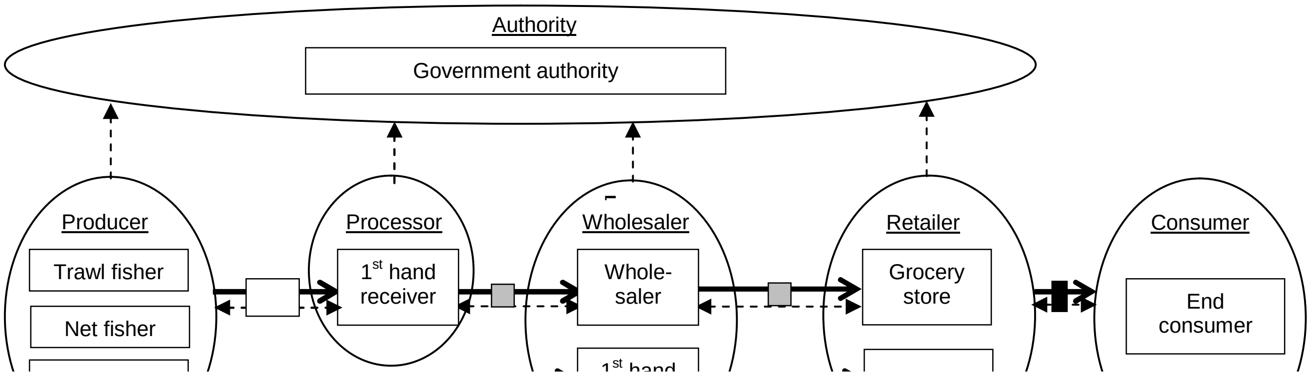

Figure 4.1 Flows, actors and transport units in the fresh cod supply chain under study.

In the analysis of logistic operations effects, RFID-labelled fish boxes (having the Global Returnable Asset Identifier: GRAI number) and cardboard boxes (having the Serialised Global Trade Item Number: SGTIN) were used for unique identification of transport units. A data structure based on the EPCIS standard was implemented to store and transfer master data about food traceability (Table 4.1).

Table 4.1 Master data used to achieve traceability in the fresh cod supply chain.

Parameter	Data definition	Entry example
Identification number	Logbook identification number for the fishing activity	No. SWE 1265676
External marking	The external identification number of the vessel	<XXNN>, vessel external marketing number (GG11)
Vessel name	The name of the vessel	<XXXXX>, vessel name (“Elvy”)
FAO code	Code of Conduct for Responsible Fisheries	<XXX>, FAO code (“COD”)
Catch date	Date of catch	Date (DDMMYY)
Weight	The net weight of the catch related to species caught	Kg
Supplier’s name and address	The address and name of the fisherman	<XXXX>, suppliers business name (“Andersson”)
Trade name	The Swedish trading name of the species caught	<XXXXX>, Swedish trading name (“Torsk”)
Scientific name	The scientific name (Latin) of the species caught	<XXXX>, Latin name of the species (“Gadus morhua”)
Geographical area	The name of the geographical area in which the fishing activity occurred	West Baltic sea zone (23) (24)
Production method		
Gear	The name of the fishing gear used during the fishing activity	Gillnet
Landing date	The date when the catchment was discharged (i.e. put ashore)	Date (DDMMYY)
Preparation level	Letter code of the product presentation (way fish was processed)	<XXX> (GUH; gutted/head cut)

The supply chain starts by scanning the identity (i.e. the GRAI number) of all RFID-tagged fish boxes dedicated to one fishing activity at the producer. The scanning is reported as an EPCIS object event, linking EPC data (e.g. the GRAI number, time/date and location) of each fish box to pre-reported information stored at governmental authorities about the upcoming fishing activity. Then the fishing activity occurs, during which the fisherman lifts his fishing gear, sorts the caught fish and finally places the fish in the dedicated fish boxes.

Once the fishing activity has ended, the landing activity starts in which fish boxes are moved from the fishing vessel on to the quay. During transport, each fish box is then scanned to report the landing activity as an EPCIS transaction event (Table 4.2), and a “landing declaration” is sent to the governmental authorities. Landed fish boxes are then sold by the fisherman to either a processor or a wholesaler according to sales agreements.

Table 4.2 Reported EPCIS transaction event information, fish boxes.

