The Efficacy of Using the EPCIS Standard for Livestock and Meat Traceability

Thesis for Master of Logistics and Supply Chain Management

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Abstract

Radio Frequency Identification (RFID) systems have been used for many years in identification applications. The efficacy of using UHF RFID technologies for livestock traceability and related applications has been widely repudiated within the global livestock sector. Technical inadequacies and constraints of physics are typically identified as the basis for discrediting the RFID form.

The EPCglobal Network is a secure means to connect servers containing information related to items identified by using globally unique numbers known as EPC (Electronic Product Code) numbers. The servers, called Electronic Product Code Information Services – or EPCIS - is an open public standard used to track the progress of objects as they move through the supply chain.

Published research into the use and efficacy of using the suite of EPC RFID standards, especially the EPCIS Standard to assess traceability performance outcomes in any industry sector, let alone the livestock sector is minimal. This thesis investigates, examines and assesses the use of UHF RFID technology within the context of the EPCglobal suite of standards, focusing specifically on the component EPCIS standard to determine efficacy for livestock traceability.

The thesis examines regulatory based definitions of traceability in order to adopt a reference definition and uses a multi-stage proof of concept process model to assess and draw conclusions in determining the efficacy of using the EPCIS Standard for livestock traceability.

A definition of *Chain Traceability*, defined by the Food Business Forum (CIES 2005 p.7) was adopted as a benchmark reference against which objectives were measured and assessed. Because all EPC identifiers and relevant associations used in the research was able to be identified, recorded and reported using the EPCIS standard and database, chain traceability was demonstrated, thereby verifying traceability objectives and the efficacy of the EPCIS standard as a tool for livestock traceability.

Acknowledgements

I would like to thank those who have worked with me on a difficult journey over the past six years in evangelising the use of EPCglobal Standards for livestock traceability in New Zealand. A special thanks to colleagues at GS1 New Zealand and The New Zealand RFID Pathfinder Group Incorporated but also to those who have in some way been involved in our research and trials.

Special thanks also to evangelist colleagues from across the world especially those of GS1 Hong Kong, GS1 Denmark and Invengo Limited, China. To Ian Robertson, former Director of EPCglobal Incorporated without you beside me all the way, this would not have been possible – thanks so much.

To Dr Norman Marr, Massey University. Thanks for your counsel and patience. You gave me the confidence to undertake this assignment and then complete it; I never thought I could - my sincere thanks.

To my mum and dad (Alan Doig) - Agnus Dei, qui tollis peccata mundi, dona nobis pacem.

I write the dedication to my wife on a special day in our calendar, August 11th, the feast day of St Suzanne. I need say no more.

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Chapter 1 Introduction

1.1 Introduction

Radio Frequency Identification (RFID) systems have been used for many years in identification applications. Cooke and Diprose (Cooke and Diprose 2010) outline that RFID tags have been used in animal applications since the late 1980's. The low frequency (LF) form of RFID has typically been used in livestock applications around the world. RFID rumen bolus and ear tag technologies are widely used for livestock management and inventory control and are mandated in some parts of the world for animal traceability and biosecurity.

In many other industries, the ultra-high frequency (UHF) form of RFID technology is being used in preference to the low frequency form. While UHF RFID adoption is by no means ubiquitous, the standardisation work undertaken by global standards organisation EPCglobal Inc; is believed to have provided a platform for increased research and implementation worldwide.

The efficacy of using UHF RFID technologies for livestock traceability and related applications has been widely repudiated within the global livestock sector. Technical inadequacies and constraints of physics attributed to water and metal are usually identified as the basis for discrediting the UHF form. However, findings from research within the context of livestock completed by standards organisation GS1 New Zealand in conjunction with the New Zealand RFID Pathfinder Group Inc; between 2008 and 2010 (Hartley et al., 2008); and Rezare Systems (Cooke and Diprose 2010) outlined that UHF RFID technologies work at least as well as the globally favoured and entrenched low frequency option form of RFID technology.

The EPCglobal Network is a secure means to connect servers containing information related to items identified by using globally unique numbers known as EPC (Electronic Product Code) numbers. The servers, called Electronic Product Code Information Services – or EPCIS - is an open public standard used to track the progress of objects as they move through the supply chain. EPC Information Servers are linked via a set of standards-based network services and the internet infrastructure. The EPCglobal Network is being used in many industries worldwide to provide traceability outcomes but for livestock applications, its efficacy has not been thoroughly investigated as a tool for robust traceability outcomes and objectives.

Research into the efficacy of using the EPCIS standard for livestock and meat traceability using a simulated supply chain involving a nine-step process, from a farm, through a meat processing facility to a retailer has demonstrated that the standard provides efficient and effective livestock and meat traceability outcomes.

1.2 Background

Prompted by their constituents and by their own concerns about public safety, government legislators in Europe and in the United States have been drafting laws requiring various degrees of traceability, especially in the food industry. These new regulatory requirements are creating increased demand for traceability than ever before. Companies need systems that can provide end-to-end traceability with accurate information and precise identification of the products and services, locations and the supply chain actors involved. Increasingly, open, globally standardised systems that enable efficient and accurate traceability for food and food products are being investigated to address these traceability requirements.

In New Zealand, biosecurity concerns have prompted the New Zealand National Animal Identification and Tracing Authorities (NAIT) to mandate the use of RFID technologies. As of July 2012, all cattle were required to have RFID ear tags inserted using low frequency (LF) RFID devices. Other species will be mandated in a phased implementation approach; deer scheduled for March 2013.

Because of significant advances and improvement in UHF RFID hardware performance in recent years, interest in the use of UHF RFID technologies for livestock applications has gained widespread interest within the community both nationally and internationally.

Research into the use of UHF RFID technologies utilising EPC compliant hardware (tags and readers) and identifiers is not uncommon. The focus however, has primarily been on the use of the UHF spectrum (850Mhz – 950Mhz) to test and examine RFID hardware performance in identifying animals and their movements. New Zealand research into the use of UHF RFID for livestock applications is considered amongst the first globally. Notable research (Hartley et al., 2008) investigating the efficacy of UHF RFID technologies (and implicitly, the associated EPC RFID Standards) for livestock applications highlight promising results. However, the efficacy of using the EPCIS Standard, a key component of the EPCglobal Network suite of Standards as a tool for livestock traceability has not been investigated.

1.3 Objectives

This research seeks to demonstrate the efficacy of using the EPCIS Standard as a core component of the EPCglobal Network, for livestock and meat traceability. A literature review outlines that definitions of traceability within the context of livestock and meat are inconsistent. This analysis explores regulatory definitions and adopts a reference definition for traceability to benchmark, examine and assess stated objectives against. The research objectives are summarised as follows:

- Examine various regulatory based definitions of traceability and adopt a reference definition as a basis for the research in achieving desired regulatory, legislative and corporate outcomes.

- Using the research methodology outlined, the definition will be assessed to determine the efficacy of using the EPCIS standard for livestock and meat traceability.

1.4 Format of the Thesis

This thesis is structured in six chapters.

1. Chapter one provides an introduction into the efficacy of the using EPCglobal Network and its constituent suite of component standards for traceability outcomes. The chapter also

outlines the component EPC RFID standards, the architectural framework and overall functionality of the EPCglobal Network with specific reference to the EPCIS (Electronic Product Code Information Services) standard.

2. Chapter two describes a background summary of radio frequency identification technologies (RFID) focusing on the emergence and application of the EPCglobal suite of standards.

3. Chapter three provides a comprehensive literature review of RFID technology and includes:
    a. Outlining a summary of RFID's renaissance in the early 2000's.
    b. An overview of RFID related trials specific to EPC RFID standards in food related industries with an overview of trials in other industry sectors including retail, FMCG and transportation and logistics.
    c. An overview of the limited number of published EPCIS pilots with specific reference to seafood and livestock.
    d. A discussion on traceability and its definition within the context of the agriculture and food sectors; regulatory initiatives and requirements in New Zealand for livestock traceability, and a review of the 'Internet of Things'.
    e. A brief review of academic research and analysis of EPC RFID standards within the context of livestock.

4. Chapter four outlines the research methodology used to examine and evaluate the efficacy of using the EPCglobal Network with a focus on the EPCIS standard for livestock and meat traceability. The methodology outlines a process model involving nine discrete steps that describe the movement of a sample of cattle and finished packaged meat cuts through a supply chain involving a farm location, a livestock processing facility and a retail shop where the process of identifying, capturing, retrieving and reporting on the information at each process stage is outlined.

5. Chapter five provides an analysis and discussion focusing on the elements necessary for defining traceability as it provides a benchmark on which to measure research objectives. The salient outcomes and findings of the research are outlined and their significance with respect to the stated objectives and definitions are discussed. Technical issues uncovered during the research are also addressed and discussed along with implications in respect of the New Zealand National Animal Identification Tracing (NAIT) initiative.

6. Chapter six outlines the research conclusions and provides commentary and discussion of the key findings. Recommendations for future research is highlighted.

Chapter 2 Background

2.1 Introduction

The essence of this research is to examine and assess the efficacy of the EPCglobal Network and its constituent suite of component standards within the context of livestock and meat traceability outcomes. This chapter outlines the component standards, the architectural framework and the overall functionality of the EPCglobal Network with specific reference to the EPCIS standard.

2.2 The EPCglobal Network Elements

The EPCglobal Network is a computer network used to share product data between trading partners. It was created by EPCglobal Inc; a global standards development organisation operating under the GS1 organisation. The basis for the information flow in the network is the Electronic Product Code (EPC) of each product which is stored on a RFID tag. The network manages dynamic information that is specific for individual products. This includes data regarding the movement of an object throughout the product life cycle.

One of the objectives of the EPCglobal Network is to allow sharing information of observed EPC traces (Guinard et al., 2010). Thus, the network specifies a standardised server-side EPCIS, in charge of managing and offering access to traces of EPC events. Whenever a tag is read, it goes through a filtering process and is eventually stored in an EPCIS database together with contextual data. In particular, these data deliver information about:

- The ‘what’: what tagged product (EPCs) were read.
- The ‘when’: at what time the items were read.
- The ‘where’: where were the items read in terms of business location (eg: Boning Room).
- The ‘who’: what readers (Read Point) recorded this trace.
- The ‘which’: what was the business context (Business Step) recording the trace (eg: shipping).

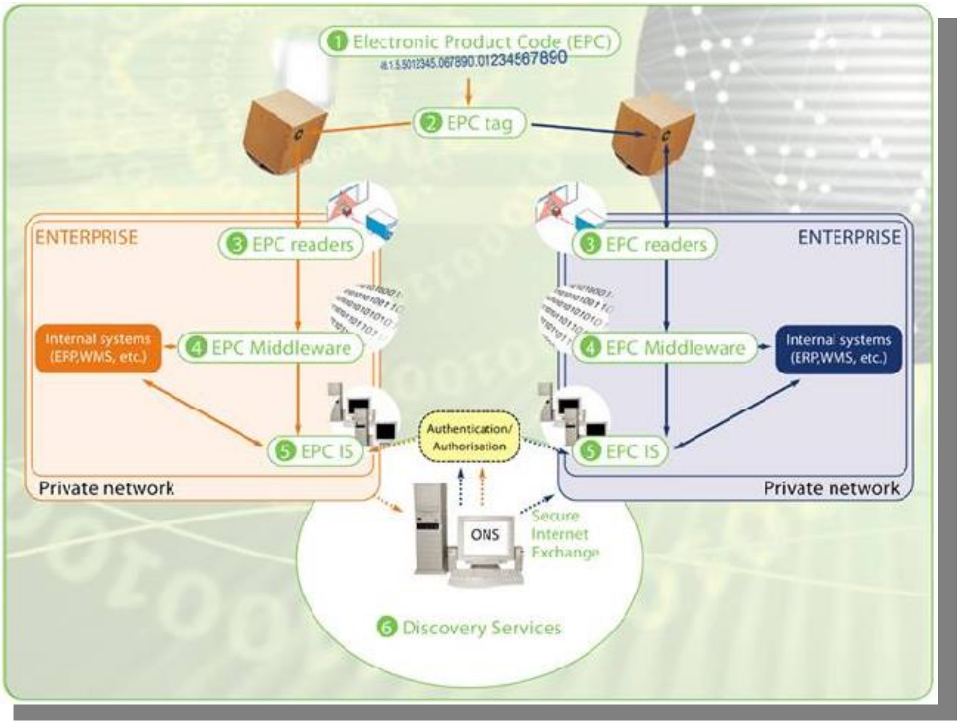


Figure: 2.1 - The EPCglobal Network™ (Source: EPCglobal Inc;)

The EPCglobal Network consists of a number of components as outlined in Figure 2.1.

The **Electronic Product Code** (**EPC**) is a family of coding schemes touted by some as an eventual successor to the barcode. The EPC was created as a low-cost method of tracking goods using radio-frequency identification technology. It is designed to meet the needs of various industries, while guaranteeing uniqueness for all EPC compliant tags. EPC tags were designed to identify each item manufactured as opposed to just the manufacturer and class of products, as bar codes do today. The EPC accommodates existing coding schemes and defines new schemes where necessary.

Object Name Service (ONS) - is a service that enables the discovery of object information on the basis of an EPC. With the Electronic Product Code a matched URL or IP-address is searched within a data base and sent back to the requester when found. Under the URL, further information about the object which is associated with the EPC can be found. The ONS is comparable to the Domain Name System (DNS) which is used in the internet to translate names into IP addresses. The Object Name Service (ONS) is often described as the EPCglobal Network's, *'Yellow Pages'*.

The ONS is a network directory service that is interrogated by network subscribers to locate EPCIS implementations on the EPCglobal Network. If the EPCIS details are known by subscribers, interrogation of the ONS is neither necessary nor required.

EPC Discovery Services are an instrument to find EPC Information Services within the network. They can be compared to search engines of the internet. They offer trading partners the ability to find all parties who had possession of a given product and to share RFID events about that product.

EPC Information Services (EPCIS) is a standard designed to enable EPC-related data sharing within and across enterprises. This data sharing is aimed to enable all network participants a common view of object information. At the EPCIS, each subscriber has access to its dynamic information.

EPC Security Services are tools which allow a secured access to the information of the EPCglobal Network in accordance to the access rights of the participants.

EPC Identifiers

An EPC (Electronic Product Code) provides a unique, serialised identifier for any kind of object. Identifiers from the barcode environment can be encoded into an EPC format including: GTIN (Global Trade Item Number), GRAI (Global Returnable Asset Identifier), SSCC (Serialised Shipping Container Code) and GIAI (Global Individual Asset Identifier. EPC serialises item identifiers to establish instance level identification.

EPC Headers

The Header defines the overall length, identity type, and structure of the EPC Tag encoding, including its Filter Value, if any. The header is of variable length (EPCglobal, 2005) and the format is outlined in Figure 2.2. The filter value (optional) is extra information that is encoded into the RFID tag to assist RFID readers filter tag data when confronted with a large number of tags.

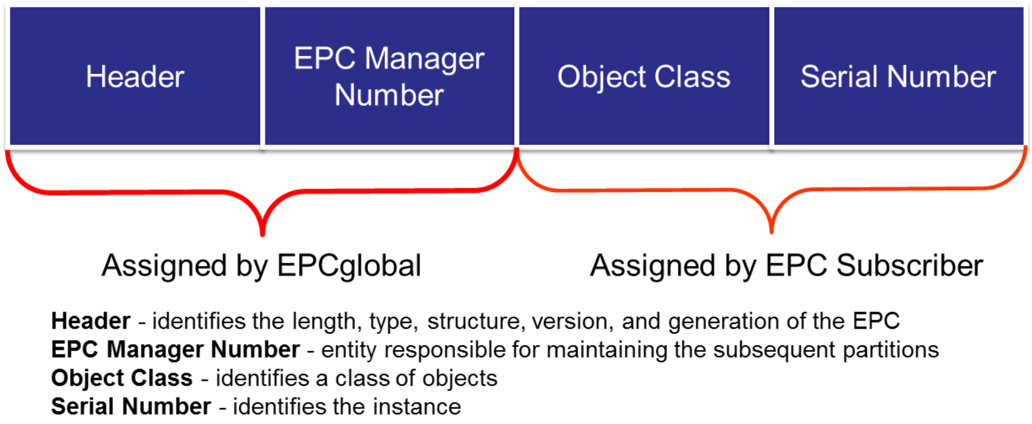


Figure: 2.2 - EPC Header (Source: EPCglobal Inc; 2005)

Global Trade Item Number (GTIN) is an "umbrella" term used to describe the entire family of data structures for **trade items** (products and services) identification. GTIN is constructed in a standardised manner. A serialised GTIN (sGTIN) has a defined format as outlined in Table 2.1.

	Header	Filter Value	Partition	Company Prefix	Item Reference	Serial
SGTIN- 96	8 bits	3 bits	3 bits	20-40 bits	24-4 bits	38 bits
	0011 0000 (actual value)	8 (decimal capacity)	8 (decimal capacity)	999.999 – 999.999.999 .999 (decimal capacity)	9.999.999 - 9 (decimal capacity)	274,877,90 6,943 (decimal capacity)

Table: 2.1 - Data Structure for Serialised Global Trade Item Number (sGTIN).
(Source: EPCglobal Inc; 2005)

Serialised Global Location Number (sGLN) is part of the suite of standards. It is a simple tool used to identify a location and can identify locations uniquely where required. It is also the identification key used to identify physical locations or legal entities. Table 2.2 outlines the key of a sGLN that comprises a Company Prefix, Location Reference, and Check Digit. GLN's can be serialised to provide for multiple locations within an entity ie: a specific department within a processing plant.

	Header	Filter Value	Partition	Company Prefix	Location Reference	Serial Number
SGLN- 96	8 bits	3 bits	3 bits	20-40 bits	21-1 bits	41
	0011 0010 (actual value)	8 (decimal capacity)	8 (decimal capacity)	999,999 – 999,999,999,9 99 (decimal capacity)	999,999 – 0 (decimal capacity)	[Not Used]

Table: 2.2 - Data Structure for Serialised Global Location Number (sGLN)
(Source: EPCglobal Inc; 2005)

Serialised Shipping Container Number (SSCC) - is an eighteen digit number used to identify logistics units. The SSCC can be encoded into a barcode, generally the GS1-128 standard, an EPC RFID tag and is used in electronic commerce transactions. Table 2.3 outlines the data format of the SSCC in an EPC tag which comprises a Header, Filter Value (optional) a GS1 company prefix and a serial reference.

	Header	Filter Value	Company Prefix *Index*	Serial Reference
SSCC-64	8 bits	3 bits	14 bits	39 bits
	0000 1000 (actual value)	8 (decimal capacity)	16,383 (decimal capacity)	99,999 – 99,999,999,999 (decimal capacity)

Table: 2.3 - Data Structure For Serial Shipping Container Number (SSCC)
(Source: EPCglobal Inc; 2005)

Hill et al., (2012) provides an example of a 96-bit data coding structure for livestock unique identification based on sGTIN in Figure 2.3. There is currently no specific EPC identifier for livestock identification for any species. In general, within the context of UHF RFID research for livestock applications, researchers have opted to use the *Serialised Global Trade Item Number* (sGTIN) as the unique 'animal' identifier.

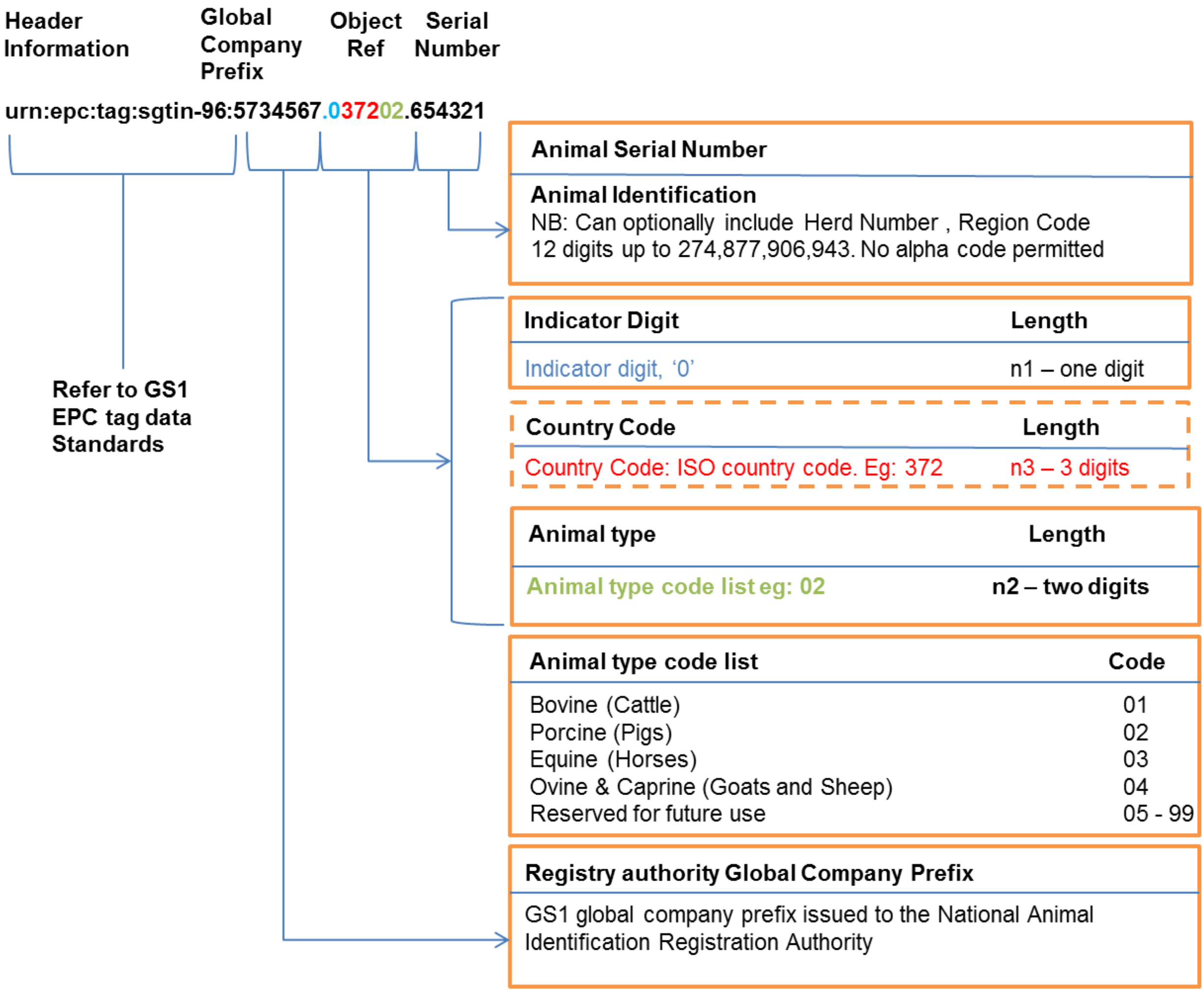


Figure: 2.3 - A 96 bit sGTIN EPC Coding Structure (example) for a livestock application. Source: Hill et al., 2012)

2.3 The EPCglobal Architectural Framework

The EPCglobal Architecture Framework is represented in Figure 2.4. It outlines a collection of interrelated hardware, software and data standards (EPCglobal standards), together with shared network services that are operated by EPCglobal, its delegates, and others (EPC Network Services), all in service of a common objective of enhancing the supply chain efficiency and visibility through the use of Electronic Product Codes (Traub et al., 2010 p.7).