Tag ID	Event time	BizLocation	Read point	BizStep
Urn:epc:id:grai7316272.22222.471	2011-03-08T06:18:33.819+01:00	Simrishamn.Produsent	Simrishamn.Produsent.GLN.1	Urn:epcglobal:cbv:bizstep:accepting
Urn:epc:id:grai7316272.22222.440	2011-03-07T09:28:59.302+01:00	Simrishamn.Produsent	Simrishamn.Produsent.GLN.1	Urn:epcglobal:cbv:bizstep:accepting

Fish boxes received at the processor and at the wholesaler are reported as EPCIS transaction events according to transfer operations and sales agreements of fresh caught fish. Because of this, fish boxes are either sent to the processor for processing, or directly sold further to wholesalers indicating a shift in ownership of goods in the supply chain. This sale of fish boxes is characterised by submission of conveyance and deductive bills to governmental authorities.

Processing of fresh fish starts by scanning all incoming fish boxes that are to be manually emptied into a filleting machine. In the scanning, information about the identity (i.e. the GRAI number), time/date of arrival and location of each fish box is reported as an EPCIS transaction event. The machine produces fish fillets, manually placed in cardboard boxes and labelled with unique stickers including an RFID tag and printed product information. This creates not only a split in materials but also a re-labelling of units in the supply chain. This is reported as an EPCIS aggregation event including information about time/date of filleting, location and unique identity (i.e. SGTIN) of each cardboard box. Once labelled and reported, each cardboard box is lifted on to a pallet and transported by forklift into cooling storage, or into a cooling lorry for further transport. Shipments of cardboard boxes of filleted fish from the two storage facilities are made according to sales agreements between the processor and wholesaler. The shipments are reported as EPCIS transaction events, and as conveyance and deductive bills sent by the processor to governmental authorities. In the EPCIS transaction event, information about time/date of dispatch, the location and unique identity (i.e. SGTIN) of each cardboard box is reported.

All incoming fish boxes and cardboard boxes are scanned at the wholesalers and reported as EPCIS transaction events before they go into storage. Shipment of cardboard and fish boxes from the storage are made according to sales agreements between the wholesaler and retailers, and reported as EPCIS transaction events (Table 4.3) and as “delivery notes” sent by the wholesalers to governmental authorities.

Table 4.3 EPCIS transaction event information on shipment of cardboard boxes from wholesaler to retailer.

Tag ID	Event time	BizLocation	Read point	BizStep
Urn:epc:tag:sgtin-96:1.7332788.000002.7	2011-03-04T12:49:40.216+01:00	epcis.no-tech.co:mda:loc:WholesalerGBG	epcis.no-tech.co:mda:imei:354717043670778	Urn:epcglobal:cbv:bizstep:shipping
Urn:epc:tag:sgtin-96:1.7332788.000001.95	2011-03-04T12:04:21.785+01:00	epcis.no-tech.co:mda:loc: WholesalerGBG	epcis.no-tech.co:mda:imei:354717043670778	Urn:epcglobal:cbv:bizstep:shipping

The identification number (i.e. the SGTIN and GRAI number) of each box received is scanned at retailers and reported as an EPCIS transaction event, transferring information about time/date of arrival and location of the box. If the retailer is a store, fish fillets from the 5 kg cardboard boxes are sold to end consumers in wrap-up paper labelled with a sticker including a barcode and traceability information in plain text. This sale is reported as an EPCIS aggregation event. If the retailer is a restaurant, the fish is sold to end consumers as a component in meals, which is reported as an EPCIS quantity event. Traceability information is provided in plain text on the menu. When reporting sales of fresh fish to end consumers according to the EPCIS standard, it is common to include extraction and presentation of stored traceability information (i.e. master data, Table 4.3) and final reporting of units used as EPCIS object events at the end of the supply chain.

5. RESULTS

To analyse traceability enabled by the implementation of the EPCIS standard and RFID technology, food supply chains were modelled as logistical chains consisting of links, traceability partners and events. A link connects two or several partners, representing either the physical movement or the information flow linked to a traceable resource unit (TRU) of goods (Senneset et al., 2010). Each link is set by the two main categories, external and internal traceability, which exist in food supply chains. External traceability exists when a traceable item is physically handed over from one partner to another. Internal (or local) traceability exists within a partner or production unit (Olsson and Skjöldebrand, 2008; Moe, 1998). Links representing the information flow between supply chain partners are classified into monitored and managed links based on requirements in regulations and of legal control of food products.