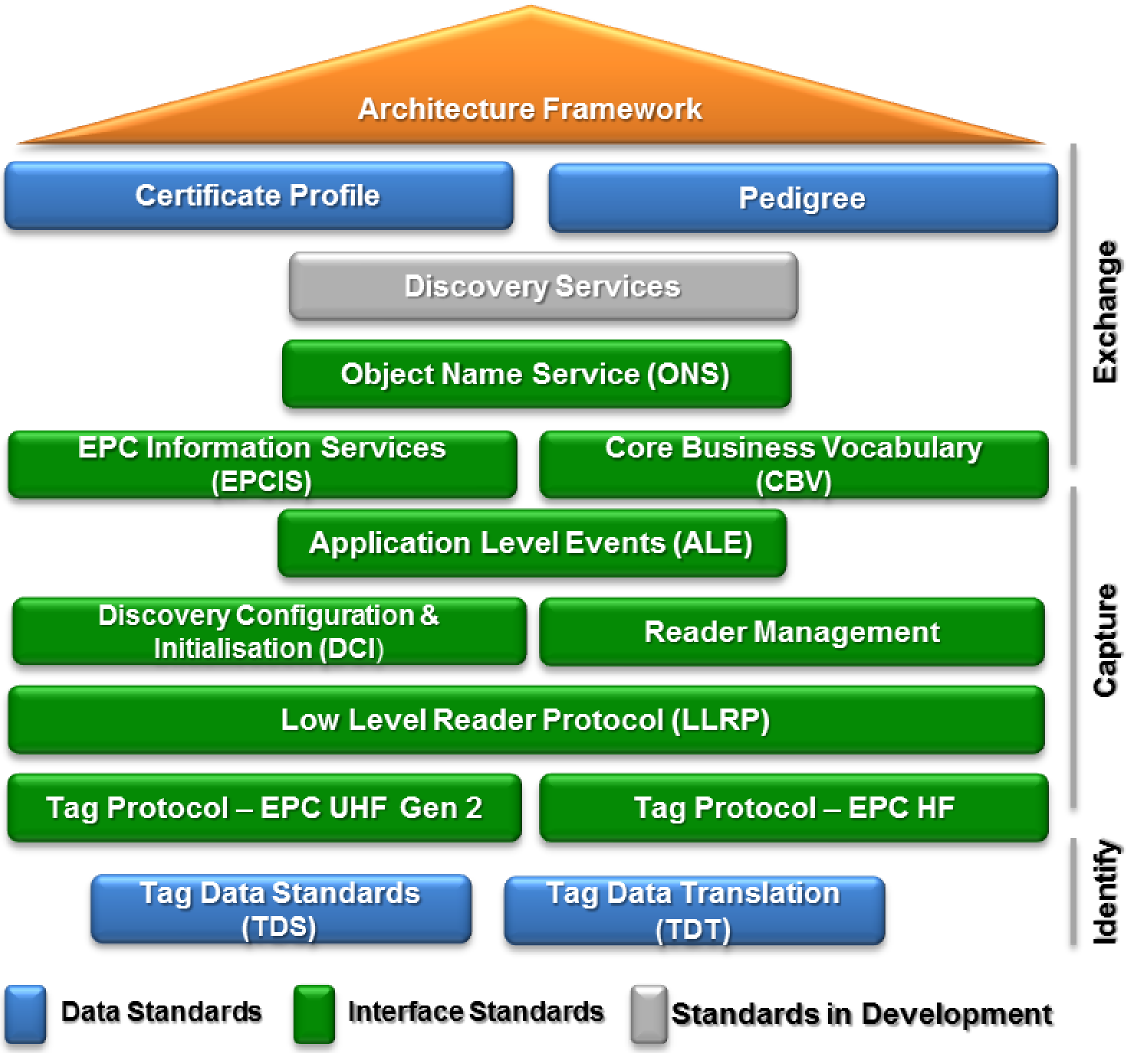


Figure: 2.4 – The EPCglobal Network Architecture Framework.
(Source: EPCglobal Inc; 2005)

2.4 Electronic Product Code Information Service – EPCIS

The EPCIS standard allows companies to associate information to RFID tag reads. When there is an "event", for example, a pallet passing through a portal where the pallet tag is 'read' - the EPCIS standard enables businesses to append additional information to the tag ID, such as the date and time, as well as the RFID reader's unique location (IP address). A business can indicate whether the pallet is being received or shipped. This enables software systems to interpret, for instance, if a tag is read at a receiving bay but isn't read after a certain period at the doorway between the back of a store and the retail floor. If that occurs, an alert can be generated to have someone bring the product to the retail floor. Associating individual tag reads with a business context is also essential for offline EPC data-mining that can identify inefficiencies and trigger business process changes.

The main objective of the EPCIS is to store these data to allow creating a global network where participants can gain a shared view of these EPC traces. As such, the EPCIS deals with historical data allowing, for example, participants in the supply chain to share the business data produced by the EPC-tagged items. Summarised, the EPCIS offers three core features to client applications: capture information, a query information interface for EPC events and client subscription to the network.

RFID middleware is a set of components which aims to manage RFID readers, read events and end user applications and is a central point in the integration process of any RFD solution (Traub et. al 2010, P.156). Today, middleware and network challenges are partially addressed in the scope of the EPCglobal Architectural Framework and related EPC standards but implementation remains challenging.

Figure: 2.5 illustrates an example of product movement and the associated information flow from point of dispatch at a manufacturer's location to receipt of the product at a retailer's facility using the EPCglobal Network infrastructure where the steps are described in Table 2.4. The significance of the EPCIS as an integral component of the network infrastructure is highlighted by providing information of what, when, where, who and which dimensions.

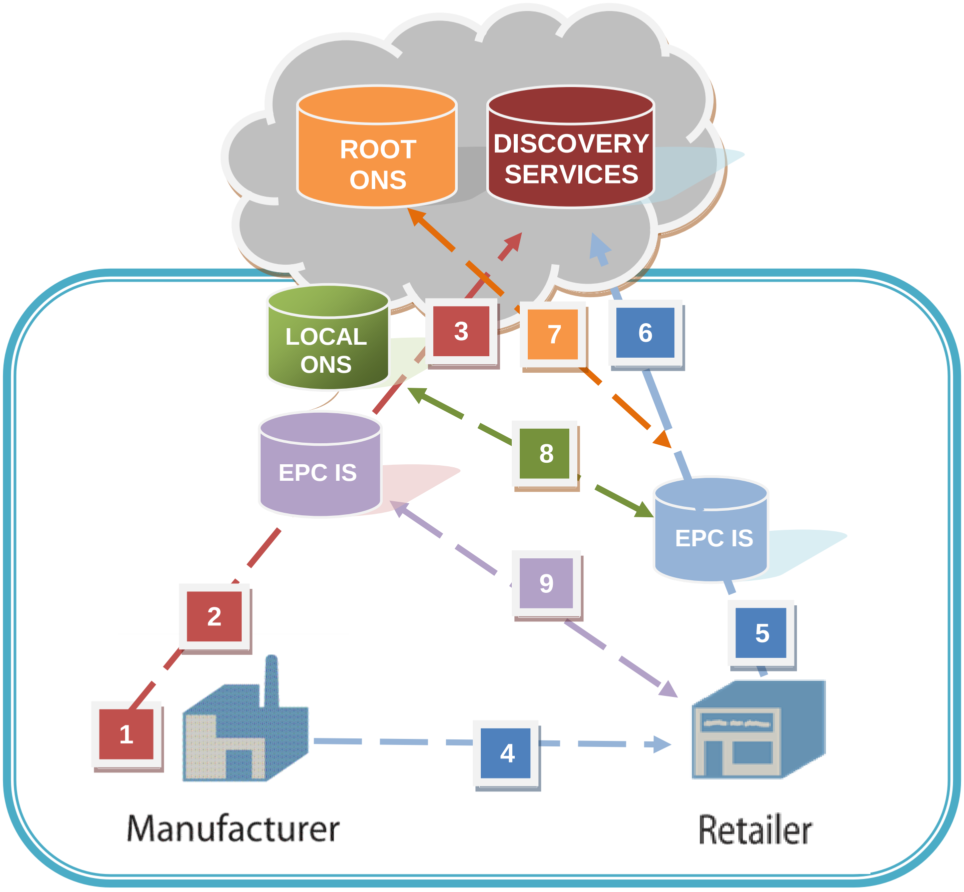


Figure: 2.5 - Process Steps - Product/Information Flow - Manufacturer to Retailer
(Source: Hartley 2005)

Steps	Description
1 – 3	The EPC *lifecycle* begins when a manufacturer tags the product with a UHF RFID tag and encodes the tag with a unique EPC identifier for the consignment. The manufacturer records product information (e.g., manufacture date) into their local EPC Information Service and registers the EPC "knowledge" with EPC Discovery Service (eg: date, location – once ratified by EPCglobal Inc;) into EPC Information Service.
4 - 6	The Manufacturer sends the product to the Retailer. The Retailer records "receipt" of product into their local EPCIS. The Retailer's EPCIS then registers product "knowledge" with EPC Discovery Services.
7- 8	If the Retailer requires product information, the Root ONS is queried for location of Manufacturer's Local ONS. The Manufacturer's Local ONS is queried for location of EPCIS and communication is then initiated between the supply chain partners.
9	The Retailer queries the Manufacturer's local EPCIS for desired product information (e.g., manufacture date, expiration date, etc.).

Table: 2.4 - Process Steps from Manufacturer to Retailer.
(Source: Hartley 2005)

Chapter 3 Literature Review

3.1 Introduction

The emergence of RFID technologies in the early 2000's as a tool for improved, actionable supply chain visibility generated worldwide interest and enthusiasm from the business and commercial sector given the business benefits and opportunities promised. RFID also attracted interest from the academic and research community from a technical and business enhancement perspective.

A review of the literature identifies a clear chronology of RFID thought and emphasis beginning with a fundamental analysis of the technology from a business enablement and enhancement perspective focusing on potential business benefits. Published research began to appear in the early to mid-2000's focusing primarily on enhancing existing RFID capability and performance through technology, network and systemic enhancements. This coincided with the gradual emergence of feasibility studies, proofs of concept, case studies and research on the use of RFID technologies in supply chain operations focused predominantly but not exclusively, on the FMCG transport and apparel sectors.

3.2 RFID Technology – Background

RFID technology utilising tags that emit radio signals and reader devices to pick up the corresponding signals has existed since the 1940's war years. Despite this, its popularity as a business enabler has developed only within the last decade or so. This RFID renaissance originated out of the original Auto-ID Center at Massachusetts Institute of Technology. The idea was to put a standardised serial number on a low-cost radio frequency identification tag and then store data related to that tagged object on the Internet (Roberti 2009). This concept was the basis of Sarma and Ashton's (MIT) - '*The Internet of Things*' (Roberti 2009). When the Auto-ID Center passed the commercialisation of ubiquitous RFID to standards development body EPCglobal Inc; its Software Action Group (SAG), developed the EPC Information Service (EPCIS) - a standard involving a set of interfaces that allowed the sharing of EPC related information between trading partners to improve efficiency, security and visibility in the global supply chain (Roberti 2009).

Radio Frequency Identification (RFID) has witnessed a renaissance over the last decade. The advantages offered by the technology along with strong signals towards mandates from early technology adopters like Wal-Mart, The US Department of Defense and retail giant METRO Group to their supplier community led to large numbers of research and commercialisation efforts in the early 2000's (Bolic 2010). However, despite initial early enthusiasm, ubiquitous adoption has not materialised (Hartley 2012; Bolic 2010).

A report on the use of UHF RFID technologies in livestock, Hartley and Sundermann (Hartley and Sundermann 2010) begin by observing an intensification of competition causing profitability and the continual erosion of company margins, accompanied by increasing legislative requirements for robust traceability in national and international supply chains, forcing business to look increasingly for new and innovative ways to remain competitive and sustained. Huei-Huang and Chen (Huei-Hung and Chen 2005) outline that architecturally, the EPCglobal Network (and implicitly the EPC Information Services - EPCIS) offers significant business promise. The potential of EPCIS in delivering business benefit was outlined in a submission to the New Zealand Government (GS1 2007) outlining that the EPCIS has the potential to make a huge contribution to commerce and trade in terms of improved track and trace capability, inventory control and responsiveness to demand signals. Governments are also interested in EPCIS in terms of its potential for strengthening border protection, safeguarding public health and much more (GS1 2007).

In a report into the use of UHF tags in deer and sheep, Cooke, Diprose and Brier (Cooke et al., 2010) summarised that the international EPCglobal item identification and data interchange standards showed great promise in streamlining the flow of supply chain information, and provided a useful standard for countries and organisations implementing new traceability systems – avoiding the need to reinvent the wheel in numbering and identification. The benefits for this standardisation were seen to accrue primarily from the processor onwards through the supply chain.

While recommending the use of UHF RFID for livestock applications following technical feasibility research, Cooke and Diprose (Cooke and Diprose 2010) saw benefits in the use of the EPCglobal Network for tracking objects through the supply chain (Cook and Diprose 2010).

RFID performance imperfections generally focus on technical shortcomings (Bolic et al., 2010) and are one of the main obstacles to more widespread adoption. The proliferation of innovative homogenous systems (cf: standardised and interoperable) to address a broad range of implementation requirements are also seen to frustrate broad adoption (Bolic et al., 2010).

Bolic et al., (2010) begin their analysis of RFID systems by presenting the characteristics of a hypothetical *ideal* RFID system acknowledging that such a system would be unrealisable in practice. The authors point out that their *ideal* system is formulated in the context of UHF passive RFID systems and while most of the components are of a technical nature, several of the ideal component features rely on standards-based systems interoperability features, including simple deployment, networking and synchronisation of multiple RFID readers (Bolic et al., 2010). Passive RFID is viewed as the primary candidate technology to fulfil the aim of ubiquitous tracking of items, thereby realising the dream of 'the Internet of things'. Compared to magnetic induction-based versions of passive RFID, UHF comes much closer to fulfilling the functional requirements that will make the widespread use of RFID a reality. This does not mean that the effort to produce UHF RFID technology is without challenges.

The ratification of EPCglobal's EPCIS standard in 2008 initiated interest in research in the development of independent EPCIS development adapters. Plugin and interface tools began to emerge upon which different applications could be built. Driving these tools included collaboration between the AUTO-ID Labs (MIT and Zurich), Distributed Systems Lab of ETH, the Software Engineering Group of the University of Fribourg and SAP Research, Zurich (Guinard et al., 2010).

An analysis by Guinard, Mueller and Pasquier-Rocha (Guinard et al., 2010) identifies the great potential of the EPC Network for research in the ubiquitous computing field that led to a number of initiatives attempting to make it more accessible and open for prototyping. Academic commentary emerged regarding the EPCIS standard and apart from the ground-breaking research and development of the AUTO-ID labs (sponsored and supported by EPCglobal Inc;), academic publications began to emerge on plausible business applications, streamlining applications and improving functionality. Guinard, Mueller and Pasquier-Rocha (Guinard et al., 2010) initiated the Fosstrak project which, at the time, was said to be the most comprehensive open-source implementation of the EPC standards (Roberti 2009). Guinard, Mueller and Pasquier-Rocha (Guinard et al., 2010) outline that despite the EPCIS providing a lightweight HTTP interface for recording EPC events, a different approach for querying the interfaces for tracing by other applications was advocated because the EPCIS specifies a standardised WS-* (ie:SOAP,WSDL etc.) interface which is well adapted to combine business applications but are complex with high entry barriers requiring developer expertise in the domain. Hence, the WS.* was not considered to be well adapted for more light weight application scenarios (Guinard et al., 2010). Their efforts translated into the Fosstrak EPCIS Webadapter module that sought to lower the entry barrier for developers and foster rapid prototyping by bringing the EPCIS data closer to Web languages such as Javascript while offering more lightweight access to (Fosstrak available at https://code.google.com/p/fosstrak/, accessed on July 23, 2012) data. Fosstrak is an open source RFID software platform that implements the EPC Network specifications. The Fosstrak open-source software suite gained initial but sporadic traction as it provided core components for RFID applications and included an EPCIS Repository, a Tag Data Translation (TDT) Engine, Application Level Events (ALE) middleware and a Low-Level Reader Protocol (LLRP) Commander (Roberti 2009).

However, most companies have not deployed an EPCIS repository because they employ non-standardized communication protocols to exchange Electronic Product Code (EPC) data within their organization, or with partners. Despite initial optimism from Christian Floerkemeier, associate director of the MIT Auto-ID Lab, having stated that the Fosstrak module had been downloaded more than 2,000 times, deployments remained effectively nil (Roberti 2009).

Huei-Huang and Chen (2005) outlined that academic research on RFID and the EPCIS in particular was based on theoretical analysis focused on system component parts of RFID technology, RFID operation methodology and EPC standards; but they failed to address how the respective technologies could be used in tandem to create efficient supply chains. Huei and Shih (2005) found that application cases were rare. Huei and Shih (2005) also reported that there were no established applications in distribution repair and return process. Their studies focused on the functions of EPCIS and operational models describing possible scenarios of utilising RFID to show how EPCIS information flow could support the forward and reverse logistics but they offered no practical field study analysis.

3.3 EPCIS Case Studies – Food Industries

The commercial sector identified opportunities in developing EPCIS implementations and EPCIS middleware as a service and developed business capabilities to support this including a consortium involving the University of California Los Angeles (UCLA), Northrop and Hewlett Packard (O'Conner 2004). EPCIS pilots began to emerge in the mid-2000's driven by increasing demand from regulators and jurisdictions for enhanced food traceability. Food traceability has become top of mind for regulators around the globe and within the context of meat and fish, several pilots are reported (Thakur and Ringsberg 2011) and Thakur et al., (2011).

In two Norwegian projects, Thakur and Ringsberg (2011) and Thakur et al., (2011) introduce research methodology for modeling traceability information using the EPCIS framework and what is referred to as UML statecharts; a standardised general-purpose modeling language used in the field of object-oriented software engineering where use of a chart or diagram clarifies the purpose of the diagram and other details while describing different states of a component in a system. In the Thakur et al., (2011) research, a generic model is presented and evaluated based on its practical application by providing illustrations from two supply chains; frozen mackerel production and a corn wet milling processes. All states and transitions for these processes as well as the information that is needed to be captured for each state were identified and outlined. The model included the product, process and quality information. The model presented was designed for mapping food production processes to provide improved description and integration of traceability information using the EPC core vocabulary and identifiers (Thakur et al., 2011).

An EPCIS implementation was used along with other applications for monitoring events based on the phased logistic processes. An application of a current EPCIS framework for managing food traceability information was presented by mapping the transitions identified in two product chains to the EPCIS events. The corresponding quality parameters to be linked to these EPCIS events were also identified. The researchers mapped food production transitions for frozen mackerel to two

EPCIS events; ObjectEvent and AggregationEvent. However, as EPCIS is based on discrete recording of events and event locations, corn wet milling was not able to seen as a transition event process as the processing of corn wet milling is a continuous process. Quality parameters for transformational events were linked to subsequent ObjectEvent to provide for extent discretisation (Thakur et al., 2011). Thakur et al., (2011) also outlined that most of the research in automatic data capture presents traceability solutions where only the product packaging is tracked through the supply chains but fail to address the internal traceability issues linked to the production events within a food facility.

Regattieri et al., (2007) presented the application of a RFID system integrated with alphanumeric codes, barcode labels and RFID to trace Parmigiano Reggiano cheese through the complete supply chain in an effort to clarify the legal and regulatory aspects of food traceability and to present a framework for a traceability system with particular reference to analysing different technical resources as outlined. Further, as a consequence of attempts to imitate the cheese, in 2003 the EU had to intervene in order to protect the product brand (Regattieri et al., 2007). The Regattieri et al., (2007) research was promoted by what they considered to be an absence of specific legal requirements concerning product traceability in the food supply chain creating disorder, notwithstanding existing guidelines including the Codex Alimentarius (Food & agriculture Organisation of the United Nations, 1999) and the United States Department of Agriculture publication 'Traceability for Food Marketing and Food Safety: What's the Next Step" (2002) – a non-prescriptive, performance based document that made suggestions on how traceability goals should be achieved. (Regattieri et al., 2007).

Regattieri et at., (2007) based their traceability framework on four pillars: *product identification* (physical characteristics, mechanical properties, bill of material structure and life cycle), *date to trace* (data type and number format), *product routing* (production process, product life and lead times) along the supply chain, and *traceability tools* that are selected based on data accuracy and reliability requirements of the goods (Regattieri et al., 2007). The research methodology sees a process of product characteristic identification in its different aspects along the supply chain from farm (milk) to factory, defining data and process traceability requirements and related capture technologies throughout the process (manual recording, using sensors, barcodes and RFID tags), recording data and storage in a centralised repository system and finally, product marking of finished goods. Regattieri et al., (2007) concluded that the framework establishes end-to-end supply chain traceability providing good results for both cheese producers (supply chain visibility and traceability) and consumers (consumer confidence in product authenticity) at a tolerable cost given the high price Parmigiano Reggiano attracts. 'In contrast, when a low priced product requires an individual [RFID] Tag (for example a box of pasta) the situation is very different (Regattieri et al., 2007). In conclusion, Regattieri et al., (2007) confirm a framework design that represents a significant and reliable reference. They also push for global standardisation of RFID systems at an affordable cost to supply chain stakeholders as an opportunity for more ubiquitous adoption and system growth.

Senneset et al., (2010) outlined a data model for exploiting technologies like RFID in the food industry. This model considers the unique identification of load carriers (ie: returnable transport items (RTI) and their contents) and other equipment equally important as traceable units. The model facilitates flexibility and allows for better precision as the production processes are changed to accommodate finer granularity. The research describes the linking of unique identifiers using several scenarios including utilising the unique identification of a transport item for identifying its contents, mixing raw materials by emptying several small RTIs into one larger RTI, splitting the content of one RTI into several new RTI's, recording product properties and environment data and tracking internal and external transport and logistics operations, Senneset et al., (2010). The RFID technology was based on the EPCglobal UHF Generation 2 Standard (RFID Tag interface protocol) and the EPCglobal unique identifier, Returnable Asset Identifier (GRAI). The scenarios defined formed the basis for more detailed requirements for an information model aimed at supporting traceability, process improvement and end-to-end product differentiation where traceable units are uniquely identified, transition points between traceable units are captured and stored in an interoperable IMS system (Senneset et al., 2010). For rigorous traceability the researchers outline the need for all relevant property data, like fat measurement of minced meat of the weight of a loaded pallet, must be supported and should be linked to the relevant entity which can be a traceable unit or a piece of equipment (Senneset et al., 2010). Further, Senneset et al., (2010) advocated a simple and generic information model in order to provide a common model core which could be extended to meet particular needs in a certain value chain.

Senneset et al., (2010) conclude by noting that an application-independent information model is an important element in systems implementation while acknowledging that topics like overall integration and flexibility need addressing further (Senneset et al., 2010). The only example cited in their summary is the EPCIS standardisation information model that was seen to be useful when used in practical pilot implementations (Senneset et al., 2010) but recognising the inherent challenges involved in doing so including integration with legacy IT systems and alternative database architecture requirements.

Myhre et al., (2009) provided a conceptual solution on how EPCIS (EPC Information Services) can be used to achieve both upstream and downstream traceability. The use of EPCIS and RFID is limited to tracking the product packages between stakeholders but the additional food product transformations (or transitions) that include process and quality parameters are not covered under the basic EPCIS specification (EPCIS standard). Before EPCIS can be implemented as a tool for food traceability information exchange, it is crucial to identify the specific transitions that take place internally at a food business operator.

A European consortium dedicated to food safety named SafeFoodEra, conducted a collaborative RFID traceability pilot in 2010 with Swedish Fisheries to test the efficacy of an EPCIS implementation for fish through the supply chain (Hild 2010). The research was part of eTrace, a project within the EU food safety programme. The initial project scope was to track fish through the supply chain from vessel, through landing site, processor and wholesaler to final retailer to examine and evaluate traceability systems and product recall solutions (Hild 2010). The pilot outlined a series of process transitions using unique product and location identifiers from catch to retailer over a four day period. The pilot demonstrated chain of custody information of individual boxes of fish throughout the supply chain (Hild 2010).

According to the Swedish Fishery Board, the pilot result proved positive (Margeirsson and Gunlaugsson 2011) not only as a tool for traceability but because of enhanced levels of information sharing between supply chain stakeholders. The retailer stakeholders attested to significant increases in sales due to traceability assurances (Hild 2010). Other supply chain participants experienced decreases in manual data entry processes and data redundancy (Hild 2010). The report outlined that RFID and EPCIS worked well in harsh environments as ‘a potential tool to meet the demands of the control regulation, (EG) nr 1224/2009 in EU’ (Hild 2010).

The researchers reported that the EPCIS pilot also demonstrated IT tools for solving traceability problems while outlining that the EPCIS standard also proved a viable standard in enabling compliance with European regulations on food safety when used in conjunction with RFID technologies (Hild 2010). In summary, the pilot provided EPCIS compliant traceability systems that could integrate data from different information sources related to food safety and suitable enterprise management systems. EPCIS systems were shown to improve the speed and efficiency of traceability operations (Hild 2010).

Another pilot carried out in Reykjavik, Iceland (25-28 October 2010) aligned to the eTrace Project, sought to track red fish internally at the processor and to integrate food safety and quality information using RFID technologies with the EPCIS standards framework (Margeirsson and Gunlaugsson 2011). The study corroborated the Swedish pilot findings on the ability to integrate food safety and quality information into the EPCIS system, better information visibility throughout the supply chain and the efficient capture and exchange of information. Given the focus of the research was on internal applications, the findings of improved internal traceability by modelling transformation, split and merge events were supplementary outcomes Thakur et al., (2011).

Turkish company Bereket Doner is using EPC Gen 2 RFID technology to track goods as they are loaded onto pallets and weighed prior to shipping, while also ensuring against theft by reading tags passing through doorways. The RFID solution is based on UHF EPC Generation 2 passive tags. The company has used approximately 450,000 tags in one year (Swedberg 2012b).

3.4 EPCIS Case Studies – Other Industry Sectors

Research and pilots have also been conducted in other industry sectors including the pharmaceutical, transport and logistics, retail and manufacturing sectors. Outlining examples of research and pilots highlights opinion on the efficacy of the EPCIS standard as a tool for use in numerous industry sectors seeking business benefit through supply chain visibility and interoperability. Bottani and Rizzi (2011) studied the impact of RFID technology and the EPC system on the main processes of the fast moving consumer goods supply chain that composed of manufacturers, distributors and retailers. They outline the adoption of RFID technology for product identification is experiencing an increasing diffusion in the logistics pipeline, where RFID systems are expected to have a major impact on the efficiency of the whole supply chain. Bottani and Rizzi (2011) cite commonly quoted benefits including increased process automation, accuracy, and labour efficiency and by exploiting the EPC Network for real time data sharing, companies have access to broad and plain visibility over logistic flows that aid in the optimisation of logistics processes and supply chain management. Quantitative research by Bottani and Rizzi (2011) into the impact of RFID and the EPC Network on the bullwhip effect in the Italian FMCG supply chain using a three echelon representative supply chain, highlighted that centralising information and providing updated point of sale data exploiting RFID technology and the EPC Network provided significant potential in reducing the bullwhip effect in the FMCG supply chain. This positively benefited supply chain stakeholders in varying degrees, especially the manufacturer's distribution centre through a considerable reduction in demand variability as a consequence of improved visibility of the whole supply chain.

An early adopter of RFID in retail, German based conglomerate METRO Group, announced in November 2006 that they would use RFID technologies and IBM's EPCIS implementation to capture and manage inventory and expiration information on meat sold in its German based 'Store of the Future' (Webwire 2008). The EPCIS repository would also be used to track items associated with special promotions. METRO group also sought to allow their suppliers using the EPCIS standard to track items destined for the group's stores across Germany; the goal being to provide suppliers with visibility into the whereabouts of items targeted for special promotions such as advertising campaigns or special events. The METRO vision was for all information concerning each supplier's promoted products, EPC code, order number and other key information, to be connected. Stakeholders would be able to securely share information on tagged items which would provide suppliers with a clear view of where their products were after having been shipped. For consumers, this meant that the products they wanted were more likely to be available on the shelves of a real store. It is understood that METRO's initial plan for the widespread use of RFID in its operations as projected has not materialised.

In a 2006 study, global manufacturing giant Unilever launched a trial using the EPCIS protocol to determine the functionality and interoperability of the EPCIS (then a proposed working draft standard) (Bacheldor 2006, Michael 2006). The test involved an EPCIS standard compliant prototype data repository from IBM using a data analysis application from an analytic application provider – T3Ci. The two companies conducted trials to test standard application queries between IBM's repository and T3Ci's applications. The trial confirmed that using standards-based protocols to send and receive event information between stakeholders, they were able to communicate with different applications both within and outside the four-walls. The participants concurred that the EPCIS standard would improve data exchanges among different RFID applications, data stores and product information management systems. Without a cohesive standard, companies would likely have to implement multiple, proprietary mechanisms and data protocols in order to communicate RFID data with supply chain partners meaning costlier, more time-consuming communication interfaces between supply chain stakeholders.

In a post pilot announcement, Unilever said that as a result of the interoperability test it would initiate a trial using EPCIS software to collect and access RFID data from its own manufacturing operations and from several retail customers and focus on promotion management to better analyse promotions and the impact on sales, supply chain visibility and metrics (Bacheldor 2006), (Michael 2006). It is understood that Unilever's EPCIS intentions have also stalled.

In October 2007, standards development organisation GS1 UK, together with BT Auto-ID Services, announced that it was seeking innovative and leading organisations to participate in a major new supply chain project involving the EPCIS to demonstrate and prove the concept of managing and exchanging RFID-sourced data between trading partners and the quantifiable benefits this brings. Trading partners participating in the pilot would be able to exchange Electronic Product Code (EPC); RFID and sensor data carried on a RFID tag within and between their organisations and be among the first organisations worldwide to prove the value of a fundamental element of the business case for RFID. The initiative did not eventuate despite GS1 UK and BT Auto-ID providing the pilot service at no charge.

In the transport and logistics sector, a rare EPCIS pilot utilising active RFID technology is notable. A project undertaken by US based iControl (EPCglobal US, 2008) outlined a pilot that evaluated and demonstrated the readiness and interoperability of multiple equipment and software vendors complying with the EPCIS specifications.

The pilot tracked two shipments of three containers (each containing 20 pallets of tyres mounted on wheels consigned to John Deer Tractors) from Shanghai, China to Janesville, Wisconsin – USA from December 2007 – January, 2008. The pilot used the vendor's proprietary GPS capable *active tags* (iControl iTAG), gateways/readers and server performance within the EPCIS network for the duration of the pilot programme. Data packets were routed to the iControl server for display and automated publication to the EPCIS database. In the initial part of the transit from Shanghai to Los Angeles, United States, data was published using a third party EPCIS implementation (operated by electronics company NEC) and likewise from Los Angeles to Janesville, data was published to an EPCIS implementation operated by electronic company, Schneider.

After tagging containers in a Shanghai container yard with both active and passive RFID tags, the pilot described a series of ocean going and intermodal land based transits between various freight facilities in Shanghai and Los Angeles to final destination in Janesville, WI. iControl's iTAG recorded the route as a series of waypoints, providing additional insight into the routing performance for each journey. The pilot demonstrated the efficacy of using multiple, interoperable EPCIS implementations for tracking shipping containers from point of manufacture (Commissioning) in China to delivery at customer (arrival) in The United States.

In November 2008, EPCglobal Inc; announced plans for the third phase of its Transportation and Logistics Services (TLS) Industry Action Group RFID (Radio Frequency Identification) Pilot Programme (M2Presswire 2008). The pilot, started in December 2008, sought to demonstrate how organisations across a global supply chain could exchange real time event data and track shipments from a third party logistics provider in Japan to a distribution warehouse in the Netherlands. Customs authorities and supply chain partners would benefit from having real-time access to information about products and shipments as they travel along the supply chain. The pilot would utilise the EPCIS to track the progress of products in cartons, pallets and containers moving along the supply chain from Tokyo to Amsterdam. Several shipments of goods involving sea freight containers would be transported from Tokyo to Amsterdam within a month. One of the pilot's objectives was to validate the use of both passive and active UHF EPC tags for sea-shipment of cartons and containers between Hong Kong and Japan while another objective was to demonstrate the impact of GS1 EPCglobal standards on providing visibility of goods on a global level between source factories in China and distribution centres in the US, flowing through the ports of Shanghai and Los Angeles (iControl pilot). Soon and Sinichi (2009) outline that at the time of the EPCglobal Inc; pilot, the EPCIS standard was not sufficiently developed and based on their analysis and review of the pilot, concluded that more work needed to be done on developing the EPCIS to better provide for supply chain visibility as the project partners did not use it as scoped.

Gerry Weber International, a large German-based manufacturer of woman's fashion and part of the METRO Group, is credited as the pioneer in the use and sole reliance of RFID technologies in a retail environment (Wessel 2009). In 2010, the fashion house began embedding garment-care labels into apparel in a roll out involving 150 of its retail stores across Germany. The application was designed to improve the efficiency of incoming goods and inventory processes and to function as an electronic article surveillance system (EAS). Gerry Weber's board studied the test results and the business-case analysis and decided that the retailer should adopt RFID garment-care labels for all of its apparel in 2010 focusing on the EPCglobal standards (Wessel 2009).

In a cross-border traceability pilot involving cases of wine shipped from Italy to Hong Kong in late 2011, a pilot focused on providing improved supply chain visibility for premium vintage Italian wine producer, Le Macchiole. Individual bottles were tagged with EPC compliant tags and identified using the sGTIN standard. Cartons were also tagged and encoded with the EPC SSCC standard logistics identifier. Data from the export shipments was captured and transmitted through GS1 Italy's EPCIS network to GS1 Hong Kong's EPCIS network providing shipment traceability information (GS1 Hong, GS1 Italy 2012).

3.5 Defining Traceability for Agriculture and Food

Schuster et al., (2007) outline a fundamental requirement for any traceability system is some form of unique identification and while establishing a traceability system for agriculture bears similarities with other industry sectors including the pharmaceutical and medical industries, agriculture has basic differences that make agriculture unique regarding the application of RFID technology. Schuster et al., (2007) explain agricultural supply chains as having a shared commodity orientation where production of like goods takes place on numerous farms as a fundamental differentiator to other industry sectors as well as the complexities of the agricultural supply chain due to agricultural products having significant variations in taste, nutritional content and value and numerous other attributes that define the quality, safety and identity of food. Other important factors impacting on the agribusiness environment in their view require traceability systems to serve several functions for different constituencies including place of origin identification, counterfeit, product falsification, risk mitigation and liability, public safety and mitigating the effects of economic loss (Schuster et al., 2007). Schuster et al., (2007) outline several areas of traceability research effort being investigated including retinal and DNA technologies and recognise previous research and development work in livestock traceability by researchers at the University of Adelaide (Cole et al., 2005) into the use of UHF RFID technology.

Myhre et al., (2009) outline that Governments and consumers are increasingly concerned with food safety prompted among other reasons, by several food scandals over the last decades. Outbreaks of food-borne illness invariably heightens social awareness of food safety issues and leads authorities and producers to tighten up and enhance both internal quality and control procedures and traceability systems. For regulators and consumers especially, efficacy of traceability is usually quantified by food safety and human health outcomes. This implicates heightened focus in the agri-food supply chain with regard to transparency, integration and food tracking technologies (Myhre et al., 2009). Regattieri et al., (2007) outline that recent diseases such as bovine spongiform encephalitis (BSE) and the questions concerning genetically modified organism (GMO) mean such systems that enable control of each link in the food chain have become particularly relevant. Traceability is becoming a method of providing safer food supplies and of connecting producers to consumers (Regattieri et al., 2007). Two deaths reported in a New Zealand hospital traced back to listeria infected meat sourced from a local supplier (Stuff 2012) tend to support this position.

As previously outlined, Myhre et al., (2009) provided a conceptual solution on how EPCIS (EPC Information Services) can be used to achieve both upstream and downstream traceability. The use of EPCIS and RFID is limited to tracking the product packages between stakeholders but the additional food product transformations (or transitions) that include process and quality parameters are not covered under the basic EPCIS specification (EPCIS standard). Before EPCIS can be implemented as a tool for food traceability information exchange, it is crucial to identify the specific transitions that take place internally at a food business operator. In the next section, we present the method for application of EPCIS.

'Being able to effectively recall contaminated or harmful product requires that information be available on time and preferably on line' (Myhre et al., 2009 p.1). Myhre et al., (2009 p.1) also report that *traditionally, making links between the input and output of a production process has been made using proprietary, non-standardised and in-house solutions*. As such, they propose a traceability solution for food supply chains based on the EPC Information Services (EPCIS) standard (Myhre et al., 2009) commenting that the EPCIS appears to be the de facto standard for exchange of RFID/EPC events. Examining efficacy of the EPCIS to determine if the solution may be used to implement value-chain traceability and also internal traceability in the industry was the focus of their research (Myhre et al., 2009). The researchers put forward that an EPCIS-based traceability solution for the meat industry should (Myhre et al., 2009): (*1) Uniquely define the ingredients that have been used in each product, (2) be based on predefined queries provided by the EPCIS standards, and (3) provide both upstream and downstream traceability.* The Myhre et al., (2009) research methodology combined insight from practice, operations management (OM) theory and information systems (IS) theory to construct a possible solution for tracing meat from farm to fork, based on simple EPCIS queries.

The suggested traceability solution arrived at was based on EPC and EPCIS making use of the EPCIS TransactionEvent in order to construct a logical link between input and output. Furthermore, the researchers suggest utilising three EPCIS fields bizTransactionList and bizLocation to associate a traceability event with business transactions and business locations, as well as bizStep to describe that event contains traceability information according to a specified format, enabling different solutions and standards to exist in parallel without (too much) confusion (Myhre et al., 2009). Finally, the researchers outline that in order to retrieve traceability information, the SimpleEventQuery be used to match specific ParentID or EPC's present in the epcList (eg: sGTIN, GLN) (Myhre et al., 2009).

The manifestation of Bovine Spongiform Encephalopathy (BSE) commonly known as Mad Cow Disease in the UK, Canada and The United States (Washington State) and other countries raised questions around the world about food safety and food production practices (Hobbs 2004); (Hobbs , 2005). Given the impact on both animal and human health a BSE outbreak would cause and the economic consequences, interest in agricultural traceability specifically began to emerge (Hobbs 2004). The discovery of BSE in a Canadian beef animal in 2003, and the U.S. BSE case later the same year that was traced back to a Canadian cow, has intensified the interest in traceability. In the aftermath of the outbreak, several systems were proposed to improve animal identification, tracking and tracing capabilities within agricultural chains including initiatives by the United States Department of Agriculture.

On August 9, 2011, The United States Department of Agriculture (USDA) issued a proposed rule to establish general regulations for improving the traceability of U.S. livestock moving interstate when animal disease events take place, citing the prevention and control of animal disease as the cornerstone of protecting American animal agriculture (USDA 2011). Interestingly, under the heading of food safety, the USDA's animal disease traceability announcement only focused on animal health and aimed to assist USDA in quickly finding out where diseased animals had been and what other animals they may have come in contact with. Animal disease traceability isn't a food safety programme. The USDA's animal disease traceability is focused on disease traceability that ends when an animal is slaughtered, although the USDA's Food Safety and Inspection Service (FSIS) has the responsibilities for tracing packaged meat back to a processing facility or slaughter house. In terms of using RFID technologies as a tool traceability, the USDA allow low frequency ear tags, low frequency injectable transponders and UHF ear tags where an industry specific Animal Identification Number (AIN's) is encoded as the unique animal identifier (USDA 2011).

The Government of Canada has recently announced an important investment in building a single national livestock traceability system with robust data management capabilities in an effort to demonstrate more solid farm practices in animal health, zoning capability, emergency management and food safety systems (Agriculture and Agri-Food Canada, 2012). The goal is to have an integrated National Agriculture and Food Traceability System (NAFTS) starting with livestock and poultry. The investment will help track information of the Canadian beef, dairy, bison, sheep, and other animal producers. The Canadian authorities define traceability as the ability to follow an item or a group of items such as animal, plant or food products or their ingredients from one point in the supply chain to another but limit the extent of traceability under its new NAFTS initiative for animal movements from farm-to-slaughter traceability for livestock and poultry species, analogous to New Zealand NAIT implementation (Agriculture and Agri-Food Canada, 2012).

There are many definitions and different terms for traceability. The *Codex Alimentarius* is a collection of internationally recognized standards, codes of practice, guidelines and other recommendations relating to food and food production and food safety. The *Codex Alimentarius* is administered by The Codex Alimentarius Commission, a body established in 1963 by the Food and Agriculture Organisation of the United Nations (FAO) and the World Health Organisation (WHO), (Codex Alimentarius, 2012). Codex Alimentarius is recognized by the World Trade Organisation (WTO) as an international reference point for the resolution of disputes concerning food safety and consumer protection (Codex Alimentarius, 2012). In the Codex Alimentarius the term *Traceability/Product Tracing* is used (Codex Alimentarius, 2012). Many others speak of tracking and tracing and in the United States this is simply called record-keeping (CIES 2005) but the effects they have are basically all the same. Traceability is also mentioned in ISO 9001:2008 - Quality management systems – Requirements, as one of the aspects that should be considered in a quality management system.

The Food Business Forum – Comite International d'Entreprises a Succursales (CIES), the independent global Food Business Forum define traceability as 'the ability to trace the history, application or location of an entity by means of recorded identifications' (CIES 2005) based on the ISO 9001 Standard: *"Traceability: ability to trace the history, application or location of that which is under consideration."* CIES expand their definition to *Chain Traceability* - the ability to trace the history, application or location of an entity by means of recorded identifications throughout the entire food chain (CIES 2005). To facilitate this CIES describe*, 'in practice, the requirement for traceability is to keep records of suppliers and customers, sometimes called "one step up, one step down". If all food businesses keep these records and the information therein, it can be communicated and exchanged, chain traceability is achieved'* (CIES 2005).

The CIES guidance document (CIES 2005) contains the following paragraph concerning traceability: *"6.1.17 Traceability - The standard shall require that the supplier develop and maintain appropriate procedures and systems to ensure:*

- *Identification in any case through a code marking on container and product, to identify the source of any out-sourced product, ingredient or service;*

- *record of purchaser and delivery destination for all product supplied."*

From a farmers perspective, place of origin is recognised as an important input in defining efficacy of traceability systems. Nielsen and Kristensen (Nielsen and Kristensen 2008) emphasise that international competition is seen as a threat to farmer livelihood and the fact that Salmonella is found three times as often in foreign pig meat compared to Danish meat is an incentive for Danish pig/pork producers to provide the country of origin labels. Lees et al., (2003) focus on the issue of meat authentication and discuss analytical methods for species identification including DNA, electrophoretic and antibody techniques. Useful as methods for meat species identification, their use when used in conjunction with traditional AIDC traceability systems would provide robust and granular traceability outcomes but likely at a high cost.

In the defining the efficacy of using the EPCIS standard for livestock traceability then, it is at once a question of rigor, product recall/ withdrawal performance, required levels of traceability robustness and desired outcome(s) dependant on which function in a supply chain a stakeholder participates.

For processors and slaughter plants, efficacy may be defined by tracking and tracing the flow of production metrics. Nielsen and Kristensen (2008) outline that two primary motives have driven development of traceability for meat and meat products in Denmark: supply chain management and efficiency and lean, flexible production with safety and quality control. Traceability systems assist plants minimise the extent of safety or quality failures thereby minimising damages.

On analysis, *Chain Traceability* as defined by CIES (2005) establishes a rigorous benchmark of requirements that define traceability and this is the definition this analysis will reference as the test for efficacious traceability.

3.6 Traceability in the Open Supply Chain

Organisations balance their benefits and costs to determine the breadth, depth and precision of the traceability system they establish (Golan et al., 2004). *Breadth* refers to the amount of information the traceability system records, *depth* referring to how far back or forward the traceability system is able to record tracking and *precision* how precisely something can be traced at its most granular level (Golan et al., 2004). As Nielson and Kristensen (Nielson and Kristensen 2008) point out, given the voluminous number of attributes that could be used to describe any food product, full traceability is a theoretical goal notwithstanding the increasing capability of some technologies to cope with the requirements. Nielson and Kristensen’s (Nielson and Kristensen 2008) analysis of the European traceability regulations suggests a lack of definition for traceability and outlines a general requirement which has created compliance doubt for the broad global supply chain community.

The EU Regulation CE 178/2002 is often cited as one of the main traceability compliance documents for New Zealand exporters to Europe (GS1 2008), analogous to The United States' Public Health Security and Bioterrorism Preparedness and Response Act of 2002, (United States Food and Drug Administration (FDA), June 12, 2002). According to the definition of traceability in Article 3, 15 of the regulation, food businesses must be able to 'trace and follow' every 'substance' included in the production process. Article 18 however, setting out the requirements for traceability, is more general requiring 'systems and procedures' for identifying 'any person from whom they have been supplied with a food, a feed, a food-producing animal, or any substance intended to be, or expected to be, incorporated into a food or feed' and also 'the other businesses to which their products have been supplied, i.e. one stage forward and one stage back to/from the food business (OJL, 2002). The interpretation of this traceability requirement by Danish Authorities has not been very strict (Nielson and Kristensen 2008), motivated by the potential to burden producers if a more strict interpretation was enforced, a view supported by Swedish and UK authorities (Nielson and Kristensen 2008).