Food traceability emphasises the existence of strong connections between different supply chain partners through common business and logistic operations. Partners who perform processes that affect the ownership, the physical movement, position, or condition of the traceable unit within the connections are classified as internal traceability partners (Internal TP). These partners (i.e. producer, wholesaler, processor, and retailer) are directly attached to the chain links through processes initiated by the four event types in EPCIS. External traceability partners (External TP, i.e. authorities and consumers) are not directly attached to the supply chain, but affect its processes because of requirements for preservation of food quality, safety, and environmental sustainability. Authorities affect the processes by monitoring operations according to laws and regulations; consumers affect supply chain processes by requiring information about food products bought at the retailers.

In addition, the paper classifies the four EPCIS events into two main categories: distribution events (DE) and local events (LE), based on the logistic operations initiated by each supply chain process. Distribution events initiate logistic operations for primary production (i.e. fishing, harvest, and breeding), purchase/sales, transport, storing, and monitoring of traceable units, goods and operations. Local events include operations for refinement of food products (i.e. filleting, grinding, or mixing products), and operations for changing the structure of the traceable unit (i.e. splitting or composition of units). However, the two main categories are similar in operations for receiving/dispatching, monitoring and storing information according to EPCIS. A summary of logistic operations initiated by each EPCIS event at different traceability partners is presented along with the two main event categories in Table 5.1.

Table 5.1 Summary of logistic operations, EPCIS events, event categories at traceability partners.

Traceability partner	Event category	Logistic operation	EPCIS event
Producer	Distribution	Primary production	Object event
	Distribution	Sales	Transaction event
Processor	Distribution	Transport	Transaction event
	Local	Filleting	Aggregation event
	Distribution	Sales	Transaction event
Wholesaler	Distribution	Storage	Transaction event
	Distribution	Sales	Transaction event
	Distribution	Transport	Transaction event
Retailer (grocery store)	Distribution	Purchase	Transaction event
	Local	Sales	Aggregation event
	Distribution	Final report of traceable units	Object event
Retailer (restaurant)	Distribution	Purchase	Transaction event
	Distribution	Sales	Quantity Event
	Distribution	Final report of traceable units	Object event
Authority	Distribution	Monitoring of sale and primary production	Transaction event
Consumer	Distribution	Purchase	-

Analysing potential effects on logistic operations of enabling traceability in food supply chains shows that the affected operations are categorised into two event types: distribution and local events. The analysis also shows that distribution events occur at all partners, while local events only occur at the processor and retailer, based on logistic operations for the splitting of materials. Figure 5.1 illustrates the proposed conceptual model with its components.

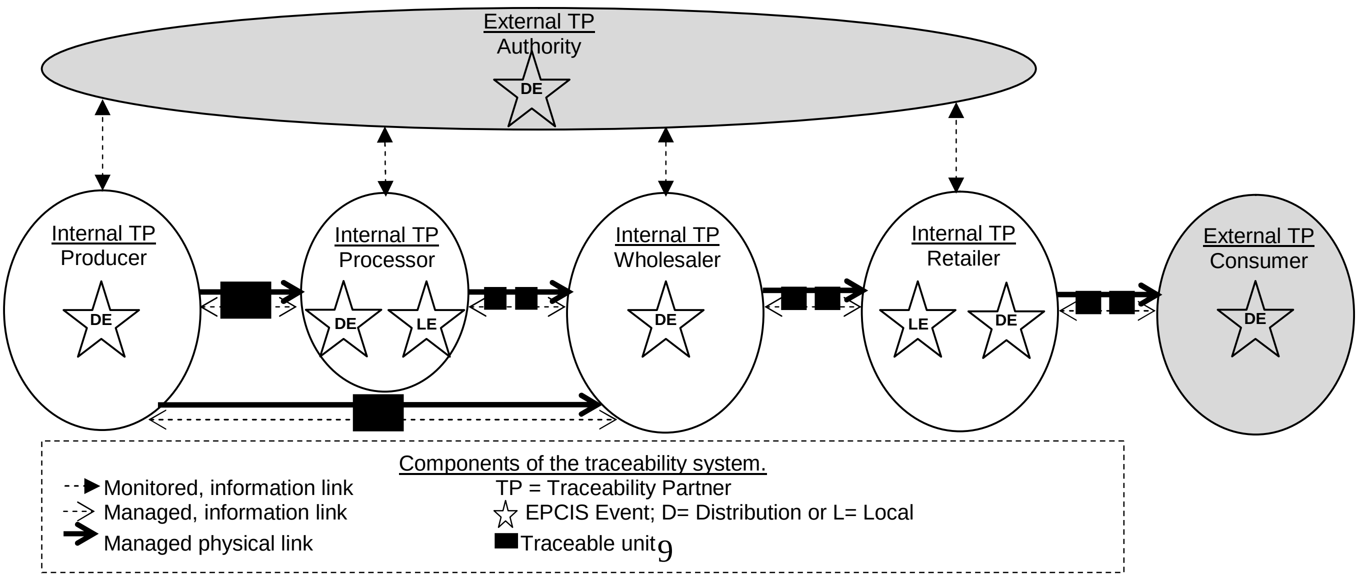

Figure 5.1 Conceptual model analysing effects on logistic operations of RFID- and EPCIS-enabled food traceability.

5.1. Benefits and trade-offs of the RFID- and EPCIS-enabled traceability system

Time benefits and trade-offs

Adopting the conceptual model (Figure 5.1) shows potential effects on activities in logistic operations. These are related to time and cost of logistics operations and to verification of food safety and quality aspects. Time was used as a criterion in the analysis because of its role in improving logistic efficiency. This entails the analysis of changes in time spent handling goods (i.e. labelling, identification and reporting), and time spent handling product reclaims and reporting to authorities. The results show that implementation of RFID technology instead of using paper-based techniques (i.e. handwritten stickers and documents) decreases the time allocated to the capture and transfer of information between different processes and actors through the supply chain. These effects include reduced time for labelling and reporting in primary production, and reporting within processing, wholesale and retail. The results also emphasise a reduction in time for identifying goods in storage operations linked to processing, purchase and sales operations, and time reduction in the identification during product recalls (confirmed by all actors).

However, negative effects are found on time spent re-labelling within processing due to the added time needed to exchange current GS1 identification numbers in the RFID tags. Another time-related trade-off confirmed in the empirical results is the increase in time in transport of goods at the producer, processor and wholesaler. Other time-related deficiencies confirmed are the increase in time in transport of goods at the producer, processor and wholesaler. This is because the fork-lift used in transport needed to pass the RFID scanner within a certain distance and at a low speed to ensure readability of the goods. A comparison in time of logistic operations between an RFID-enabled traceability system and the present paper-based information system are shown in Table 5.2.

Table 5.2 Time comparison in logistic operations between the present information system and an RFID-enabled traceability system.

Supply chain actor	Logistic operations	Present information system (time)	RFID-based traceability system (time)
Producer	Labelling (fish box)	4 seconds	<1 second
	Reporting	15 minutes [III]	2 seconds
Processor	Identification (storage)	270 minutes [I]	3 seconds
	Re-labelling (cardboard box)	6 seconds [II]	60 seconds [II]
	Reporting	15 minutes [III]	3 seconds
Wholesaler	Identification (storage)	45 minutes [I]	3 seconds
	Labelling (fish box)	3 seconds [II]	<1 second [II]
	Reporting	10-15 minutes	30 seconds
Retailer (grocery store)	Identification (storage)	30 minutes [I]	4 seconds
	Reporting	10 minutes [III]	3 seconds
Retailer (restaurant)	Identification (storage)	20 minutes [I]	3 seconds

Notes:
I Half storage, includes time for moving goods.
II Pre-requires that the box has been located and lifted out.
III Faxed/mailed within 48 hours according to regulations for fishery control.

The effects on time in logistic operations due to implementation of the EPCIS standard include reduced time in reporting of production to authorities, in identifying goods in storage operations and during product reclaims, and in the identification of goods in registers and systems used for business management, logistics and fishery control systems. This was confirmed by all actors in the supply chain based on that the EPCIS standard offered a standardised approach in reporting and identifying information in the systems and registers held.

Cost benefits and trade-offs

Implementation of RFID technology and the EPCIS standard to enable food traceability affects economic aspects of logistic operations, both positively and negatively. Positive effects are reduced costs for labelling and re-labelling of goods in operations for primary production and storage. These effects are related to decreased costs by using re-usable RFID tags instead of non-reusable stickers. Another economic benefit of implementing RFID technology is the reduction of labour costs due to the decrease in time spent for labelling, identification, and reporting of goods. For example, the results show that labour costs corresponding to a full-time job, approx. 2600 €/month, can be saved just at the wholesaler.