The GS1 Traceability Standard (GS1 2010) supports Nielson and Kristensen's contention regarding a limited understanding of traceability requirements in some countries despite the fact that products are supplied to sophisticated markets where traceability is required. GS1 (2010) outline that this incongruence can be addressed by using generic requirements for traceability using simple business processes.

In most cases, traceability legislation is performance based and generally does not specify the traceability system to be used. Many regulators neither recommend or endorse any specific automatic data capture technology; some recommend best practices with bar-codes and EDI, some are beginning to use RFID and others are implementing a traceability network to be able to electronically retrieve information about products from each point along the chain, e.g. using EPCIS (Electronic Product Code (EPC) Information System (IS). GS1 acknowledge that the challenge for a traceability process standard is to agree on generic requirements and a common way to describe the traceability process irrespective of these differences. The GS1 Global Traceability Standard defines a high level description of the process enabling and promoting supply chain collaboration but allowing each organisation to design its traceability system in terms of breadth, depth and precision to support its own business objective(s). GS1's standardised traceability process outlines that organisations have different objectives and ways of implementing traceability. Differences are intrinsic to their various roles in the supply chain (e.g., manufacturer, distributor, transporter), from the diversity of products and industry sectors, to their regulatory and business environment and to their different strategies in terms of costs and benefits.

3.7 RFID and EPCIS in Livestock

The use of RFID in livestock has been utilised for many years around the world typically using low frequency RFID based on a suite of ISO standards. Schuster and Brock (2007) lament the use of passive LF RFID in US livestock applications as being sub-optimal due to short read distances (ie, within about ten centimeters) and slow data retrieve and transmission rates. They remain pessimistic about the proposed use of passive UHF RFID ear tags promoted by Australian researchers (Cole et al., 2005) notwithstanding the promise of longer read ranges and faster data transmission rates requiring larger antenna configurations and a larger ear tag as negative factors thwarting adoption (Schuster and Brock 2007).

Following the Council of Europe announcement in December 2003 of Regulation (EC) No 21/2004 providing for the introduction of compulsory electronic identification of ovine and caprine in Europe from January 2010 to establish a comprehensive traceability system to prevent the spread of contagious diseases and in view of food safety, Bauer et al., (2009) undertook a six month research project starting in September 2007 to investigate different electronic identification devices, readers and management systems under typical German husbandry systems with mobs of sheep and goats. Their efforts focused on determining implementation recommendations for both farmers and administration. Their findings however focused on infection analysis caused by the ear tags in the animal's ears and as a consequence established an optimal ear tag placement recommendation to mitigate ear infection. Further proposed research sought to focus on the interaction between electronic identification devices (EIDs), RFID readers and management programmes.

Other research centered around RFID hardware performance, ear tag retention performance and process efficiency improvements through the use of AIDC (cf. traceability outcomes) including European analysis on the use of RFID technology with high frequency (HF) transponders to monitor behaviour of laying hens in alternative housing systems (Pauli et al., 2009), the use of injectable transponders for sheep identification (Binnendijk et al., 2009) in The Netherlands, the use of electronic ear tags for tracing fattening pigs in Switzerland (Burose et al., 2009) and the application of RFID technology in herd management on dairy herds in Canada (Murray at.al 2009).

In recent years, following the ratification of EPCglobal UHF RFID standards coupled with advances in performance and utility, interest in UHF RFID applications for livestock applications has increased. Apart from the research undertaken for this thesis and the Scandinavian fish pilots, most research and/or implementations have focused on the use and applicability of EPC compliant hardware and identifiers but not the integration of EPC data within an EPCIS networked environment. Danish livestock pilots also focused on EPC compliant hardware performance and not network related utility and functionality using EPC Standards. (Hill et al., 2012).

In 2008, New Zealand's National Animal Traceability scheme (NAIT) sought submissions for the design of a national animal (livestock) traceability system for New Zealand. A submission published by GS1 New Zealand, recommended that the sector specific animal identification numbering structure NZ/ISO 11785:2001 proposed by NAIT be abandoned in preference for the globally ubiquitous, supply chain agnostic standards offered by the GS1 EPCglobal suite of standards (GS1 New Zealand 2008). As of 2012, while the GS1/EPCglobal identifiers have not officially been endorsed by NAIT, provision for its inclusion in the system design architecture is provided for when/ if UHF RFID and the associated EPC suite of standards are endorsed.

Research conducted by Irish researchers (Shanahan et al., 2009) into Irish beef traceability recommended the use of RFID and a Biotrack database which maintains biometric identifiers for individual animals to meet EU traceability law requirements established by EC/1760/2000 which is supplemented by the Food Law EC/178/2002 (Shanahan et al., 2009). In a discussion document, the researchers also proposed the EPCglobal Network be utilised for the exchange of traceability information between all stakeholders in the supply chain based on a standard format compliant with EPCglobal standards (Shanahan et al., 2009).

RFID is preferred by the Irish researchers over the prevailing barcoding data capture systems because of the efficiencies offered by the latter; reduction in labour costs, reduction in delivery disputes, better tracking and tracing of quality problems, and importantly the interconnectivity of RFID systems (Shanahan et al., 2009). Further, RFID based on the suite of EPC standards is recommended including the individual animal identifier sGTIN while recognising that the EPCIS did not provide for a standardised tag data structure for the exchange of beef traceability data pre-slaughter (Shanahan et al., 2009).

A Scottish research pilot referred to as ScotEID undertaken in 2009 using low frequency (LF) RFID, sponsored by the Scottish Government Rural Directorate (Livestock Traceability Policy), coordinated by the Scottish Agricultural Organisation Society (SAOS), sought to examine the use of electronic identification of sheep in an effort to identify workable and affordable EID systems for Scotland (SAOS 2009). The six month pilot (August 2008 - April 2009) involved 36100 sheep arranged in 1366 separate consignments being scanned with EID reading equipment in farms, marts and abattoirs at over 60 different locations. The 'learning by doing' pilot generated a number of important practical insights mainly around performance inadequacies of tags and readers and interoperability constraints between different hardware components (SAOS 2009). The lack of industry standards around data storage and data transfer from readers was cited as a fundamental issue as was a lack of tag data standards, data management protocols and procedures. Follow up research undertaken in 2011 identified both procedural and policy related issues but of the technical issues cited, user interface difficulties between read events and the central database featured (SAOS 2011).

ScotEID is undertaking further testing of UHF equipment alongside LF equipment. ScotEID pilots as outlined are being conducted to identify workable and affordable electronic tagging systems to comply with European regulations on livestock traceability. ScotID seeks to be technology-neutral in simply presenting empirical evidence of how competing applications perform under commercial conditions in Scotland. As a consequence, given the encouraging findings of UHF findings reported elsewhere, ScotEID consider it remiss to not give some consideration to the potential UHF RFID offers (Moxey 2011). Recognising that to date agricultural applications have been dominated by LF (125-135khz) rather than UHF (850Mhz – 950Mhz) Moxey, (2011) outlines that 'this may be due to a number of factors, including the relative maturity and thus familiarity and incumbent market share of LF technology compared to UHF. It may also stem from perceptions of UHF as being too expensive and/or unsuitable for agricultural conditions due to relatively poorer read rates in the presence of metal, water and dense material or objects'. Moxey (2011) agrees with Hartley et al., (2010) that even if this was the case in the past, technical progress in the design, manufacture and use of UHF systems over the past decade suggests that such perceptions may now be misplaced.

Moxey (2011) cautions that technical possibilities reported in academic publications and claims made by commercial entities should always be viewed with a degree of caution but suggests nevertheless, the existence of such reported findings is sufficient to challenge generic pre-conceptions about the scope for using UHF in cattle traceability given that, unlike for sheep, there still remains some flexibility regarding technical choices within the EU regulatory regime.

The *PigTracker Project* is a Danish research project involving collaboration between the Pig Research Centre Danish Agriculture & Food Council, Prosign RFID, RF-Labeltech and The Danish Technological Institute. The objective is to develop a system for unique identification and tracking of pigs in Danish pig production utilising UHF RFID technology. PigTracker has received support from the Danish Ministry of Food, Agriculture and Fisheries (Swedberg 2012). Utilising the EPCIS standard or infrastructure is not in scope, however.

In mid-2012, The Chinese Agricultural Ministry CAM, (Shanghai News 2012) released a notification named *Trial solution on livestock ear tag application* to require livestock ear tag trial testing to be undertaken in four Chinese cities later the same year. CAM's notification acknowledges RFID as a candidate solution for livestock traceability in China. The project would involve 40,000 head of cattle being RFID ear tagged. CAM would put forward measures and recommendations on further ear tag deployment commensurate with the test results. The testing, performed under different climatic conditions will be conducted to find the most optimum technology for livestock traceability by comparing LF and UHF performance in real applications. The findings will also support further ear tag technology deployment. The CAM schedule outlined testing to be completed by August, 2012. Detailed regulations have been set by the notification on ear tag parameters including RFID operating frequency, air interface protocols, IC memory, anti-collision protocols and working temperatures. Regulations also require ear tag suppliers to offer information on data collection and transmission solutions; however it is not known if the use of the EPCIS infrastructure is in scope. After approval by CAM, the provincial agricultural bureaus will be permitted to select hardware based on provincial preference. Implicitly, this suggests there is no requirement on the provincial authorities for standardisation or intra or inter-system interoperability.

Apart from the research efforts of the EPCglobal sponsored Auto ID labs (Keio University, University of St Gallen, Fudan University, University of Cambridge, University of Adelaide, Massachusetts Institute of Technology, Korea Advanced Institute of Science and Technology) other tertiary institutions undertaking RFID application-based research into the use of RFID technologies for livestock applications include, Michigan State University (Baburajan 2011) and Kansas State University (Advanced ID Corporation 2005) are notable mentions. These efforts are in part motivated by the FDA Food Safety Modernization Act (FSMA) passed into law in 2011 mandating that all food, feed, ingredients, and beverages have to be labelled and tracked, and data stored for two years if a recall is necessary. None of these institutions is involving the use of EPCIS is their research.

3.8 The New Zealand NAIT Livestock Traceability Scheme

From 2005, both the EU and US regulators have required traceability systems for all food and feed sold or moved in their jurisdictions. European Union Regulation 178/2002 effective 1 January 2005 requires all food products in the EU to be traceable back to the supplier and provides that "*…where an "incident or crisis" occurs all food in the "batch, lot or consignment (shall be presumed to be) also unsafe unless following a detailed assessment there is no evidence that the rest of the batch lot or consignment is unsafe"* (European Union Regulation 178/2002 - Article 14). Similar provisions exist in Section 306 of the US Bioterrorism Act 2002. The intent of these articles is to provide risk mitigation solutions when, for example, a single "incident or crisis" occurs involving a carton or carcass of New Zealand meat then *all* meat from the processor concerned and possibly from the whole country may be excluded from the market involved unless it is possible to *affirmatively prove* that all other meat comes from sources that can be proved to be safe from whatever had caused the "incident or crisis." A robust traceability system that could be linked to locations is the only way this could be achieved. It is clear that the trend internationally is towards full traceability for animals, feed and food from origin to delivery and beyond (GS1 2008).

The New Zealand National Animal Identification and Tracing System (NAIT) is an animal identification and tracing scheme established by The National Animal Identification and Tracing (NAIT) Act in 2012 (NAIT, 2012a). NAIT was founded in response to potential biosecurity threats and increasing traceability requirements from off-shore regulators and consumers. The NAIT database stores information about each animal's individual RFID tag number, its location and the contact details of the person in charge of the animal. NAIT's remit is to provide a robust, stable and responsible agricultural industry in New Zealand by enhancing its reputation for producing food to the highest standards of quality, safety and environmental responsibility. NAIT's goal is to provide a reliable, up-to-date information service on individual animal locations and movements. NAIT is now mandatory for cattle in New Zealand and will be mandatory for deer from 1 March, 2013. NAIT declare that their IT system database meets animal tracing requirements for New Zealand consistent with World Organisation for Animal Health guidelines (NAIT, 2012a). The NAIT Act authorises NAIT Limited to issue standards, policies and rules necessary for the operation of the NAIT scheme, for example, standards for identification devices (RFID ear tags) and for individuals or organisations to be accredited to provide information to NAIT on behalf of New Zealand farmers (NAIT 2012a).

NAIT (NAIT 2012b) has outlined its preference for the NZ/ISO Standards - NZ/ISO 11784:2001 and NZ/ISO 11785:2001. These standards, with their origins in the 1980s are focused on simply 'getting' an ID number off a RFID tag and are not designed for networked supply chains. The standards are not interoperable with the established identification system supported by the likes of the GS1 system (which includes the EPC suite of standards for use with RFID technologies). Using one set of data standards and technologies for on farm applications and another set for post-slaughter applications introduces unnecessary complexity, risk, expense and potential unreliability for the entire ‘farm-to-fork’ system. There could also be a not insignificant impact on biosecurity and market access systems which is incongruous with the EU and USA regulations. A number of known issues with these standards have been identified including the inability to ensure unique identification codes, a lack of manufacturers’ accountability despite audit requirements and no minimum transponder performance being stipulated. The proposed NAIT unique animal identification numbers are based on the International Committee for Animal Recording (ICAR) system. Clause 3.3 of the NAIT RFID Standard’s Specifications outlines that transponders included in a NAIT RFID device shall be encoded with the relevant manufacturer’s code granted by the International Committee on Animal Recording (ICAR). Whilst such systems may indeed deliver customised solutions to a particular industry’s needs, such systems provide significant barriers to the facilitation of interoperability between industry sectors and/or nations. In addition, vendors of sector specific systems clearly have strongly vested interests in keeping components of their solution proprietary. Supplier lock-in and capture is often the predicable, costly result for end-users in particular. NZ/ISO 11785:2001 does not guarantee animal uniqueness; the standards and associated protocols only provide a mechanism whereby countries and regulatory organisations, such as ICAR can manage number uniqueness using a combination of country and manufacturer codes and database management – but not a guarantee (RFID News 2009).

Low frequency (LF) RFID technology is selected for the NAIT scheme because part of NAIT’s brief from its major shareholders (Government and industry) was to select proven and commercially available technology. Low frequency continues to be seen as the only proven and commercially available form of RFID technology for animal identification worldwide. NAIT outline that in their view there is currently no proven ultra-high frequency (UHF) animal tags commercially available locally or internationally but the NAIT IT System has been designed to accommodate the UHF data standard and would be able to take such data if and when UHF tags and UHF reading systems are proven technically and commercially (NAIT - 2012b).

In its publication 'Implementing Traceability in the Food Chain (*CIES 2005),* Paris based, Consumer Goods Forum (CGF) describes the potential impact of the implementation of a traceability system and provides recommendations. The recommendations highlight the components of such a system, the pitfalls when designing and implementing such a system and above all how to ensure that systems can be aligned along the food supply chain. CIES also identifies an underlying need to define the specific information elements that each sector of the food business must agree upon when designing functional robust traceability systems (CIES 2005). At the heart of their recommendations is the requirement to share standardised information and identifiers between the different sectors in order to achieve supply chain traceability (CIES 2005).

3.9 Creating a Global Traceability Standard

Common global standards are considered the bedrock of commerce; standards enable interoperability and the free flow of various business transactions. Ashton and Brock (2000) explain that the original designers of the EPCglobal Network had a predetermined idea of how to use the Internet as a means of implementing unique identification. Early researchers also introduced the goal of interoperability across all levels of the supply chain. The basic design comprised three fundamental components; low cost RFID tags as a baseline to drive innovative, mass manufacturing processes, a globally standardised, unique identification number capable of identifying trillions of items in supply chains and a standardised computer infrastructure capable of processing tag data and associated RFID read event information (Schuster and Brock 2007).

In business, it is generally considered that the value of information increases as organisations collaborate using the information to drive business benefit. Schuster and Brock (2007) suggest that the greatest value of the EPCglobal Network are the baseline set of standards embedded into the core of the system because they foster and stimulate supply chain wide communication of unique identification data and all that this provides network participants. This type of collaboration and control has definite benefits that are quantifiable once the EPCglobal system is in place (Schuster and Brock 2007). In the five or so years since the EPCIS standard was ratified and published in 2008, it has proven extremely versatile, yet there are some business situations that are not able to be expressed naturally in the EPCIS language. This has prompted EPCglobal Inc; to create the next generation EPCIS. Traub (2012) explains that one expected enhancement is the ability to more easily trace objects identified by a batch or lot code. The new EPCIS feature is expected to allow an event to indicate one or more batch/lots as well as the number of items from each code that took part in the event.

Of particular interest to the food and livestock industries is an enhancement that handles transformations. Many companies in this sector render (transform) meat portions to minute portions to make meat patties and the like. The new EPCIS enhancement would allow both a list of inputs consumed and a list of outputs produced to be carried in the same event. Traub (2012) also outlines that a new feature may include what he refers to as the standardisation of data that many implementations today include through proprietary customisation, such as 'ship from' and 'ship to' information and packaging levels. This standardisation, he contends will lead to greater cross-business and cross-industry interoperability.

3.10 Defining the Internet of Things

A report published by Forrester Research (Forrester 2012) highlights that there has been no single standard definition of the Internet of Things (IoT) since the term was coined some 15 years ago. As a consequence, a variety of technologies are now used in implementation (e.g., RFID tags, barcodes and GPS technologies) to monitor and transfer the status of physical assets to remediate business problems like supply chain inefficiencies in industries such as manufacturing, healthcare, transportation and retail as well as to inspire innovation in organisations (Forrester 2012). The executive summary of the Forrester research (Forrester 2012) outlines a number of points of interest including positive perceptions of IoT solutions from enterprise decision makers; that barcodes and RFID devices are considered valuable components of IoT solution implementations; many firms are planning to deploy IoT solutions and applications in the future; and supply chain visibility and asset tracking applications are a key focus for many firms.

Forrester's report (Forrester 2012) also outlines that 85% of respondents (analysis taken from on-line surveys from 646 IT executives from global enterprises) who were familiar with the term

Internet of Things, strongly or completely agree with the definition provided by Forrester namely: *‘Smart interconnected devices that business use to get more visibility into the identification, location, and condition of products, assets, transactions, or people to drive more effective and timely business decisions or to improve customer interactions* (Forrester 2012).

Kortuem and Kawsar (2010) outline concerns about the direction of the development of the Internet of Things (IoT), identifying the influence and domination of commercial and industrial players at the expense of user development and innovation thereby impeding market innovation and broader adoption. Kortuem and Kawsar (2010) posit that the IoT is beyond the mere connectivity of objects to the internet; it is about data, information and objects to the internet, stating that object identification is the foundation and ultimate purpose of RFID technology. Their contention is that the wide availability of scanning technologies, including mobile phones coupled with Web2.0-syle open social collaboration empowers people to invent their own naming schemes and to collectively compile open product databases unlike the closed EPC suite of RFID standards (Kortuem and Kawsar 2010). They conclude by describing marketplace innovation and user-led innovation as necessary complements for the way forward in developing the Internet of Things (Kortuem and Kawsar 2010).

This conclusion supports earlier concerns expressed by Guinard et al., (2010) who summarise that the WS.* protocols are verbose and do not fully meet the requirements of resource constrained devices such as mobile phones and wireless sensor/actuator networks. As a consequence they contend, these shortcomings limit the type of applications built on top of EPCIS servers to rather heavy-weight business applications. This is unfortunate in their view since track and trace applications are also relevant beyond the desktop (Guinard et al., 2010).

Ashton (2009), cofounder and once executive director of the Auto-ID Center at The Massachusetts Institute of Technology, pinpoints the genesis of the phrase as the title of a presentation prepared by him for Procter and Gamble in 1999 that described the linking of RFID in P&G’s supply chain to the internet. Aston outlines that It summed up an important insight – one that [then] ten years later, after the Internet of Things has become the title of everything from an article in Scientific American to the name of a European Union Conference, is still often misunderstood (Ashton 2009). He further elaborates that what he meant, was that today computers and implicitly the Internet, are almost wholly dependent on human beings for information. He contends that if we had computers that knew everything there was to know about things, and using data they gathered without any help from human intervention, we would be able to track and count everything, and greatly reduce waste, loss and cost. He concludes that we would know when things needed replacing, repairing or recalling, and whether they were fresh or past their use by date. (Ashton 2009).

3.11 Conclusion

The literature reveals a significant volume of research into RFID from a technology perspective and also as a potential business enabler. There is also a wealth of published information on the characteristics and performance of RFD readers, antennas and tags. There is however an insignificant amount of published research on the network dimension of RFID technology as envisioned in The Internet of Things paradigm enabled through the EPCglobal Network infrastructure of standards and specifically the EPCIS. Despite the promise of increased business opportunity offered under the paradigm, the limited amount of research and implementations in business contexts in regard to EPCIS highlight incongruity. The incongruity may be explained in part by Moore's (Moore 1999) analysis of the *Technology Adoption Life Cycle* as outlined in Figure 3.1. Moore posits that attitudes towards technology adoption become significant when the introduction of new products or technologies are seen as disruptive in some way especially behaviour or process modification. RFID can be viewed as a disruptive, change-sensitive technology and one of discontinuous innovation beyond just a normal technology upgrade.

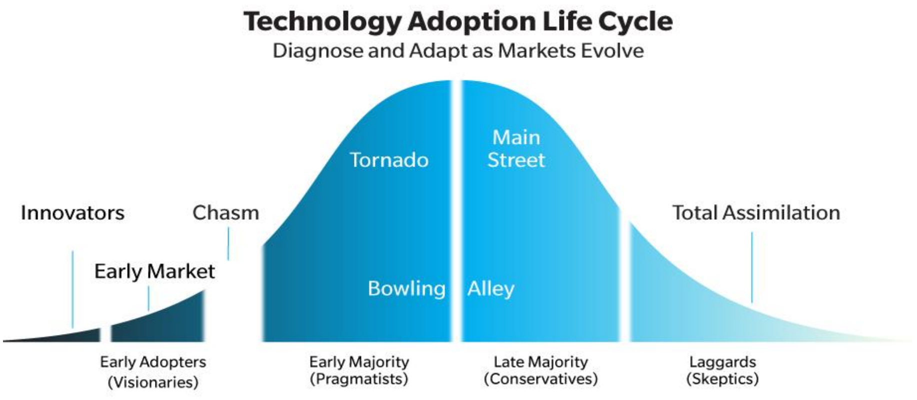


Figure: 3.1 - Technology Adoption Life Cycle
(Source: Adapted from Weifels 2002)

With RFID adoption, a handful of organisations such as Wal-Mart, METRO, Gillette and Unilever are considered RFID technology innovators and early adopters, aggressively pursuing the technology for the business benefits promised, most notably competitive advantage. As a consequence, because the technology caught on with the early adopters, the publicity positing it as *the next big thing* followed. Roberti (2012) asserts that within the context of Moore's Technology Adoption Life Cycle (TALC), the global adoption of RFID technology is in a Chasm, a gap in the technology adoption life cycle bell curve; a transitional separation stage between early adopters and the early majority before more mainstream adoption; or as Moore describes, a rapid acceleration in market development followed by a dramatic lull occurring whenever a discontinuous innovation is introduced (Moore 1999). Wiefels (2002) outlines that discontinuous innovations represent risk, sometimes profoundly so, to investors, first buyers and infrastructure providers. Roberti (Roberti 2012) posits that global RFID adoption will be accelerated when the full suite of RFID standards are ratified and when RFID is seen as a technology that solves business issues no other existing technology can. Seemingly, this has yet to occur. Moore's thesis may explain, in part, the limited amount of research effort into the efficacy of the EPCIS since its ratification as a standard in 2008.