Economic trade-offs of implementing RFID to enable traceability are related to initial costs of adopting the technology. These comprise costs for the labelling of goods and for visualisation of information. A comparison between labelling costs and visualisation costs in the present information system and the RFID-based traceability system is provided by Table 5.3.

Table 5.3 Comparison of labelling and visualisation costs between the present information system and an RFID-based traceability system.

Supply chain actor	Logistic operations	Present information system (€)	RFID-based traceability system (€)
Producer	Labelling/ re-labelling (fish box)	Labelling stickers: 0.06/ label	RFID tags: 0.21 [I] RFID portal: 5400 [I]
Processor	Re-labelling	Labelling stickers: 0.06/ label	RFID tags: 0.21 RFID portal: 5400 [I] RFID antenna: 140 [I]
Wholesaler	Labelling	Labelling stickers: 0.06/ label	RFID portal: 5400 [I]
Retailer (grocery store)	Labelling	Labelling stickers: 0.01/ label	Labelling stickers: 0.01/ label [I] Handheld RFID scanner: 5300 [I]
	Visualisation	-	Monitor: 270 [I]
Retailer (restaurant)	Labelling	-	Handheld RFID scanner: 5300 [I]

Notes:
I) Initial investment cost

Table 5.3 shows increased initial RFID implementation costs for all supply chain actors and increased permanent labelling costs for the processor. Over the last decade RFID technology price have decreased and are now half of what they were five years ago. Still, RFID technology is more expensive than other labelling techniques (e.g. labelling stickers and barcodes), but when the price becomes economical enough it is expected that RFID will be implemented in further setups (Attaran, 2007).

The economic effects of implementing the EPCIS standard are related to extended information visibility and exchange possibilities. Positive economic effects are found on sales and purchasing activities emphasising increased sales for all supply chain actors because reliable traceability information (or master data extracted from the chain of EPCIS events) was provided to end consumers. This increased consumer confidence and new business partnerships in the supply chain. However, the results show negative effects on purchasing activities for all supply chain actors, except producers, due to master data supply. This is because providing master data affects the ability of producers to require and receive a better price for the goods in sales. This negatively affects the purchasing price for all actors downstream in the supply chain, since the price of fresh fish is not fixed in Sweden. This is also in line with published benefits about implementing RFID technology and the EPCIS standard in FMCG supply chains introduced by Bottani and Rizzi (2008). The provision of master data also increases the opportunity for producers to sell their goods on the open market through internet auctions or directly to international partners.

However, it is to be noted that the costs for system integration according to the structure proposed by the EPCIS standard, and the tagging of fish boxes with RFID-tags to create a stationary traceability system have been excluded in the cost analysis.

5.2. Implementation recommendations

Difficulties in implementing an RFID-based and EPCIS-enabled food traceability system include efficiency trade-offs related to the readability of RFID-tagged goods, and costs for tagging of physical units and system integration and data structuring. Some advisory notes related to these two are listed below:

Readability of RFID-tagged goods
The readability of RFID-tagged goods in food supply chains is affected by temperature, presence of water/moisture and metal, since these elements disturb the signal between the RFID reader and tag. Moreover, readability of RFID-tagged goods is determined by the reading frequency of RFID antennas and RFID tags affecting reading distance. Because of this, laminated RFID tags Gen 2 with an operating temperature of -40°C and a frequency of 860-960 MHz providing a maximum reading distance of 3 m was selected. These tags were glued underneath the flange on the fish boxes and on the outside of the cardboard boxes to protect the tags from mechanical damage, water and temperature changes.

Costs for tagging of physical units and system integration
Because of the physical conditions, labelling of fish boxes with RFID tags is expensive with high initial set up costs for the producers. It is to be noted that these costs, referring to efficiency differences, either can be shared by all partners directly attached to the traceability system (e.g. processor and wholesaler), or be placed on the leasing company of fish boxes. Costs for system integration and restructuring of data according to the proposed structure in the EPCIS standard should be borne by each company.

6. CONCLUSIONS AND FURTHER RESEARCH

Implementing the EPCIS standard provides a standardised approach for exchanging and storing information to enable food supply chain traceability according to regulatory requirements. The demand for getting reliable information to preserve food safety and quality through electronic information exchange has increased among food consumers. Introducing the EPCIS standard and RFID technology affects not only exchange and storage of information, but also logistic operations and activities for managing food supply chains to meet food traceability requirements. A limited amount of literature has been published to date about the effects on logistic operations and activities of implementing the EPCIS standard to enable food traceability.

This paper presents a conceptual model for analysing food supply chains in which the four event classes of EPCIS are classified into two main categories – distribution and local events – based on initiated activities in food supply chains. The analysis of a fresh cod supply chain according to the model shows that distribution activities for the handling of goods, visualisation of information, and for monitoring goods and production in registers are affected. Activities in local events (i.e. re-labelling and sales of goods) are also affected due to a split of materials in supply chains. The study stresses the potential effects on temporal, economical and food safety aspects of food traceability. However, because the dependent variable in the analysis is potential rather than actual, the effects found may be regarded as tentative (Cameron, 1986). Further empirical data collection according to statistical methods may be needed for validation of the results.

Implementation of the EPCIS standard and RFID technology for managing food traceability requires restructuring of data sets and information according to the structure suggested by the standard (e.g. according to EPC architecture). It also requires organisations to subscribe for identification numbers from the GS1 organisation, for example, for labelling goods and hardware (e.g. RFID tags, RFID scanners, RFID portals, servers, etc.). These requirements increase the initial costs for system development and setup, and for labelling goods to enable traceability. One suggestion for further research is the study of such initial costs.

Furthermore, accommodating food traceability requirements involves communication with systems supported by food quality and safety standards (e.g. BRC, HACCP, ISO22000), and legal sustainability requirements (fishery control systems, such as vessel monitoring systems and digital logbook systems). Another subject for further study is the integration of such systems with those used for business management, production management, logistics or traceability to provide end consumers with reliable traceability information about product quality, origin, and safety. Such studies may include further development of the EPCIS standard, especially when it comes to internal traceability.

REFERENCES

Abad, E., Palacio, F., Nuin, M., Gonzalez de Zarate, A., Juarros, A., Gomez, J.M. and Marco, S. (2009), "RFID smart tag for traceability and cold chain monitoring of foods: demonstration in an intercontinental fresh fish logistic chain", *Journal of Food Engineering*, Vol. 93 No. 4, pp. 394-399.

Attaran, M. (2007), "RFID: an enabler of supply chain operations", *Supply Chain Management: An international Journal*, Vol. 12 No. 4, pp. 249-257.

Banterle, A. and Stranieri, S. (2008), "The consequences of voluntary traceability system for supply chain relationships. An application of transaction cost economics", *Journal of Food Policy*, Vol. 33 No. 6, pp. 560-569.

Bottani, E. and Rizzi, A. (2008), "Economical assessment of the impact of RFID technology and EPC system on the fast-moving consumer goods supply chain", *International Journal Production Economics*, Vol. 112 No. 2, pp. 548-569.

Bottani, E., Montanari, R. and Volpi, A. (2010), "The impact of RFID and EPC network on the bullwhip effect in the Italian FMCG supply chain", *International Journal Production Economics*, Vol. 124 No. 2, pp. 426-432.

Bushnell, R. (2000), “RFID’s wide range of possibilities”, *Modern Materials Handling*, Vol. 55 No. 1, p. 37.

Cameron, K.S. (1986), “Effectiveness as a paradox: consensus and conflict in conceptions of organizational effectiveness”, *Journal of Management Science*, Vol. 32, No. 5, pp. 539-553.

Cantero, J.J., Guijarro, M.A., Arrebola, G., García, E., Baño, J., Harrison, M. and Kelepouris, T. (2008), “Traceability applications based on discovery services”, in *Proceedings of the International Conference on Emerging Technologies and Factory Automation, (EFTA)*, IEEE, Hamburg, Germany, pp. 1332-1337.

Donnelly, K.A-M., Karlsen, K.M., Olsen, P. and van der Roest, J. (2008), “Creating standardized data lists for traceability – a study of honey processing”, *International Journal of Metadata, Semantics and Ontologies*, Vol.3 No. 4, pp. 283-291.