In The *Hype Cycle for Emerging Technologies* Report published by The Gartner Group (Sembassy 2012), their analysis on the pace of global RFID adoption supports Roberti (2012) as identified in figure 3.2.

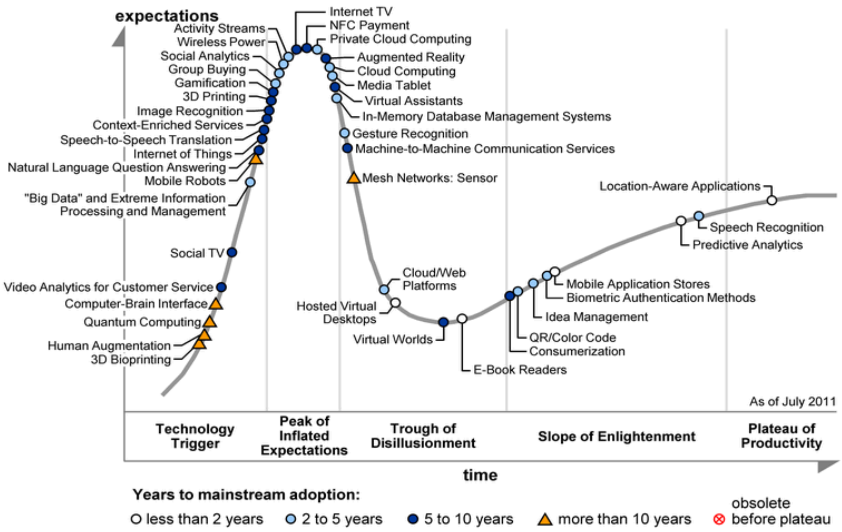


Figure: 3.2 - Gartner Hype Cycle for Emerging Technologies 2012
(Source: Sembassy 2012)

Of the transformational technologies researched that will eventually gain broader global adoption, Gartner predict that The Internet of Things will take more than ten years to eventuate as highlighted in Figure 3.2 (Sembassy 2012). The Gartner analysis (Sembassey 2012) further outlines that advances in embedded sensors and wireless connectivity is a slow moving area but one that is accelerating with the growing pervasiveness of low-cost, embedded sensors and cameras. The *Internet of Things* as well as identification technologies such as location-aware applications and communications technologies such as machine-to-machine communication services and sensor networks will take at least another decade to fully manifest themselves while offering many interesting and profitable opportunities along the way (Sembassy 2012).

Forrester's definition (Forrester 2012) may provide additional insight into the lack of research into the efficacy of using the EPCIS standards and repositories for traceability. The definition is sufficiently broad to include any device capable of interconnectivity (but not necessarily interoperability) to the Internet, including but certainly not limited to the EPCIS and the suite of open, global standards that support it.

Ashton's involvement in MIT's transferring The Internet of Things architectural building blocks to EPCglobal Inc; for commercialisation (Roberti 2009), indicates his definition of the Internet of Things and presupposes the use of open interoperable standards-based RFID related solutions and not the broad definition used by Forrester (Forrester 2012) and supported by those *familiar* (Forrester 2012 p.2) with the term.

Chapter 4 Methodology

4.1 Introduction

This chapter outlines the methodology used to test and evaluate the efficacy of using the EPCglobal Network focusing on the EPCIS standard for livestock and meat traceability. The methodology describes a process model involving nine discrete steps outlining the movement of cattle and cartons of meat cuts through a supply chain involving a farm location, meat processing facility and a retail shop and the process of identifying, capturing, retrieving and reporting on the information at each process stage.

4.2 Objectives

The objectives are summarised as follows:

- Examine various regulatory based definitions of traceability and adopt a reference definition as a basis for the research in achieving desired regulatory, legislative and corporate outcomes.
- Using the research methodology outlined, the definition will be assessed to determine the efficacy of using the EPCIS standard for livestock and meat traceability.

4.3 Methodology

The researchers concluded that the optimal opportunity to achieve stated objectives was not to test and evaluate efficacy using a contrived laboratory or theoretical model. In alignment with both the Thakur and Ringsberg's (2011) and Matri et al., (2011) research methodology, the research utilised a 'real' supply chain environment that involved the movement of cattle from an on-farm environment through a meat processing facility where meat cuts were packed into cartons and delivered as finished cuts to a suburban retailer as illustrated in Figure 4.1.

Figure: 4.1 - The Nine Proof of Concept Process Steps Flow Chart

4.4 Research Alternatives

'Good research generates dependable information and data that are derived by professionally conducted practices and that can be used reliably for decision making'. (Cooper and Schindler 2008 p.13). Good research also follows standards of scientific method including a clearly defined purpose, a detailed research process, a thoroughly planned research design which is ethics based, identifies research limitations and provides adequate analysis for decision maker's needs where the findings are presented unambiguously with justifiable conclusions (Cooper and Schindler 2008).

Prior to adopting an appropriate research methodology, the researchers undertook a critical review of both the qualitative and quantitative research methodology and antecedents, recognising that:

- *Qualitative research techniques seek to describe, decode, translate and come to terms with the meaning, as distinct from the frequency, of certain phenomena (*Cooper and Schindler 2008 p.710); a fundamental approach of exploration which includes among other research, document analysis and case studies (Cooper and Schindler 2008) and,

- *Quantitative research is the precise count of behaviour, knowledge, opinion or attitude* (Cooper and Schindler 2008 p.710). Cooper and Schindler (2008) also outline that qualitative methods often do not command unqualified support from senior decision makers as the data are often perceived as too subjective and susceptible to human error and bias in data collection and interpretation (Cooper and Schindler 2008).

The literature review outlines the use of case studies, proofs of concept and simulations as research methodologies Thakur and Ringsberg (Thakur and Ringsberg 2011) and Hild (Hild 2010). With reference to simulations, specifically the replication of the essence of a system or process, Cooper and Schindler (Cooper and Schindler 2008 p.145) *identify that this methodology is becoming increasing used in research especially in operations research*. The term *case study* has multiple meanings (Myers 2012). It can be used to describe a unit of analysis or to describe a research method. The discussion here concerns the use of the case study as a research method. Myers (Myers 2012) outlines that case study research is the most common qualitative method used in information systems and is a research method particularly well-suited to information science research. Myers (Myers 2012) also outlines that there are numerous definitions; the scope of a case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident (Myers 2012) and (Yin 2012).

Cooper and Schindler (Cooper and Schindler 2008 p.700) also outline that a *'case study is a methodology that combines record analysis and observation and is used to understand events and their ramifications and processes; emphasises the full contextual analysis of a few events or conditions and their interrelations for a single participant; a type of experimental design (one-shot) case study'.*

This research has adopted what Cooper and Schindler (Cooper and Schindler 2008 p.12) *describe as both a qualitative and an applied approach involving a practical problem-solving emphasis as it is conducted to reveal answers to a specific question related to action, performance or policy needs* namely; does the EPCIS standard provide efficacy for livestock and meat traceability or otherwise ?

The decision to use a sampling technique; the process of selecting some elements of a population to represent that population was considered both compelling and justified given the lower research costs, greater accuracy of results, faster data collection and availability of population elements, typically experienced when using this technique as Cooper and Schindler (Cooper and Schindler 2008) describe.

Phenomenological research is an approach that seeks to illuminate the specific, to identify phenomena through how they are perceived by the actors in a situation (Lester 1999). Groenewald (Groenewald 2004) outlines the fundamental phenomenological basis where realities are treated as pure phenomena and the only absolute data from where to begin – the science of pure phenomena; the return to the concrete, *back to the things themselves* (Groenewald, 2004 p.4). Groenewald (Groenwald 2004) also explains that the operative word in phenomenological research for some researchers is 'describe' where the aim of the researcher is to describe as accurately as possible the phenomenon, refraining from any pre-given framework, but remaining true to the facts (Groenewald, 2004).

Pure phenomenological research seeks essentially to describe rather than explain, and to start from a perspective free from hypotheses or preconceptions (Husserl 1970). Phenomenological methods are particularly effective at bringing to the fore the experiences and perceptions of individuals from their own perspectives, and therefore at challenging structural or normative assumptions. Adding an interpretive dimension to phenomenological research, enabling it to be used as the basis for practical theory, allows it to inform, support or challenge policy and action (Lister 1999). Phenomenologists, in contrast to positivists, believe that the researcher cannot be detached from his/her own presuppositions and that the researcher should not pretend otherwise (Groenewald, 2004).

Phenomenological and associated approaches can be applied to single cases or selected samples (Lister 1999). While single-case studies are able to identify issues which illustrate discrepancies, different situations and system failures, positive inferences are less easy to make without a small sample of participants. In multiple participant research, the strength of inference which can be made increases rapidly once factors start to recur with more than one participant. In this respect it is important to distinguish between statistical and qualitative validity: phenomenological research can be robust in indicating the presence of factors and their effects in individual cases, but must be tentative in suggesting their extent in relation to the population from which the participants or cases were drawn (Lister 1999).

Groenwald (Groenewald, 2004 p.6) outlines that *some researchers who deploy phenomenology techniques are reluctant to prescribe techniques stating that "[t]here is a reluctance to focus too much on specific steps" because imposing method on a phenomenon would do a great injustice to the integrity of that phenomenon.*

Finally, phenomenological approaches are good at surfacing deep issues and making voices heard (Lister 1999). This is not always comfortable for clients or funders, particularly when the research exposes taken for granted assumptions or challenges a comfortable status quo. On the other hand, many organisations value the insights which a phenomenological approach can bring in terms of cutting through taken-for-granted assumptions, prompting action or challenging complacency (Lister 1999).

Mixed methods research, also called mixed research is becoming increasingly articulated, attached to research practice and recognized as the third major research approach or research paradigm, along with qualitative research and quantitative research (Johnson, et al., 2007). The primary philosophy of mixed research is that of pragmatism. *Mixed methods research is, generally speaking, an approach to knowledge (theory and practice) that attempts to consider multiple viewpoints, perspectives, positions, and standpoints (always including the standpoints of qualitative and quantitative research* (Johnson et al., 2007 p.112). Although mixed methods research is not new, it is a new research paradigm that has arisen in response to the currents of quantitative research and qualitative research where new antitheses and syntheses continually develop in response to current theses. *Mixed research is a synthesis that includes ideas from qualitative and quantitative research* (Johnson, et al., 2007 p.112).

Johnson et al., (2007) outlines the essence of the formalising of a practice of using multiple research methods referred to as triangulation, referring to “multiple operationalism,” in which more than one method is used as part of a validation process that ensures that the explained variance is the result of the underlying phenomenon or trait (Johnson et al., 2007 p.113) and not of the method (e.g., quantitative or qualitative); a measurement and construct validation technique, in its original formulation, than it is a full research methodology. It is argued that the convergence of findings stemming from two or more methods *enhances our beliefs that the results are valid and not a methodological artefact* (Johnson et al., 2007 p.113). The idea of multiple operationalism follows more closely with what is referred in modern research as *multi-method research*, in contrast to what currently is called *mixed methods* (Johnson et al., 2007 p.113). Johnson et al., (2007 p.114) explain that other researchers have extended the definition to assert that o*nce a proposition has been confirmed by two or more independent measurement processes, the uncertainty of its interpretation is greatly reduced. The most persuasive evidence comes through a triangulation of measurement processes.* The term *triangulation emerged,* the combination of methodologies in the study of the same phenomenon establishing that *if a proposition can survive the onslaught of a series of imperfect measures, with all their irrelevant error, confidence should be placed in it. Of course, this confidence is increased by minimizing error in each instrument and by a reasonable belief in the different and divergent effects of the sources of error* (Johnson et al., 2007 p.114).

4.5 Justification for Selected Research Method

Good research has inherent value only to the extent that it aids in decision making and as such business research is justified based on the contribution it makes to decision makers and related bottom lines where the ultimate test of sample design is how well it represents the characteristics of the population it purports to represent (Cooper and Schindler 2008). In measurement terms, the sample must be valid taking into account accuracy - the degree to which bias is absent from the sample, and precision – how closely the sample represents the population (Cooper and Schindler 2008).

This research purposely adopted a case study based methodology, a selection based on the following discussion. All case study research begins with the desire to derive an up-close or otherwise in-depth understanding of a single or a small number of cases set within a real world context (Yin 2012) in order to produce an insightful appreciation of the case(s) resulting in new learning about real world behaviour. *The distinctiveness of the case study therefore, also serves as its abbreviated definition: An empirical inquiry about contemporary phenomenon (e.g., a 'case'), set within its real-world context especially when the boundaries between phenomenon and context are not clearly evident* (Yin 2012 p.4). Yin (2012) outlines that of the situations that create relevant opportunities for applying the case study method, emphasising the study of phenomenon within its real-world context favouring the collection of data in natural setting, compared with relying on *'derived'* data (Yin 2012 p.5) is compelling.

Despite its apparent applicability in studying relevant situations and addressing real-world research questions and scenarios, case study research has not achieved widespread recognition as a method of choice. Case study modes are seen as exploratory preambles to more scientific method (Yin 2012). Yin (2012) disputes this, advancing the argument that case studies have their own exploratory modes that investigate phenomena well beyond exploratory functions (Yin 2012). Yin (2012 p.6) also argues against the lack of trust in the credibility of case study research procedure outlining that case studies, *correctly structured do follow systematic data collection procedures and analysis procedures and case study finding can be generalised to other situations through analytic (not statistical) generalisation.*

This research model aligns with Yin's multiple-case design (Yin 2012) – multiple experiments, each case seeking to examine a *complimentary face of the main research question. Thus, a common multiple case design might call for two or more cases that deliberately test the conditions under which the same findings might be replicated – that intentionally mimics the same principle used in multiple experiment* be they direct or theoretical replications (Yin 2012 p.8). Direct Observation in a field setting is one of the most common methods of data collection (Yin 2012).

One of the benefits of case study methodology cited by Yin (2012) is the opportunity for triangulating evidence of observations as outlined by Johnson et al., (2007); the convergence that occurs when three or more independent observation sources all point to the same set of events, facts or interpretation.

4.6 Advantages and Disadvantages of Research Methodology

The advantage in selecting the research methodology to demonstrate utility and efficacy using a 'real world' scenario is just that – it emulates closely the real world in a cost conscious manner and aligns with accepted norms of research as outlined. Having undertaking subsequent research focusing exclusively on the efficacy of using EPC compliant UHF RFID hardware (Hartley et al., 2008) for livestock applications, the 'industry' discredits results and analysis attained from simulated or contrived environments. Using antecedent research Thakur and Ringsberg (2011) and Maitri et al., (2011) also provides useful comparative analysis.

There are disadvantages and risks involved in selecting this methodology as outlined:

- Live animals are unpredictable as is weather.

- Utilising 'working' facilities such as a meat processing plant for research purposes can be disruptive for the workforce as it often causes disruption and interruption to carefully planned production schedules. There are also concerns in compromising health, safety and quality procedures.

- Invariably there is a significant amount of 'good-will' involved with on-location research which needs to be accounted for both in research design and the on-site research itself – as good-will has limits.

- Equipment failure during research is disruptive and can cause lengthy, unplanned delays.

- Performance of RFID equipment can be compromised by electromagnetic fields caused by motors and working machinery. UHF RFID has known performance degradation issues in environments containing moisture and metal. Setting up readers and tags in these types of environments often requires on-site pre-configuration and setup to ensure optimal performance and to mitigate potential disruptive delays.

- Secure, reliable access to computer networks (especially for wireless requirements) for event data transmission may be difficult and can compromise data transfer performance.

- When undertaking research in on-site locations, a limited opportunity exists for repetitive testing given the testing environment is a working production environment where production lines generally will not/ cannot postpone or stop for research purposes and where animals are easily stressed.

Having outlined the disadvantages and risks associated with on-location research, the rigor and authenticity of the results gained in the research justifies the methodology selection. Indeed, understanding the requirements of a discerning regulatory and user community, results secured in any other way may be viewed as contrived or theoretical.

4.7 Sampling and Data Collection

The EPCIS standard specifies two interfaces and a data model. The EPCIS data model specifies a standard way to represent visibility information about physical objects including descriptions of product movements in a supply chain. The main components of the data model include EPC, Event Time, Business Step, Disposition, Read Point, Business Location, and Business Transaction. The data model is designed to be extended by industries and end users without revising the specification itself. EPCIS also adds another layer to the EPC standards architecture framework and mandatory visibility information in EPCIS takes the form of "*events*" that describe specific occurrences in the supply chain. An example event would be that EPC 456 (product) was Received (business step) in Non-Sellable condition (disposition) at Distribution Centre X (location) yesterday at 3pm EDT (time). A quick way to summarize the components of an EPCIS event are *what* (product), *when* (time), *where* (location), and *why* (business step and disposition).

The EPCIS Event Capture Interface specifies a standard way for business applications that generate visibility data to communicate that data to applications that wish to consume it. In many cases, the receiving side of the Event Capture Interface will be a repository, but this is not necessarily the case. The EPCIS Query Interface provide a standard way for internal and external systems to request business events from repositories and other sources of EPCIS data using a simple, parameter-driven query language. There are two types of queries – Poll Queries for a synchronous, on-demand response, and Subscription Queries for an asynchronous, scheduled response component is the use and encoding of EPC standard identifiers.

The data collection and sampling design involved a nine step process of RFID tag 'reading and recording' from a farm located in Ashburton, New Zealand (for live animals - cattle) through a livestock processing plant based in Ashburton to a suburban retail store, for cartons of finished meat cuts, located in Christchurch, New Zealand.

The research design describes a statechart type data collection and sampling methodology where research process steps (EPC read event locations) are identified. The process steps outline the product identifiers assigned (sGTIN, SSCC) at each event read point and the EPC location identifiers (sGLN). The RFID hardware utilised at each read event is described (and its performance) as is the EPC Business Step which is assigned in accordance with EPCglobal's Core Business Vocabulary. EPC's in the form of Serialised Global Trade Item Numbers (sGTIN) were encoded into EPC compliant RFID ear tags for the live animals and encoded into RFID inlays in paper labels for the logistics cartons containing finished meat cuts. RFID 'read points' (RFID event locations) were pre-assigned using the EPC unique location identifier - Serialised Global Location Number (sGLN). Network IP addresses and details of the EPCIS were preset and given the Object Name Service (ONS) functions as a 'yellow pages' for network IP addresses, its use in the research was not required.

Read Number	Process Step, Identifier and Hardware	Process Image
1	**Tagging the animal on farm** EPC Identifier (Cattle) - sGTIN EPC Identifier (Farm Tagging Station) - sGLN Reader – Tracient Padl UHF (Handheld) Tag Read Performance - 100% **Business Step - Commissioning**	
2	**Animal leaves farm on truck** EPC Identifier (Cattle) - sGTIN EPC Identifier (Farm Race) - sGLN Reader – Intermec (Fixed) Tag Read Performance - 100% **Business Step - Loading**	
3	**Animal arrives at processor holding yards** EPC Identifier (Cattle) - sGTIN EPC Identifier (Processor Race) - sGLN Reader – Motorola XR-450 (Fixed) Tag Read Performance - <100% **Business Step - Receiving**	
4	**Animal arrives at Stun Box** EPC Identifier (Cattle) - sGTIN EPC Identifier (Processor Stun Box) - sGLN Reader – Convergence Systems CS203 (Fixed) Tag Read Performance - 100% **Business Step - Transforming**	
5	**Carcass stored in Chiller Room** EPC Identifier (Carcass) - SSCC EPC Identifier (Processor Chiller Room) - sGLN Reader – Motorola XR-450 (Fixed) Tag Read Performance - 100% **Business Step - Commissioning**	
6	**Carcass moved to Boning Room** EPC Identifier (Carcass) - SSCC EPC Identifier (Processor Boning Room) - sGLN Reader – Motorola XR-450 (Fixed) Tag Read Performance - 100% **Business Step - Transforming**	
7	**Finished cuts packed into cartons** EPC Identifier (Cartoned meat) - sGTIN EPC Identifier (Processor Packing Line) - sGLN Reader – Motorola XR-450 (Fixed) Tag Read Performance - 100% **Business Step - Commissioning**	

8	**Loading cartons in shipping container** EPC Identifier (Cartoned meat) - sGTIN EPC Identifier (Processor Dock Door) - sGLN Reader – Motorola XR-450 (Fixed) Tag Read Performance-– 100% **Business Step** - **Shipping**	
9	**Cartons received at retailer** EPC Identifier (Cartoned meat) - sGTIN EPC Identifier (Retailer Dock Door) - sGLN Reader – Tracient Padl (Handheld) Tag Read Performance - 100% **Business Step** - **Receiving**	

Table: 4.1 - The Proof of Concept Nine Step Process

Chapter 5 Analysis and Discussion

5.1 Introduction

This chapter summarises the elements considered necessary for defining traceability while providing a benchmark reference on which to examine, measure and assess research objectives. The salient outcomes and findings of the research are outlined and their significance discussed with respect to the stated objectives. An analysis of recently published research using similar methodology using live deer as the sample species and cartons of finished venison cuts is also outlined and discussed.

Commentary is also provided on significant technical issues uncovered during the research and a discussion is provided on the potential issues and implications with respect to the New Zealand National Animal Identification Tracing (NAIT) initiative.

5.2 Defining Traceability

A benchmark definition for traceability is advanced to measure objectives against. In general, traceability systems have four core elements (CIES 2004).

1. Unique identification for physical items, batches of items, events, organisational entities and locations.

2. Data capture and recording systems. Data carriers provide a means of transporting identity related information and making it available for collection at certain points in the supply chain. Generally, data carriers are either bar code labels or radio frequency identification (RFID) tags from which information can be retrieved by scanning or radio transmission.

3. A links management system which enables items, batches, events, entities and locations to be related to each other.

4. An information exchange system which enables supply chain participants to add and retrieve information as appropriate to their role in the traceability system. This might be one centralised database or some form of standardised electronic messaging and an interface between distributed data stores.