Donnelly, K.A-M., van der Roest, J., Höskuldsson, S.T., Olsen, P. and Karlsen, K.M. (2009), “Improving information exchange in the chicken processing sector using standardised data lists”, in Sartori, F., Sicilia M.Á. and Manouselis, N. (Ed.), in *Proceedings of the third International Conference Metadata and Semantic Research, MTSR 2009*, Milan, Italy, pp. 312-321.

Dreyer, C., Wahl, R., Storøy, J. and Forås, E. (2004), “Traceability standards and supply chain relationships”, in Aronsson, H. (Ed.), in *Proceedings of the 16th Annual Conference for Nordic Researchers in Logistics, NOFOMA 2004*, Linköping, Sweden, pp. 155-170.

EPCglobal (2007), “The EPCglobal Architecture Framework, Version 1.2”, available at: http://www.gs1.org/gsmp/kc/epcglobal/architecture (accessed 7 February 2012).

EPCglobal (2007), “EPC Information Services (EPCIS) Version 1.0.1 Specification”, available at: http://www.gs1.org/gsmp/kc/epcglobal/epcis (accessed 7 February 2012).

Folinas, D., Manikas, I. and Manos, B. (2006), “Traceability data management for food chains”, *British Food Journal*, Vol. 108 No. 8, pp. 622-633.

Gunnlaugsson, V., Thakur, M., Forås, E., Ringsberg, H., Gran-Larsen, Ö. and Margeirsson, S. (2011), “EPCIS standard used for improved traceability in the redfish value chain”, in *Proceedings of the 13th International Conference on Modern Information Technology in the Innovation Processes of the Industrial Enterprises*, MITIP 2011, Trondheim, Norway, pp.182-192.

Harrison, M., (2004), “EPC information service”, in *Proceedings of the Auto-ID Labs Research Workshop, September 23-24*, University of St. Gallen, Switzerland.

Hsu, Y.C., Chen, A.P. and Wang C.H. (2008), “A RFID-enabled traceability system for the supply chain of live fish”, in *Proceedings of the IEEE International Conference on Automation and Logistics, ICAL 2008, IEEE*, Qingdao, China, pp. 81-86.

Jacquet, J.L. and Pauly, D. (2008), “Trade secrets: renaming and mislabeling of seafood”, *Marine Policy*, Vol. 32 No. 3, pp. 309-318.

Jansen-Vullers, M.H., Van Dorp, C.A. and Beulens, A.J.M. (2003), “Managing traceability information in manufacture”, *International Journal of Information Management*, Vol. 23 No.5, pp. 395-413.

Jones, P., Clarke-Hill, C., Hillier, D. and Comfort, D. (2005), “The benefits, challenges and impacts of radio frequency identification technology (RFID) for retailers in the UK”, *Marketing Intelligence & Planning*, Vol. 23 No. 4, pp. 395-402.

Kher, S.V., Frewer, L.J., De Jonge, J., Wentholt, M., Howell-Davies, O., Luijckx, N.B.L. and Cnossen, H.J. (2010), “Experts’ perspectives on the implementation of traceability in Europe”, *British Food Journal*, Vol. 112 No. 3, pp. 261-274.

Kärkkäinen, M. (2003), “Increasing efficiency in the supply chain for short shelf life goods using RFID tagging”, *International Journal of Retail & Distribution Management,* Vol. 31 No. 10, pp. 529-536.

Kärkkainen, M. and Holmström, J. (2002), “Wireless product identification: enabler for handling efficiency, customization and information sharing”, *Supply Chain Management: An International Journal,* Vol. 7 No. 4, pp. 242-252.

Lumsden, K. and Stefansson, G. (2007), “Smart freight to enhance control of supply chains”, *International Journal of Logistics Systems and Management,* Vol. 3 No. 3, pp. 315-329.

Lyons, H. (2005), “Food industry case studies: a suitable medium for publication”, *British Food Journal,* Vol. 107 No. 9, pp. 702-713.

Mai, N., Margeirsson, B. and Stefansson, G. (2010), “Temperature controlled transportation alternatives for fresh fish – air or sea?”, in Stentoft Arlbjørn, J. (Ed.), *Proceedings of the 22nd Annual NOFOMA Conference Logistics and Supply Chain Management in a Globalised Economy,* University of Southern Denmark, Kolding, Denmark, pp. 147-162.

Mai, N., Bogason, S.G., Arason, S., Árnason, S.V. and Matthíasson, T.G. (2010), “Benefits of traceability in fish supply chains – case studies”, *British Food Journal*, Vol. 112 No. 9, pp. 976-1002.