For this analysis, a rigorous definition of traceability based on the CIES (2005) 'chain traceability' definition is adopted - namely; traceability demonstrating history, application, location and record throughout the entire supply chain - a "one step up, one step down" traceability. The basis for adopting the CIES definition is that as consumers and regulators increasingly demand more accurate and granular levels of certainty around food and food products, proof of origin and chain of custody have/will become more stringent. Measuring traceability efficacy against this more stringent set of requirements therefore is considered a more robust examination and test.

5.3 EPCglobal Core Business Vocabulary Standard

EPCglobal Inc; defines a *Core Business Vocabulary* (CBV) that specifies various vocabulary elements and their values for use in conjunction with the EPCIS standard. The vocabulary identifiers and definitions ensure that all parties who exchange EPCIS data using the CBV will have a common understanding of the semantic meaning of that data. The CBV used in this research are outlined in the glossary.

The goal of the CBV is to specify various vocabulary elements and their values for use in conjunction with the EPCIS standard which defines mechanisms to exchange information between supply chain partners across a broad set of business scenarios common to many industry sectors to facilitate interoperability in EPCIS data exchange. The vocabulary identifiers and definitions ensure all parties that exchange EPCIS data using the CBV have a common understanding of the semantic meaning of that data.

Vocabularies are used extensively within the EPCIS to model conceptual and physical entities that exist in the real world. Examples defined in the EPCIS standard are *business steps*; denoting the specific activity within the business process, *dispositions*; denoting the business state of an object where it is assumed to hold true until another event indicates a change in disposition, *business location identifiers*; the location where the subject of the event is assumed to be following an EPCIS event until a new event indicates otherwise, *physical object identifiers*; the identification of the object under consideration, *business transaction type names*; denoting a particular kind of business transaction (eg: ‘purchase order) and *business transaction identifiers* denoting a specific business transaction document of the type indicated by the Business Transaction Type (eg: The identifier that denotes a company’s purchase order # 12345).

Within the context of supply chain traceability outcomes, the CBV assists by providing supply chain partners with a common and important, interoperable vocabulary offering various levels of event observation, filtering and data collection opportunities, process and event interpretation analysis and monitoring.

5.4 Analysis and Discussion

Analysis of the read events is illustrated in Tables 5.1 – 5.4 captured as screen shots from the EPCIS server. The information captured in the EPCIS is from item tag data captured from a Parent/ Animal EPC. The recorded information includes the **unique EPC identifiers used** (sGTIN, SSCC) at a given **event location** (sGLN), with the **business steps** (Commission, Delete etc.) undertaken and the **event read times**. Figure 5.1 identifies the nine (9) step chain traceability process as outlined in Table 4.1 as recorded in the EPCIS. The three (3) EPC item identification numbers correspond to a carton (sGTIN – 96:1:9419781.0024.5004), a carcass (SSCC-96 – 96:1:9419781.1000001275) and an animal (sGTIN 96:1:942100000.0001.147). The chain of traceability that links these three objects together are illustrated in Tables 5.2 – 5.4 where screen captures from finished carton to carcass to animal are outlined thereby demonstrating backward chain traceability.

Data Link Main

Select View Search by EPC O

EPC in

urn:epd:id
urn:epc:tag:sgtin-96:1.942100000.0001.147
urn:epc:tag:sscc-96:1:9419781.1000001275
urn:epc:tag:sgtn-96:1:9419781.0024.5004

Search

9 Items found, displaying all items.
1

Event Time	BizLocation	BizStep	Event Type	Action	EPC	Parent EPC
2/06/2010 15:33:37 +1200	chiller	Receive Product	ObjectEvent	OBSERVE	urn:epc:tag:sgtin 96:1:9419701.0024.504	
2/06/2010 11:04:43 +1200	on-truck	Shipping in progress	ObjectEvent	OBSERVE	urn:epc:tag:sgtin 96:1:9419701.0024.504	
18/05/2010 09:29:02 +1200	coldstore	Apply tag to Item	ObjectEvent	ADD	urn:epc:tag:sgtin 96:1:9419701.0024.504	
18/05/2010 09:18:51 +1200	boning_room	transforming	ObjectEvent	DELETE	urn:epc:tag:sscc-96:1:9419781.1000001275	
17/05/2010 11:34:21 +1200	chiller	Apply tag to Item	ObjectEvent	ADD	urn:epc:tag:sscc-96:1:9419781.1000001275	
17/05/2010 11:13:39 +1200	slaughterboar	transforming	ObjectEvent	DELETE	urn:epc:tag:sgtin 96:1:942100000.001.147	
17/05/2010 09:38:23 +1200	yard	Receive Product	ObjectEvent	OBSERVE	urn:epc:tag:sgtin 96:1:942100000.001.147	
17/05/2010 08:57:44 +1200	on-truck	Prepare for Shipment	ObjectEvent	OBSERVE	urn:epc:tag:sgtin 96:1:942100000.001.147	
9/09/2009 14:17:28 +1200	on-farm	Apply Tag to Item	ObjectEvent	ADD	urn:epc:tag:sgtin 96:1:942100000.001.147	

Export Options: **CSV** **Excel** **XML** **PDF**

Table 5.1 - EPC Event Read Events at Identified Business Steps and Locations

Table: 5.2 outlines the Identification of a **carton of meat cuts** (sGTIN – 96:1:9419781.0024.5004) moving into the processor's **Cold Store** (sGLN Read Point - 9429000049115.5) at specified time 09:29:02 where the business step is **commissioning**. This event corresponds to the creation a carton of finished meat cuts; the highlighted extension field specifying that this carton was part of a virtual batch (batch=20100518_0915_0930), where all cartons were produced in a fifteen (15) minute window on the 18 May 2010, between 09:15 and 09:30am.

EPC Event Details

Event Time	18/05/2010 09:29:02 +1200
Timezone Offset	+12:00
Record Time	27/07/2010 23:58:22 +1200
Event Type	ObjectEvent
Action	ADD
EPC	urn:epc:tag:sgtin-96:19419781.0024.5004
BizStep	urn:epcglobal:epcis:bizstep:fmcg:commissioning
Disposition	urn:epcglobal:epcis:disp:fmcg:active
BizLocation	coldstore
Read Point	sgln:9429000049115.5
BizTransactions	
Extensions	urn:epcglobal:gs1hk:xsd:ext#group=ROLE_gs1nz urn:epcglobal:gs1nz:xsd:ext#batch=20100518_0915_0930 urn:epcglobal:gs1hk:xsd#id=40d1678b-9976-11df-bb77-05a22efae6d3.1 urn:epcglobal:gs1hk:xsd:ext#username=gs1nz_admin

Table 5.2 - The Identification of Cartons of Venison Cuts Going to Cold Store

Table: 5.3 outlines the identification of a **carcass** (SSCC-96 – 96:1:9419781.1000001275) going into the **Boning Room** (sGLN Read Point – 9429000049115.4) at specified time 09:18:51 where the business step is **transforming**. This event occurs just prior to cutting the carcass into pieces inside the boning room; the highlighted extension field specifies that this carton was part of the same virtual batch (batch = 20100518) at specified time (time_0915_0930) as the carton, indicating that the meat inside the carton should have come from this carcass.

EPC Event Details

Event Time	18/05/2010 09:18:51 + 1200
Timezone Offset	+12:00
Record Time	27/07/2010 23:55:13 + 1200
Event Type	ObjectEvent
Action	DELETE
EPC	urn:epc:tag:sscc-96:1:9419781.1000001275
BizStep	transforming
Disposition	urn:epcglobal:epcis:disp:fmcg:in_progress
BizLocation	boning_room
Read Point	sgln:9429000049115.4
BizTransactions	
Extensions	urn:epcglobal:gs1hk:xsd:ext#group=ROLE_gs1nz urn:epcglobal:gs1nz:xsd:ext#batch=20100518_0915_0930 urn:epcglobal:gs1hk:xsd#id=d0485a3a-9975-11df-bb77-05a22efae6d3.1 urn:epcglobal:gs1hk:xsd:ext#username=gs1nz_admin

Table 5.3 - The Identification of a Carcass Going Into the Boning Room

Table 5.4 outlines the identification of a **carcass** (SSCC-96 – 96:1:9419781.1000001275) going into **Chiller Room** (sGLN Read Point - 9429000049115.4) at specified time (09:18:51) where the business step is **commissioning**. This event corresponds to the creation (i.e. labeling) of the carcass; the highlighted extension field points to the source (the animal ID sGTIN – 96:1:942100000.0001.147) of the carcass.

EPC Event Details

Event Time	18/05/2010 11:34:21+1200
Timezone Offset	+12:00
Record Time	27/07/2010 23:50:50+1200
Event Type	ObjectEvent
Action	ADD
EPC	urn:epc:tag:sscc-96:1:9419781.1000001275
BizStep	urn:epcglobal:epcis:bizstep:fmcg:commissioning
Disposition	urn:epcglobal:epcis:disp:fmcg:active
BizLocation	chiller
Read Point	sgln:9429000049115.3
BizTransactions	
	urn:epcglobal:gs1hk:xsd:ext#SOURCE=urn.epc.tag:sgtin-96:1.942100000.0001.147
Extensions	urn:epcglobal:gs1nz:xsd:ext#group=ROLE_gs1nz
	urn:epcglobal:gs1hk:xsd#id=339748c0-9975-11df-bb77-05a22efae6d3.1
	urn:epcglobal:gs1hk:xsd:ext#username=gs1nz_admin

Table 5.4 - The Identification of a Carcass Going Into the Chiller Room

5.5 Levels of Traceability

Because each EPC identifier (sGTIN, sGLN, SSCC) was able to be read, identified, recorded and reported in the EPCIS along with the associated business step, read event location, date and time, chain traceability is demonstrated - “one step up, one step down” – thereby verifying the traceability objectives. This analysis corroborates the findings of the Swedish and Danish research projects regarding the efficacy of the EPCIS as a tool for traceability, notwithstanding their focus on fish. These results should provide confidence in the EPCglobal Network and the EPCIS standard specifically as a robust tool to provide and support traceability outcomes both in livestock and meat implementations and many others.

While the research demonstrated chain traceability, there is an increasing need for even more *granular* levels of traceability. The ability to trace the ingredients in processed foods (ie: meat patties, sausages) in particular, to a place of origin is currently difficult and often expensive to achieve - but nonetheless desired. The EPCIS is not an application and as Traub (2012) explains, there are some business situations that are not able to be expressed naturally in the EPCIS language. The current inability of the EPCIS to trace objects easily by a batch or lot number easily or to provide for transformations is a limitation, especially in environments involving food and food products.

While analysis of the EPCIS data allowed the researchers to identify EPC identifiers and time associations enabling batch and lot identification, the new EPCIS enhancement as outlined by Traub (2012) will greatly assist, improve and enhance traceability outcomes and confidence.

5.6 EPC Sector Based Headers and Identifiers

EPCglobal Inc; has established a limited number of industry sector specific EPC Headers and identifiers to meet specific industry requirements (eg. Aerospace and Defence, Automotive). This is a contentious practise given the potential for a proliferation of industry specific identifiers. There is currently no sector specific EPC identifier for livestock identification. In this analysis, generic EPC headers and identifiers designed for general supply chain applications focusing on global trade items, shipping and logistics units were used successfully. A consequence of this research and the Danish research (Hill et al., 2012) may prompt discussion in defining a dedicated livestock identification scheme.

5.7 EPC Discovery Services

A key component and critical step in enabling the creation and wider adoption of the EPCglobal Network is known as Discovery Services. Brier et al., (2006) outline that the establishment of Discovery Services would enable a heterogeneous enterprise system. The main purpose of the EPC Discovery Service standard is to find and obtain all of an item's relevant visibility data, of which a party is authorised and when some of the data is under the control of other parties with whom no prior business relationship exists (Lorenz et al., 2011). Discovery Services can be considered a search engine where an EPC is queried and it returns a list of URL's sourced from query interfaces of EPCIS servers which have knowledge of the particular EPC. At a functional level, subscribers to the network (authorised and authenticated clients) are able to reconstruct item traceability. Figure 5.1 illustrates the semantic difference between the Object Name Service and Discovery Services and the additional functionality it provides.

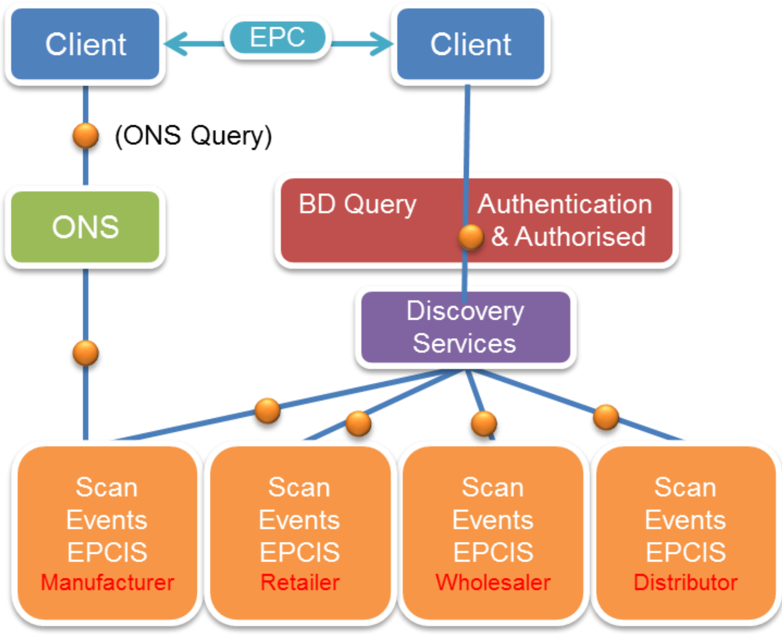


Figure: 5.1 - Object Name Service vs Discovery Service
(Source: Adapted from Lorenz et al., 2011**)**

The EPC Discovery is not yet a defined part of the EPCglobal Architecture Framework; it is envisioned but not yet architected. Further, despite EPCIS Discovery Services being labelled as core service of the EPCglobal Network, it is very much a placeholder where the final set of responsibilities remains inconclusive. Although research has been carried out in order to tackle appropriate architectures and implementations of Discovery Services, none of them has established itself as a standard and only a few have been field tested in a real supply chain environment (Berghenti et al., 2012).

As highlighted in this analysis and supported by Lorenz et al., (2011) commercial enterprises are becoming increasingly interested in moving towards a world of tagged item-level products where EPC standards are seen to be enablers in driving the labeling mechanism, the transmission and synchronisation of protocols and the network formation. However, that information is arguably the most important corporate asset, a key enabler for delivering optimal value that is a scalable, dependable and secure Discovery Service that will allow selective information to be shared and managed. But of the concerns outlined by researchers (Lorenz et al., 2011) about Discovery Services, privacy and security feature prominently. EPC event data are valuable assets that a company is very likely to share only with trusted trading partners and under controlled circumstances. Lorenz et al., (2011) outline that here is no specific security or privacy framework suggested by the EPC global standards and this comment implies inherent risk in that the Discovery Services is seen to simplify the data exchange process by offering a linking conduit about RFID enabled products as they move through supply chains allowing network participants to pro-actively manage their supply chains and ultimately realise more of the benefits of the EPCglobal Network (Lorenz et al., 2011). However, exposing important data carries with it risk through security and privacy breaches as Lorenz et al., (2011) highlight and caution.

Berghenti et al., (2012) point out that EPCglobal Discovery Services are strongly recommended when it is impractical to follow the flow of goods within the supply chain because participants are not known in advance. The issue and subsequent discussion then, is how to balance the important need for security with the desired openness of the EPCIS system. While dedicated mechanisms should be implemented for the sake of security, these tools could prevent access to the EPCIS from unknown clients and therefore stifle broad adoption of the EPC vision. Authentication of unknown clients is critical for almost every organisation that publishes strategic information on the web, although a heavily secure network leans towards a closed loop system, in contrast with the openness of the EPCglobal Network philosophy.

While this analysis concludes the efficacy of the EPCIS standard for livestock and meat traceability outcomes, the researchers are acutely aware that ultimately, a secure, interoperable and extensible Discovery Service is critical for ever increasing traceability requirements from regulators and industry alike bought about by a proliferation of product falsification, counterfeit, product diversion and the need for greater overall supply chain visibility. The researchers support the emphasis that Lorenz et al., (2001) place on the value of Discovery Services as being as critical to EPCglobal Network as the Domain Name Services but argue that the absence of a standard does not undermine the usefulness, utility and efficacy of the current EPCglobal Network suite of standards for robust traceability outcomes.

5.8 Current Livestock Traceability Initiatives in New Zealand with Deer

Continued research to the initial research outlined in Chapter Four involved investigation using deer as the sample livestock species. Conducted over a period of six weeks extending from late October 2012 to early December 2012, the research focused exclusively on deer to examine and compare earlier research (Hartley and Sundermann 2010) to examine the efficacy of using EPC standards and the EPCIS standard in particular, as a tool for use in livestock traceability. The deer research involved an extended supply chain from the earlier research (Hartley and Sundermann 2010) to include a process design model from a farm in Geraldine, New Zealand to a retail operation in Hamburg, Germany. Deer were selected as the sample species, as at the time of the research the use of RFID technologies, while mandated in New Zealand for cattle, was not for deer. The mandating of RFID in New Zealand for deer is scheduled for March, 2013 (NAIT 2012).

Although out of scope for this thesis, the efficacy of using EPC Generation 2 UHF RFID ear tags as a data carrier that also complied with NAIT tag requirements was under assessment as it is well understood that tag performance is affected (often negatively) depending on the species of animals the tags are used on. Included in the research but also out of scope for this thesis was the monitoring of carton temperature from the processors boning room in New Zealand to two delivery locations in Hamburg as outlined in Hartley (2013).

Using an eleven (11) step process design model, the process involved inserting EPC UHF RFID ear tags encoded with EPC unique identification numbers into the ears of a sample population of twenty (20) deer that were processed in a plant in Rakaia, New Zealand and where finished venison cuts were packed into cartons and exported by ocean freight in a refrigerated shipping container to retailers in Hamburg, Germany. The eleven (11) process steps are outlined in Figure 5.2 - Figure 5.21. The process design model is outlined in the Appendix.

Process Step 1 - Tagging/ recording animal identification on farm

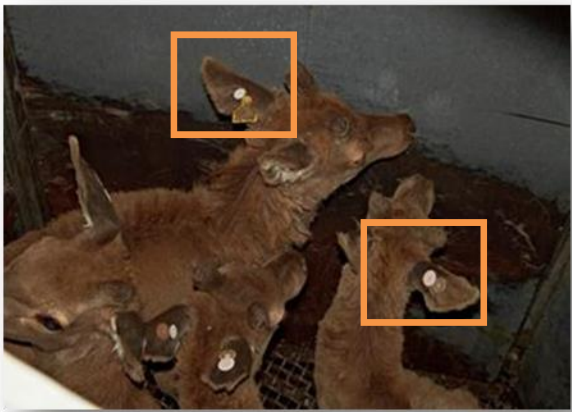


Figure 5.2 - Animals with UHF RFID ear tags

Figure 5.3 - Reading UHF RFID ear tags

Figure 5.2 illustrates the UHF EPC Generation 2 RFID ear tags inserted in the animals ears. Figure 5.3 highlights the tags being read by a handheld UHF RFID reader while the deer are in the holding pens on-farm in Geraldine.

Process Step 2 - Animals leave holding pens and are loaded onto truck

Figure 5.4 - Recording tag reads in farm race

Figure 5.5 - Truck leaving farm for processor

Figure 5.4 and Figure 5.5 illustrate Process Step 2 where deer are moved from the holding pens on farm where RFID tags are read and recorded as the animals are loaded into compartments on the truck in preparation for transport to the processing plant in Rakaia, Canterbury.

Process Step 3 - Animals arrive at processors holding pens

Figure 5.6 - View from processors holding pen to inside truck

Figure 5.7 - Inside the processors holding pen

Figure 5.6 illustrates a view looking from inside the processor's holding pen towards the truck holding pen compartments. Figure 5.7 illustrates a view from inside the processor's holding pen where a UHF RFID antenna (highlighted) is fixed to the wall of the holding pen. Animals move from truck to processor's holding pens.

Process Step 4 - Animals arrive at processors stun box

Figure 5.8 - Stun box

Figure 5.9 - RFID reader at stun box

Figure 5.8 illustrates animals in the processor's race prior to arriving at the stun box location. Note the RFID ear tags in the ears of the animals. Figure 5.9 illustrates the RFID antenna setup at the stun box location.

Process Step 5 - Cartons of packed venison cuts moved from boning room to chiller

Figure 5.10 - UHF RFID tag labels

Figure 5.11 - UHF RFID tag label used on cartons

Figure 5.12 - Cartons moving from boning room to chiller

Figure 5.10 depicts the UHF RFID tag label used in this research. Figure 5.11 depicts the label affixed on a carton and Figure 5.12 illustrates the tag label on the cartons moving on a conveyor from the boning room to the chiller in preparation for loading into the shipping container.

Process Step 6 - Cartons of venison cuts loaded into shipping container

Figure 5.13 - Loading cartons into shipping container

Figure 5.14 - Cartons of finished venison cuts loaded into shipping container

Figure 5.13 illustrates cartons of finished meat cuts being loaded into the shipping container where the RFID antenna, positioned on either side of the conveyor setup, is reading and recording the tag identification numbers from the tags affixed to each carton. Figure 5.14 illustrates cartons loaded into the shipping container at the meat processor’s facility in preparation for export to Hamburg.

Process Step 7 - Container leaving processor for Port of Lyttleton, Christchurch

Figure 5.15 - Reading shipping container RFID tag ID at processor

Figure 5.15 depicts the truck driver using a handheld RFID reader to scan and read the UHF RFID tag affixed to the outside of the shipping container prior to leaving the processing plant in Rakaia. The unique identification number (GRAI) is recorded in the EPCIS database.

Process Step 8 - Container arriving at Port of Lyttleton, Christchurch

Figure 5.16 - Reading shipping container tag ID at Port of Lyttleton, Christchurch

Figure 5.16 depicts the shipping container arriving at the Port of Lyttleton, Christchurch on the truck where the UHF RFID tag, affixed to the outside of the shipping container is scanned, read and the unique identification number (GRAI) recorded in the EPCIS database.

Process Step 9 - Cartons of venison cuts receipted on arrival at importers warehouse in Hamburg

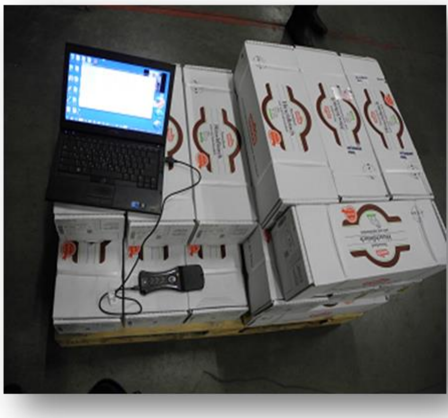


Figure 5.17 - Palletised cartons after being unloaded

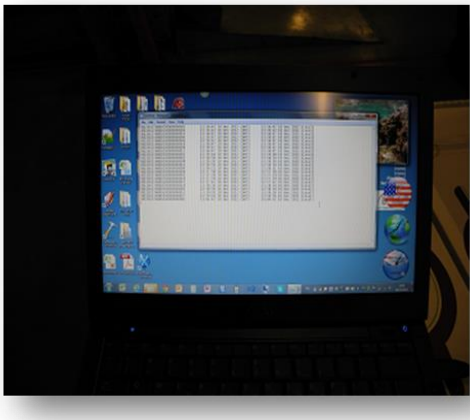


Figure 5.18 - RFID reads as cartons are unloaded from the shipping container

After the venison was inspected by German regulatory authorities, the shipping container was opened at the wholesaler's cold store facility. Figure 5.17 illustrates the 19 cartons palletised after being unloaded from shipping container in preparation for final delivery. Figure 5.18 illustrates the RFID tag read events captured during the unloading process of the 19 cartons from the shipping container.

Process Step 10 - Cartons of venison cuts loaded onto truck at importers warehouse in Hamburg

Figure 5.19 - Cartons palletised in Preparation for final delivery

Figure 5.20 - Delivery vehicle leaving importers warehouse in Hamburg

After unloading the cartons from the shipping container, they were stored on pallets overnight in the importer's cold store facility in preparation for delivery as illustrated in Figure 5.19.

Figure 5.20 illustrates the delivery vehicle en route effecting delivery of cartons to two separate retail locations in Hamburg. Carton RFID tags were scanned at the beginning of the delivery; one pallet containing five (5) cartons and the other pallet containing four (4) cartons.

Process Step 11 - Cartons of venison cuts delivered to two retailers in Hamburg

Of the nineteen (19) cartons in the research total consignment, nine (9) cartons were consigned for delivery in Hamburg to two different locations, four (4) to one location and five (5) to a second location. These nine (9) cartons were used as the sample delivery cartons for the research. Each RFID tag affixed on the cartons was read at each delivery location by a handheld RFID reader and the data transmitted and loaded into the EPCIS database thereby completing the chain traceability requirement.

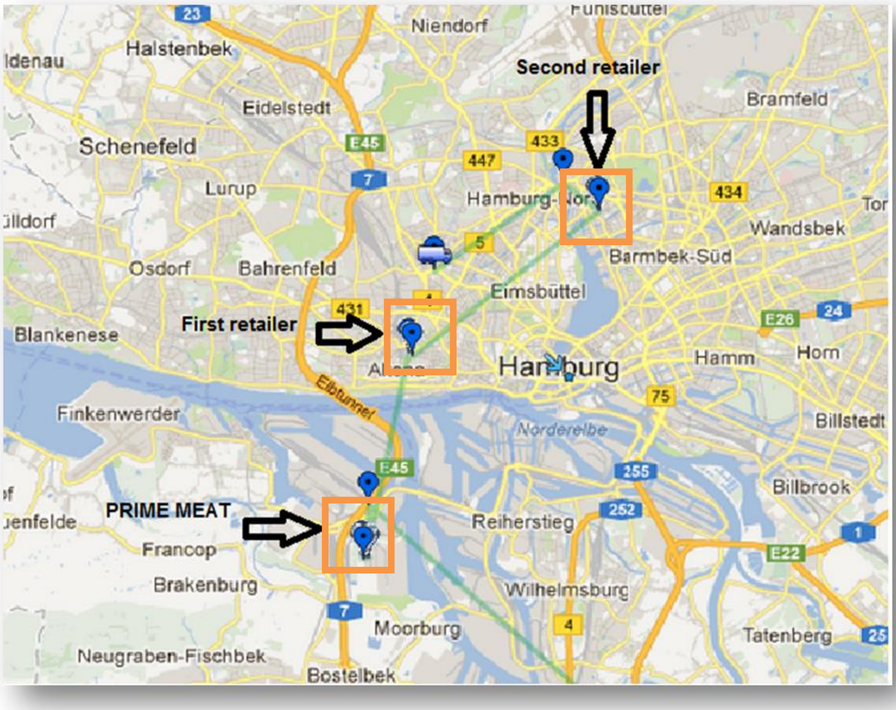
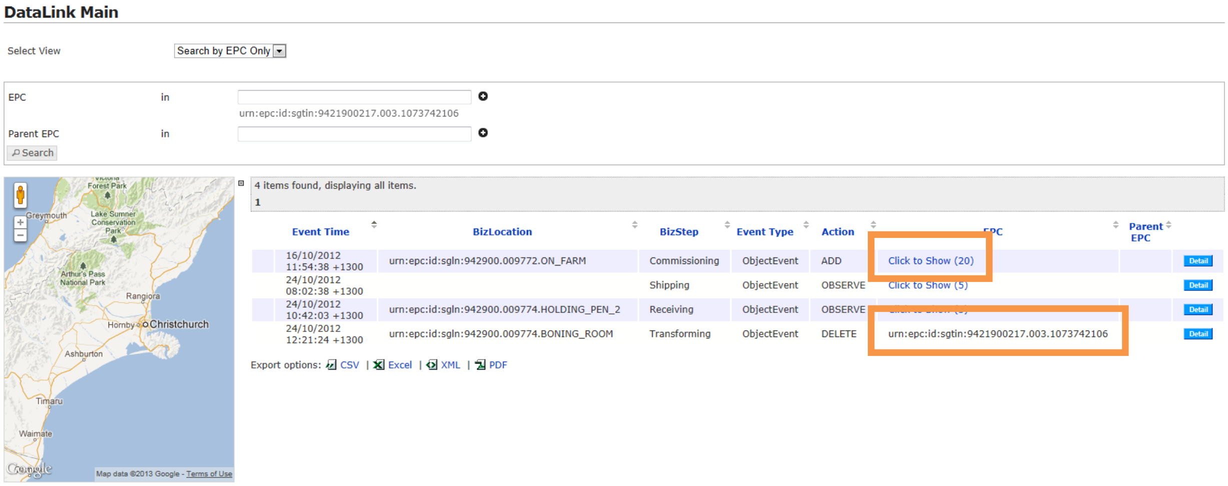


Figure 5.21 - Delivery of cartons in Hamburg

Figure 5.21 illustrates the delivery route for the two shipments to the two delivery locations in Hamburg. While the desptach data from the importers warehouse and delivery data to the two delivery locations were captured using RFID readers and recorded in the EPCIS database, the transit and deliveries were also monitored using GPS tracking technology installed in the delivery vehicle. This data was not captured in the EPCIS database as previously explained.

5.9 Data Collection and Discussion


DataLink Main

Select View: Search by EPC Only

EPC in urn:epc:id:sgtin:9421900217.003.1073742106

Parent EPC in

Search

4 items found, displaying all items.
1

Event Time	BizLocation	BizStep	Event Type	Action	EPC	Parent EPC	
16/10/2012 11:54:38 +1300	urn:epc:id:sgln:942900.009772.ON_FARM	Commissioning	ObjectEvent	ADD	Click to Show (20)		Detail
24/10/2012 08:02:38 +1300		Shipping	ObjectEvent	OBSERVE	Click to Show (5)		Detail
24/10/2012 10:42:03 +1300	urn:epc:id:sgln:942900.009774.HOLDING_PEN_2	Receiving	ObjectEvent	OBSERVE	[illegible]		Detail
24/10/2012 12:21:24 +1300	urn:epc:id:sgln:942900.009774.BONING_ROOM	Transforming	ObjectEvent	DELETE	urn:epc:id:sgtin:9421900217.003.1073742106		Detail

Export options: CSV | Excel | XML | PDF

Table 5.5 - Identification on a single animal

Table 5.5 illustrates the identification of the original twenty (20) animals (one animal escaped during movement to farm holding pen) on farm. The tag identification data relating to one animal in particular (i.e. the EPC urn:epc:id:sgtin:9421900217.003.1073742106) is highlighted. Four (4) events are identifiable for this animal and using the EPC Core Business Vocabulary Standard, the animal undertakes the following processes: *commissioning*, *shipping*, *receiving* and *transforming*. Not all events relate to only one animal. Commissioning related to the twenty (20) original tagged animals and the loading and unloading events related to five (5) animals outlined in Table 5.6 (i.e. where one compartment inside the truck held five (5) animals. The read event at the stun box related to only one (1) animal at a time.

DataLink Main

Select View: Search by EPC Only

EPC in urn:epc:id:sgtin:9421900217.003.1073742106

Parent EPC in

Search

4 items found, displaying all items.

1

Event Time	BizLocation	BizStep	Event Type	Action	EPC	Parent EPC	
16/10/2012 11:54:38 +1300	urn:epc:id:sgln:942900.009772.ON_FARM	Commissioning	ObjectEvent	ADD	urn:epc:id:sgtin:9421900217.003.1073742106 urn:epc:id:sgtin:9421900217.003.1073742107 urn:epc:id:sgtin:9421900217.003.1073742109 urn:epc:id:sgtin:9421900217.003.1073742110 urn:epc:id:sgtin:9421900217.003.1073742111 urn:epc:id:sgtin:9421900217.003.1073742112 urn:epc:id:sgtin:9421900217.003.1073742113 urn:epc:id:sgtin:9421900217.003.1073742114 urn:epc:id:sgtin:9421900217.003.1073742115 urn:epc:id:sgtin:9421900217.003.1073742116 urn:epc:id:sgtin:9421900217.003.1073742117 urn:epc:id:sgtin:9421900217.003.1073742118 urn:epc:id:sgtin:9421900217.003.1073742119 urn:epc:id:sgtin:9421900217.003.1073742120 urn:epc:id:sgtin:9421900217.003.1073742121 urn:epc:id:sgtin:9421900217.003.1073742122 urn:epc:id:sgtin:9421900217.003.1073742123 urn:epc:id:sgtin:9421900217.003.1073742124 urn:epc:id:sgtin:9421900217.003.1073742126 urn:epc:id:sgtin:9421900217.003.1073742127		Detail
24/10/2012 08:02:38 +1300		Shipping	ObjectEvent	OBSERVE	urn:epc:id:sgtin:9421900217.003.1073742106 urn:epc:id:sgtin:9421900217.003.1073742107 urn:epc:id:sgtin:9421900217.003.1073742113 urn:epc:id:sgtin:9421900217.003.1073742115 urn:epc:id:sgtin:9421900217.003.1073742117		Detail
24/10/2012 10:42:03 +1300	urn:epc:id:sgln:942900.009774.HOLDING_PEN_2	Receiving	ObjectEvent	OBSERVE	urn:epc:id:sgtin:9421900217.003.1073742106 urn:epc:id:sgtin:9421900217.003.1073742107 urn:epc:id:sgtin:9421900217.003.1073742113 urn:epc:id:sgtin:9421900217.003.1073742115 urn:epc:id:sgtin:9421900217.003.1073742117		Detail
24/10/2012 12:21:24 +1300	urn:epc:id:sgln:942900.009774.BONING_ROOM	Transforming	ObjectEvent	DELETE	urn:epc:id:sgtin:9421900217.003.1073742106		Detail

Export options: CSV | Excel | XML | PDF

Table 5.6 - List of EPC identifiers in expanded view

Table 5.6 illustrates the same information as outlined in Table 5.5 but identifies the list of EPC sGTINs (Serialised Global Trade Item Numbers) in expanded view to illustrate explicitly which other animals / tags were part of that same read event. Note that the five (5) animals that went onto the truck together (to go into one compartment together) came off together at the processor during the same read event.

The following EPC data Tables, Table 5.7 – Table 5.17, outline a selection of EPC read events and associated business step processes where key details are identified and discussed.

EPCIS EVENT DETAILS

Event Time	16/10/2012 11:54:38 +1300
Timezone Offset	+13:00
Event Type	ObjectEvent
Action	ADD
EPC	urn:epc:id:sgtin:9421900217.003.1073742106 urn:epc:id:sgtin:9421900217.003.1073742107 urn:epc:id:sgtin:9421900217.003.1073742109 urn:epc:id:sgtin:9421900217.003.1073742110 urn:epc:id:sgtin:9421900217.003.1073742111 urn:epc:id:sgtin:9421900217.003.1073742112 urn:epc:id:sgtin:9421900217.003.1073742113 urn:epc:id:sgtin:9421900217.003.1073742114 urn:epc:id:sgtin:9421900217.003.1073742115 urn:epc:id:sgtin:9421900217.003.1073742116 urn:epc:id:sgtin:9421900217.003.1073742117 urn:epc:id:sgtin:9421900217.003.1073742118 urn:epc:id:sgtin:9421900217.003.1073742119 urn:epc:id:sgtin:9421900217.003.1073742120 urn:epc:id:sgtin:9421900217.003.1073742121 urn:epc:id:sgtin:9421900217.003.1073742122 urn:epc:id:sgtin:9421900217.003.1073742123 urn:epc:id:sgtin:9421900217.003.1073742124 urn:epc:id:sgtin:9421900217.003.1073742126 urn:epc:id:sgtin:9421900217.003.1073742127
BizStep	urn:epcglobal:cbv:bizstep:commissioning
Disposition	urn:epcglobal:cbv:disp:active
BizLocation	urn:epc:id:sgln:942900.009772.ON_FARM
Read Point	urn:epc:id:sgln:942900.009772.DEER_CRUSH

Table 5.7 - Commissioning event - tagging of animals on farm

Table 5.7 illustrates a *commissioning* event where the animals are tagged on farm. As outlined, twenty (20) animals were initially tagged as a mob. The process step is *commissioning* where the tags / animals are considered to be *active* as defined by the EPC Core Business Vocabulary (CBV) from this read point on. The values for this business step and disposition have been standardised using the EPC Core Business Vocabulary (CBV), hence the *urn:epcglobal:cbv* prefix in the BizStep and Disposition labels in the EPCIS database. Global Location Number (GS1 GLN) urn:epc:id:sgln:942900.009772 uniquely identifies the deer farm and the extensions (DEER_CRUSH and ON_FARM) provide more exact location detail. In this instance, the RFID read event occurred at the DEER_CRUSH location on the farm; the animals are considered to be ON_FARM from this point on until another read event changes the status as a consequence of a subsequent process step.

EPCIS EVENT DETAILS

Event Time	24/10/2012 08:02:38 +1300
Timezone Offset	+13:00
Event Type	ObjectEvent
Action	OBSERVE
EPC	urn:epc:id:sgtin:9421900217.003.1073742106 urn:epc:id:sgtin:9421900217.003.1073742107 urn:epc:id:sgtin:9421900217.003.1073742113 urn:epc:id:sgtin:9421900217.003.1073742115 urn:epc:id:sgtin:9421900217.003.1073742117
BizStep	urn:epcglobal:cbv:bizstep:shipping
Disposition	urn:epcglobal:cbv:disp:in_transit
BizLocation	
Read Point	urn:epc:id:sgln:942900.009772.LOADING_RAMP

Table 5.8 - Shipping observation of animals in transit

Table 5.8 outlines five (5) animals being *observed* during a *shipping* process step (i.e. loading into a truck). At this stage, the animals are considered to be *in_transit* from this point on as defined by the CBV. The animals were identified at the LOADING_RAMP location at the deer farm; however given the next process step involves a transit from farm location to processor, there is minimal meaningful information to record/ report.

EPCIS EVENT DETAILS

Event Time	24/10/2012 10:42:03 +1300
Timezone Offset	+13:00
Event Type	ObjectEvent
Action	OBSERVE
EPC	urn:epc:id:sgtin:9421900217.003.1073742106 urn:epc:id:sgtin:9421900217.003.1073742107 urn:epc:id:sgtin:9421900217.003.1073742113 urn:epc:id:sgtin:9421900217.003.1073742115 urn:epc:id:sgtin:9421900217.003.1073742117
BizStep	urn:epcglobal:cbv:bizstep:receiving
Disposition	urn:epcglobal:cbv:disp:in_progress
BizLocation	urn:epc:id:sgln:942900.009774.HOLDING_PEN_2
Read Point	urn:epc:id:sgln:942900.009774.UNLOADING_RAMP

Table 5.9 - Animals received at processing plant

Table 5.9 outlines the same five (5) animals being observed coming off the truck at the processor together where the BizStep is a *receiving* process step. The animal's *Disposition* is considered to be *in_progress* at the processors at this time. Global location number (GS1 GLN) urn:epc:id:sgln:942900.009774 uniquely identifies the processing plant; the extensions UNLOADING_RAMP and HOLDING_PEN_2 providing more exact location detail within the processing facility. Table 5.9 also outlines the animals being read at the processor's unloading ramp and are considered to be in holding pen 2 until a subsequent process step occurs, anticipated to be the processor's stun box location.

EPCIS EVENT DETAILS

Event Time	24/10/2012 12:21:24 +1300
Timezone Offset	+13:00
Event Type	ObjectEvent
Action	DELETE
EPC	urn:epc:id:sgtin:9421900217.003.1073742106
BizStep	urn:epcglobal:cbv:bizstep:transforming
Disposition	urn:epcglobal:cbv:disp:in_progress
BizLocation	urn:epc:id:sgln:942900.009774.BONING_ROOM
Read Point	urn:epc:id:sgln:942900.009774.STUN_BOX
Extensions	http://www.gs1nz.org/cbv/ext: batch=deer_epcis_pilot

Table 5.10 - Animals are deleted for processing

Table 5.10 outlines a tag (and therefore an animal) being *deleted* at the stun box location (urn:epc:id:sgln:942900.009774.STUN_BOX). This event is captured one animal at a time (i.e. a unique date/timestamp for every animal). The BizStep is *transforming* but still *in_progress* from this point on as the processing is not finished at this stage. The event read taken at the stun box assumes the animal to be in the boning room from this point on. Of note is the potential for refinement with additional read points if required to provide for more granular levels of traceability. The important additional data is the *batch* entry highlighted in the *Extensions.* The *batch entry* establishes an association between a particular animal (in this case identified by sGTIN urn:epc:id:sgtin:9421900217.003.1073742106) and the batch of the original twenty (20) tagged animals named *deer_epcis_pilot.* This same batch ID is referred to in the EPCIS database records for the cartons of venison, allowing a link to be established between the animals and the cartons which highlights not as a 1-to-1 relationship but a many-to-many relationship.

EPCIS EVENT DETAILS

Event Time	25/10/2012 11:25:53 +1300
Timezone Offset	+13:00
Record Time	08/02/2013 11:35:37 +1300
Event Type	ObjectEvent
Action	ADD
EPC	urn:epc:id:sgtin:94130000.01420.1 urn:epc:id:sgtin:94130000.01420.2 urn:epc:id:sgtin:94130000.01420.3 urn:epc:id:sgtin:94130000.01420.4 urn:epc:id:sgtin:94130000.01420.5 urn:epc:id:sgtin:94130000.01420.6 urn:epc:id:sgtin:94130000.01420.7 urn:epc:id:sgtin:94130000.01420.8 urn:epc:id:sgtin:94130000.01420.9
BizStep	urn:epcglobal:cbv:bizstep:commissioning
Disposition	urn:epcglobal:cbv:disp:active
BizLocation	urn:epc:id:sgln:942900.0097741.CHILLER_ROOM
Read Point	urn:epc:id:sgln:942900.0097741.BONING_ROOM_EXIT
Extensions	http://www.gs1nz.org/cbv/ext#batch=deer_epcis_pilot

Table 5.11 - Cartons moving from boning room to chiller

Table 5.11 illustrates the movement of nine (9) of the nineteen (19) cartons of finished venison cuts moving from the boning room into the chiller where the B*izStep* is *commissioning* and the read event occurred at the BONING_ROOM_EXIT point represented by the unique location identifier (urn:epc:id:sgln:942900.009774.BONING_ROOM_EXIT). Highlighted in the extensions section is the batch extension *deer_epcis_pilot* signifying the relationship between the nine (9) cartons and the total batch of nineteen (19) animals.

EPCIS EVENT DETAILS

Event Time	26/10/2012 07:31:09 +1300
Timezone Offset	+13:00
Event Type	AggregationEvent
Action	ADD
EPC	urn:epc:id:sgtin:94130000.01420.1 urn:epc:id:sgtin:94130000.01420.10 urn:epc:id:sgtin:94130000.01420.11 urn:epc:id:sgtin:94130000.01420.12 urn:epc:id:sgtin:94130000.01420.16 urn:epc:id:sgtin:94130000.01420.17 urn:epc:id:sgtin:94130000.01420.18 urn:epc:id:sgtin:94130000.01420.2 urn:epc:id:sgtin:94130000.01420.20 urn:epc:id:sgtin:94130000.01420.21 urn:epc:id:sgtin:94130000.01420.22 urn:epc:id:sgtin:94130000.01420.23 urn:epc:id:sgtin:94130000.01420.3 urn:epc:id:sgtin:94130000.01420.4 urn:epc:id:sgtin:94130000.01420.5 urn:epc:id:sgtin:94130000.01420.6 urn:epc:id:sgtin:94130000.01420.7 urn:epc:id:sgtin:94130000.01420.8 urn:epc:id:sgtin:94130000.01420.9
Parent EPC	urn:epc:id:grai:942900000.135.24680
BizStep	urn:epcglobal:cbv:bizstep:staging_outbound
Disposition	urn:epcglobal:cbv:disp:container_closed
BizLocation	urn:epc:id:sgln:942900.009774.CONTAINER_ON_SITE
Read Point	urn:epc:id:sgln:942900.009774.CHILLER_ROOM_EXIT

Table 5.12 - Cartons being loaded into shipping container

Table 5.12 illustrates that the 19 cartons of finished venison cuts have been loaded into the shipping container (*BizStep*:staging_outbound and *Event Type* - *Aggregation*) from the chiller room (ie: urn:epc:id:sgln:942900.009774.CHILLER_ROOM_EXIT). The container number is identified by the Parent EPC urn:epc:id:grai:942900000.135.24680 (ie: The EPC *Global Returnable Asset Identifier* - GRAI).

EPCIS EVENT DETAILS

Event Time	26/10/2012 07:53:00 +1300
Timezone Offset	+13:00
Event Type	ObjectEvent
Action	OBSERVE
EPC	urn:epc:id:grai:942900000.135.24680
BizStep	urn:epcglobal:cbv:bizstep:shipping
Disposition	urn:epcglobal:cbv:disp:in_transit
BizLocation	
Read Point	urn:epc:id:sgln:942900.009774.EXIT_GATE

Table 5.13 - Container leaves processors site

Table 5.13 illustrates the shipping container, identified by its unique EPC identifier (urn:epc:id:grai:942900000.135.24680) leaving the processing plant where the read point is identified by the processor's unique EPC global location identifier (urn:epc:id:sgln:942900.009774.EXIT_GATE). The BizStep is a *shipping* event and the container is considered to be in transit from the processors plant in Rakaia to the Port of Lyttelton, Christchurch (*in_transit)*.