Moe, T. (1998), “Perspectives on traceability in food manufacture”, *Trends in Food Science and Technology*, Vol. 9 No. 5, pp. 211-214.

Myhre, B., Netland, T. and Vevle, G. (2009) “The footprint of food – a suggested traceability solution based on EPCIS”, in *Proceedings of the Fifth European RFID systems and Technologies (RFID SysTech, 2009) – workshop in Bremen,* University of Bremen, Germany.

Olsson, A. and Skjöldebrand, C. (2008), “Risk management and quality assurance through the food supply chain – case studies in the Swedish food industry”, *The Open Food Science Journal*, Vol. 2, pp. 49-56.

Pettitt, R.G. (2001), “Traceability in the food animal industry and supermarket chains”, *Review International Office of Epizootics,* Vol. 20 No. 2, pp. 584-597.

Prater, E., Frazier, G.V. and Reyes, P.M. (2005), “Future impacts of RFID on e-supply chains in grocery retailing”, *Supply Chain Management: An International Journal*, Vol. 10 No. 2, pp. 134-142.

REGULATION (EC) No 1760/2000 OF THE EUROPEAN PARLIAMENT AND THE COUNCIL of 17 July 2000 establishing a system for the identification and registration of bovine animals and regarding the labelling of beef and beef products and repealing Council Regulation (EC) No 820/97.

REGULATION (EC) No 178/2002 OF THE EUROPEAN PARLIAMENT AND THE COUNCIL of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety.

REGULATION (EC) No 1830/2003 OF THE EUROPEAN PARLIAMENT AND THE COUNCIL of 22 September 2003 concerning the traceability and labelling of genetically modified organisms and the traceability of food and feed products produced from genetically modified organisms and amending Directive 2001/18/EC.

REGULATION (EC) No 1224/2009 OF THE EUROPEAN COUNCIL OF THE EUROPEAN UNION of 20 November 2009 establishing a Community control system for ensuring compliance with the rules of the common fisheries policy.

REGULATION (EU) No 404/2011 OF THE EUROPEAN COMMISSION of 8 April 2011 laying down detailed rules for the implementation of Council Regulation (EC) No 1224/2009 establishing a Community control system for ensuring compliance with the rules of the Common Fisheries Policy.

Regattieri, A., Gamberi, M. and Manzini, R. (2007), “Traceability of food products: general framework and experimental evidence”, *Journal of Food Engineering*, Vol. 81 No. 2, pp. 347-356.

Ruiz-Garcia, L., Steinberger G. and Rothmund, M. (2010), “A model and prototype implementation for tracking and tracing agricultural batch products along the food chain”, *Journal of Food Control*, Vol. 21 No. 2, pp. 112-121.

Sari, K. (2010), “Exploring the impacts of radio frequency identification (RFID) technology on supply chain performance”, *European Journal of Operational Research*, Vol. 207 No. 1, pp. 174-183.

Senneset, G., Midtstraum, R., Forås, E., Vevle, G. and Mykland, I.H. (2010), “Information models leveraging identification of returnable transport items”, *British Food Journal*, Vol. 112 No. 6, pp. 592-607.

Senneset, G., Forås, E. and Fremme, K.M. (2007), “Challenges regarding implementation of electronic chain traceability”, *British Food Journal*, Vol. 109 No. 10, pp. 805-818.

Thakur, M., Sørensen, C-F., Bjørnson, F-O, Forås, E. and Hurburgh, C.R. (2011), “Managing food traceability information using EPCIS framework”, *Journal of Food Engineering*, Vol. 103 No.4, pp. 417-433.

Thompson, M., Sylvia, G. and Morrissy, M. T. (2005), “Seafood traceability in the United States: current trends, system design, and potential applications”, *Comprehensive Reviews in Food Science and Food Safety*, Vol. 1 No. 1, pp. 1-7.

Yin, R.K. (2009), *Case Study Research – Design and Methods*, SAGE Publications, Thousand Oaks, USA.

Zhang, L. and Wang, Z. (2006), “Integration of RFID into wireless sensor networks: architectures, opportunities and challenging problems”, in *Proceedings of the Fifth International Conference on Grid and Cooperative Computing Workshops, GCCW '06,* IEEE Computer Society, Washington, D.C. USA.