EPCIS EVENT DETAILS

Event Time	26/10/2012 09:13:00 +1300
Timezone Offset	+13:00
Event Type	ObjectEvent
Action	OBSERVE
EPC	urn:epc:id:grai:942900000.135.24680
BizStep	urn:epcglobal:cbv:bizstep:shipping
Disposition	urn:epcglobal:cbv:disp:in_transit
BizLocation	
Read Point	urn:epc:id:sgln:942900.009778.ENTRY_GATE

Table: 5.14 - Container arrives at the Port of Lyttleton, Christchurch

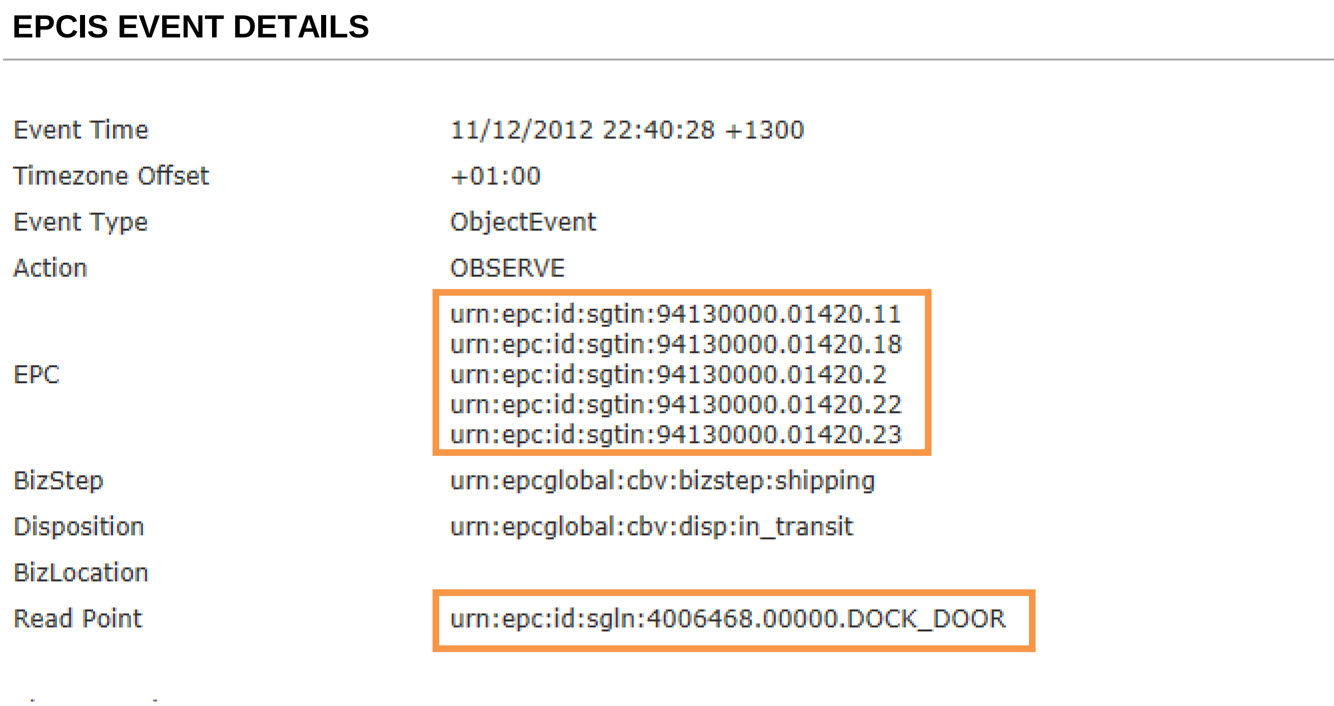
Table 5.14 illustrates a read event where the shipping container, identified by the global returnable asset identifier (urn:epc:id:grai:942900000.135.24680) is arriving at the Port of Lyttleton, Christchurch. The unique location identifier of the Port of Lyttleton is urn:epc:id:sgln:942900.009778.ENTRY_GATE. Note the transit time from the processors plant, stated in Table 5.13 (26/10/2012 07:53:00 +1300) to the Port of Lyttleton, stated in Table 5.14 (26/10/2012 09:13:00 +1300). The BizStep is *shipping*.

EPCIS EVENT DETAILS

Event Time	11/12/2012 01:09:46 +1300
Timezone Offset	+01:00
Event Type	AggregationEvent
Action	DELETE
EPC	urn:epc:id:sgtin:94130000.01420.1 urn:epc:id:sgtin:94130000.01420.10 urn:epc:id:sgtin:94130000.01420.11 urn:epc:id:sgtin:94130000.01420.12 urn:epc:id:sgtin:94130000.01420.16 urn:epc:id:sgtin:94130000.01420.17 urn:epc:id:sgtin:94130000.01420.18 urn:epc:id:sgtin:94130000.01420.2 urn:epc:id:sgtin:94130000.01420.20 urn:epc:id:sgtin:94130000.01420.21 urn:epc:id:sgtin:94130000.01420.22 urn:epc:id:sgtin:94130000.01420.23 urn:epc:id:sgtin:94130000.01420.3 urn:epc:id:sgtin:94130000.01420.4 urn:epc:id:sgtin:94130000.01420.5 urn:epc:id:sgtin:94130000.01420.6 urn:epc:id:sgtin:94130000.01420.7 urn:epc:id:sgtin:94130000.01420.8 urn:epc:id:sgtin:94130000.01420.9
Parent EPC	urn:epc:id:grai:942900000.135.24680
BizStep	urn:epcglobal:cbv:bizstep:receiving
Disposition	urn:epcglobal:cbv:disp:sellable_not_accessible
BizLocation	urn:epc:id:sgln:4006468.00000.CHILLER
Read Point	urn:epc:id:sgln:4006468.00000.DOCK_DOOR

Table 5.15 - Receipt of cartons at wholesaler, Hamburg

Table 5.15 identifies receipt of the nineteen (19) cartons of finished venison cuts at the wholesaler's cold storage facility in Hamburg identified by their global location identifiers urn:epc:id:sgln:4006468.00000.DOCK_DOOR and urn:epc:id:sgln:4006468.00000.CHILLER, where the *BizStep* is a *receiving* event. Note the date range stated in Table 5.13 (26/10/2012 07:53:00 +1300) and Table 5.15 (10/12/2012 01:09:46 +1300) which is the total transit duration from exiting the New Zealand processor's exit gate to the Hamburg wholesaler's chiller facility.



EPCIS EVENT DETAILS

Event Time	11/12/2012 22:40:28 +1300
Timezone Offset	+01:00
Event Type	ObjectEvent
Action	OBSERVE
EPC	urn:epc:id:sgtin:94130000.01420.11 urn:epc:id:sgtin:94130000.01420.18 urn:epc:id:sgtin:94130000.01420.2 urn:epc:id:sgtin:94130000.01420.22 urn:epc:id:sgtin:94130000.01420.23
BizStep	urn:epcglobal:cbv:bizstep:shipping
Disposition	urn:epcglobal:cbv:disp:in_transit
BizLocation	
Read Point	urn:epc:id:sgln:4006468.00000.DOCK_DOOR

Table 5.16 - Cartons loaded into delivery truck

Table 5.16 illustrates one (1) of the two (2) deliveries being undertaken in Hamburg. Five (5) cartons of finished venison cuts are being loaded in the delivery truck in Hamburg from the wholesaler's cold storage facility identified by the wholesaler's unique EPC global location Identifier (urn:epc:id:sgln:4006468.00000.DOCK_DOOR). The BizStep is a *shipping* event and the consignment *BizLocation* is purposely 'blank' as the location is actually the delivery transit roads within the Hamburg metropolitan area. The delivery disposition is in transit (urn:epcglobal:cbv:disp:in_transit).

EPCIS EVENT DETAILS

Event Time	12/12/2012 01:58:34 +1300
Timezone Offset	+01:00
Event Type	ObjectEvent
Action	DELETE
EPC	urn:epc:id:sgtin:94130000.01420.11 urn:epc:id:sgtin:94130000.01420.18 urn:epc:id:sgtin:94130000.01420.2 urn:epc:id:sgtin:94130000.01420.22 urn:epc:id:sgtin:94130000.01420.23
BizStep	urn:epcglobal:cbv:bizstep:receiving
Disposition	urn:epcglobal:sellable_accessible
BizLocation	urn:epc:id:sgln:4023339.00000.IN_STORE
Read Point	urn:epc:id:sgln:4023339.00000.RECEIVING_BAY

Table 5.17 - Delivery of consignment to Hamburg retailer

Table 5.17 illustrates delivery of five (5) cartons to a retailer in Hamburg where the read point location is identified by their assigned unique global location identifier (urn:epc:id:sgln:4023339.00000.RECEIVING_BAY). The BizStep is receiving (*receiving*). This stage event is considered a DELETE event, as the processes of shipment and delivery has now been completed and the items are in the custody of the retailer and available for sale (Disposition: *sellable_accessible*).

Results

The results of this research corroborate closely the findings of the thesis research involving cattle and support Myhre's thesis that the utilisation of a broad suite of supply chain standards including a common core business vocabulary, provide a reliable framework for traceability when used in combination (Myhre et al., 2009). As outlined earlier, EPC compliant UHF RFID technology has evolved significantly over the past decade. Apart from the *EPC Discovery Services Standard*, most of the standards have been ratified by EPCglobal Inc. The level of innovation and improvement in overall hardware performance is also improving as it the increasing size and geographic spread of the hardware and software vendor community.

Both the cattle and deer research outlined, demonstrate the efficacy of the EPCIS standard for chain traceability for livestock and meat yet UHF RFID technology continues to be questioned as a technology fit-for-purpose in New Zealand for livestock applications despite research findings to the contrary (Cooke and Diprose 2010). A lack of commercially available hardware, specifically tags and readers is often cited among the primary reasons for this. This is a ‘chicken and egg’ situation where the use of EPC RFID for livestock applications has not been endorsed in New Zealand. This impedes commercial interest, research and investment as without a sustainable market, the vendor community is less likely to support or undertake research and development despite the potential for groups of animals that need to be managed or the benefits provided by longer read ranges as may be required in the case of deer and/or sheep (Cooke and Diprose 2010).

There is concern from traditional livestock manufacturers, usually low frequency RFID manufacturers, in the developments of EPC RFID and the increasing interest from the wider global supply chain community for a standardised, interoperable RFID system. Cooke and Diprose (2010) outline that EPC UHF RFID tag and reader developers should collaborate with traditional manufacturers as there is much to gain from partnering. Cooke and Diprose (2012) also outline that physical tag designs, tamper proofing and methods of distribution to farmers are critical areas where combined industry experience will make a significant difference.

Findings from these two New Zealand based research, highlight implications and challenges for the New Zealand livestock industry given the Government’s recent mandating of LF RFID for livestock for traceability and biosecurity purposes. The National Animal Identification Traceability (NAIT) System is based on sector-specific ISO Standards that are technically incompatible and non-interoperable with the suite of EPC UHF RFID standards.

The NAIT design attempts to include elements to deliver on its formal objective: "To provide New Zealand livestock owners, processors and government with timely and quality information on the current location, movement history and other key attributes associated with livestock" (NAIT 2012). The NAIT system also seeks to "enhance the quality and completeness of the information needed around cattle and deer to manage the risks posed by livestock in respect of biosecurity and food safety, and facilitate market access" (NAIT 2012). However, the NAIT system design terminates at the livestock processor's facility. A system design that ring fences traceability from farm to livestock processer and does not extend to the broader supply chain is considered suboptimal for efficient and robust traceability requirements. A more optimal design would be an infrastructure that is technology agnostic; is performance based and provides for EPC RFID standards and one that adopts a more rigorous definition of traceability that is more aligned with CIES principles, for example. Such architecture would better facilitate interoperability between management and information systems both nationally and internationally.

Chapter 6 Conclusion

6.1 Introduction

This chapter outlines conclusions against stated objectives, limitations of the research undertaken and recommendations for further research.

6.2 Analysis of Objectives

The research focused on two key objectives in the examination of utilising the EPCIS standard, as a core component of the EPCglobal Network, for efficacious livestock and meat traceability.

Objective 1 *Examine various regulatory based definitions of traceability and adopt a reference definition as a basis for the research in achieving desired regulatory, legislative and corporate outcomes.*

Chain traceability, as outlined by the Food Business Forum (CIES 2005 p.7) was adopted as a benchmark reference against which stated objectives were measured and assessed, namely: *Chain Traceability* - the ability to trace the history, application or location of an entity by means of recorded identifications throughout the entire food chain. To facilitate this, CIES describe, *'in practice, the requirement for traceability is to keep records of suppliers and customers, sometimes called "one step up, one step down".* The basis for adopting what is considered a more rigorous CIES definition was to support and align with the goal of extended and interoperable supply chain traceability as the most desirous outcome for traceability especially for food and food products*. 'If all food businesses keep these records and the information therein, it can be communicated and exchanged, chain traceability is achieved'* (CIES 2005).

Objective 2 *Using the research methodology outlined, the definition was assessed to determine the efficacy of using the EPCIS Standard for livestock and meat traceability.*

All tag data (item data and location data) was successfully read, identified and captured from all nine (9) read event points and successfully transmitted using standardised GS1 XML messaging language and populated into the EPCIS server. Because each EPC identifier used in the research; sGTIN identifying items (animals and cartons of finished venison cuts), sGLN (read event location identifiers) and SSCC (carcass) was able to be identified, recorded and reported on using the EPCIS standard and implementation database, chain traceability demonstrating history, application, location and record throughout the entire supply chain was demonstrated - “one step up, one step down” – thereby verifying stated traceability performance objectives. Importantly, the results were replicated in subsequent research involving deer and venison (Hartley 2013) and therefore corroborate the findings.

Having outlined this, the researchers include an important caveat to the conclusion. In the live animal to carcass to finished cuts process in both research projects, it is difficult to determine the exact association or relationships between individual cow or venison pieces (or constituent pieces in the case of an aggregation process) and the entire animal (a live animal or entire carcass) without recording the process of decomposition in detail at every step. While possible, this has economic implications that may prove impractical and unviable in some circumstances. Within the context of chain traceability as defined, the research demonstrates chain traceability at batch level but associations can be drawn and identified on analysis of the EPCIS data for more granular assessment sufficient to make assumptions. As there is a demonstrable and reliable association and relationship between the finished cuts presented in finished cartons and a batch of animals identified at the stun box read point, the researchers consider the result to be acceptable and compliant with the definition of chain traceability as defined and adopted. As previously outlined, once the EPCIS standard for including batch information is developed and ratified (Traub 2012) this will greatly aid the automation and recording of batch information recording.

6.3 Research Limitations and Future Research

The results of this research should provide both existing and potential users with confidence that the EPCglobal suite of RFID standards and the EPCIS standard in particular is efficacious for traceability as defined. Notwithstanding, future research should is encouraged to corroborate and validate the findings while continuing to extend and expand the investigation and enquiry.

6.4 Longitudinal Studies and Sample Size

The researchers recognise that replicating research over an extended period of time in a longitudinal study may prove beneficial to overall outcomes. A longitudinal study in this context is one in which each individual animal, tagged with a RFID tag is observed over an extended period of time where the research motivation is driven by increased precision and examination of response changes over time (Cook and Ware 1983) to events. The observation may be a measurement or a state (Cook and Ware 1983). Cook and Ware (1983) distinguish longitudinal studies from follow-up studies in which individuals are followed until the occurrence of an event. Longitudinal studies however are often more difficult and entail greater expense per observation than cross-sectional studies (Cooke and Ware, 1983). In studies of change over time, precision is influenced by sample size, frequency of measurement and duration of measurement. Thus, the relative cost-effectiveness of different designs will depend on relative costs in these three dimensions (Cooke and Ware 1983). Replicating the number of research occurrences using a longitudinal approach may prove interesting within the context of this research but it is doubtful if the results will be significantly different enough to justify additional investment in time and resources as the variables involved in this research (ie: performance of RFID tags, cattle as a cohort species and established IT systems including the EPCIS) are fundamentally stable and predictable.

The researchers also recognise the importance of statistical confidence (margin of error and degree of representative certainly of a population) in the research results and therefore in drawing firm conclusions. Of the factors that determine confidence of results, sample size is highlighted as a potential issue in this research as numerically, a small sample size of animals was observed relative to the total population of cattle in New Zealand where it is generally accepted that the larger the sample size, the more certainty results reflect the population (Schmettow 2012). However, the relationship between sample size and confidence level is not linear (i.e., doubling the sample size does not halve the confidence interval). The mathematics of probability proves the size of the population is irrelevant unless the size of the sample exceeds a few percent of the total population under examination (Schmettow 2012) which is the case in this research. Further, this research is focused on the efficacy of the EPCIS standard as a tool for traceability, a qualitative performance measure which is not contingent on a rigorous assessment of quantitative performance of a large sample. The researchers are confident that the small sample size does not undermine the confidence of the results. Further, the researchers are confident in the genuine randomness of the sample as the cohorts were chosen from a larger mob of cattle that did not express or demonstrate any divergent characteristics than that of the wider, general population of cattle in New Zealand.

The researchers outline a summary of recommendations to assist future research:

- Measuring and reporting on RFID reader and RFID tag performance fell outside the scope of this analysis. However, some brief commentary will prove beneficial for future research and investigation. A critical element of the research design was utilising UHF RFID hardware components (tags, readers) that complied with EPCglobal standards. High performing tags are a necessary infrastructure component and any failure in performance at any of the supply chain read event locations would compromise traceability outcomes. Malfunctioning and/or poor performing tags should be expected. To mitigate the risk of malfunctioning tags or tags with suboptimal performance, it is recommended that tags be tested for both sensitivity and overall operating performance (preferably using an accredited anechoic chamber) before applying to animals. Further, prior to applying tags on animals, packaging or fixtures (eg: walls, for location identification) it is recommended that tags be tested in the intended operational environment (or similar) using both hand held and fixed RFID readers preferably from multiple hardware vendors. This will confirm if performance and compliance with EPC standards is achievable.

- The size of the global UHF RFID vendor community offering EPC compliant livestock ear tags and readers available commercially is increasing but remains small. This research did not require using EPC compliant ear tags from more than one tag vendor however, for future research is recommended that where possible, tag comparison testing and assessment is undertaken. Testing tags from multiple vendors in combination with RFID readers (handheld and fixed) from multiple vendors to establish performance comparison and systems interoperability is also encouraged.

- The research did not utilise the Object Name Service (ONS) component of the EPCglobal Network. Utilisation of the ONS is encouraged in future research to stress test this component of the Network to assess system performance and efficacy.

- Innovation in RFID tag technology has witnessed the emergence of sensor based tags able to monitor movement, temperature, humidity and other environmental sensitivity measurements. While the EPCglobal standards do not currently provide for capturing this data, sensor based tags used in combination with the EPCIS standards and data should prove very beneficial.

- The research focused on the use of the EPCIS standard in an agribusiness environment. There is high confidence as a consequence of this research that the EPCIS infrastructure can be successfully implemented in other industry sectors beyond those identified in this research and exploration is encouraged to accelerate overall UHF RFID adoption.

Appendix

Table - outlines the process design model utilised as identified in Chapter 5.8 - Current Livestock Traceability Initiatives in New Zealand with Deer.

<table>
<tr><th>Read Event Number</th><th>Process Step, EPC Identifier and RFID Hardware Used</th><th>Process Step Image</th></tr>
<tr><td>1</td><td>Tagging of Animals on Farm

EPC Item Identifier (Deer) - sGTIN per individual animal range
Item (Deer) sGTIN Range: urn:epc:id:sgtin:9421900.217.003.1073742106 - 1073742127
EPC Location Identifier (Farm) - urn:epc:id:sgln:942900.009772.xxx
RFID Reader Utilised – Motorola MC3190Z

EPCIS:<table>
<tr><td>Event</td><td>ObjectEvent</td></tr>
<tr><td>Action</td><td>ADD</td></tr>
<tr><td>BizStep</td><td>urn:epcglobal:cbv:bizstep:commissioning</td></tr>
<tr><td>Disposition</td><td>urn:epcglobal:cbv:disp:active</td></tr>
<tr><td>ReadPoint</td><td>urn:epc:id:sgln:942900.009772.DEER_CRUSH</td></tr>
<tr><td>BizLocation</td><td>urn:epc:id:sgln:942900.009772.ON_FARM</td></tr>
</table></td><td></td></tr>
</table>

2

Animals Leave Farm and are Loaded onto Truck via Farm Race

EPC Item Identifier (Deer) - sGTIN per individual animal range in Read Event # 1
EPC Location Identifier (Farm) - urn:epc:id:sgln:942900.009772.xxx
RFID Reader Utilised – Impinj Speedway R420

EPCIS:

Event	ObjectEvent
Action	OBSERVE
BizStep	urn:epcglobal:cbv:bizstep:shipping
Disposition	urn:epcglobal:cbv:disp:in_transit
ReadPoint	urn:epc:id:sgln:942900.009772.LOADING_RAMP
BizLocation	Not applicable

3

Animals Arrive at Processor Holding Pen

EPC Item Identifier (Deer) - sGTIN per individual animal range in Read Event # 1
EPC Location Identifier (Processor) - urn:epc:id:sgln:942900.009774.xxx
RFID Reader Utilised – Impinj Speedway R420

EPCIS:

Event	ObjectEvent
Action	OBSERVE
BizStep	urn:epcglobal:cbv:bizstep:receiving
Disposition	urn:epcglobal:cbv:disp:active
ReadPoint	urn:epc:id:sgln:942900.009774.UNLOADING_RAMP
BizLocation	urn:epc:id:sgln:942900.009774.HOLDING_PEN_2

4

Animals Arrive at Processor Stun Box

EPC Item Identifier (Deer) - sGTIN per individual animal range in Read Event # 1
EPC Location Identifier (Processor) - urn:epc:id:sgln:942900.009774.xxx
RFID Reader Utilised – Impinj Speedway R420

EPCIS:

Event	ObjectEvent
Action	DELETE
BizStep	urn:epcglobal:cbv:bizstep:transforming
Disposition	urn:epcglobal:cbv:disp:in_progress
ReadPoint	urn:epc:id:sgln:942900.009774.STUN_BOX
BizLocation	urn:epc:id:sgln:942900.009774.BONING_ROOM
Batch	EPCIS Pilot

5

Cartons of Finished Venison Cuts Moved into Chiller Room

EPC Item Identifier (Cartons) - sGTIN per carton label range urn:epc:id:sgtin:94130000.01420.1 - 99
EPC Location Identifier (Processor) - urn:epc:id:sgln:942900.009774.xxx
RFID Reader Utilised - Impinj Speedway R420

EPCIS:

Event	ObjectEvent
Action	ADD
BizStep	urn:epcglobal:cbv:bizstep:commissioning
Disposition	urn:epcglobal:cbv:active
ReadPoint	urn:epc:id:sgln:942900.009774.BONING_ROOM_EXIT
BizLocation	urn:epc:id:sgln:942900.009774.CHILLER_ROOM
Batch	EPCIS Pilot

:

6

Cartons of Venison Cuts Loaded Into Export Shipping Container at Processor

EPC Item Identifier (Cartons) - sGTIN per carton label range urn:epc:id:sgtin:94130000.01420.1 - 99
EPC Item Identifier (Shipping Container) - urn:epc:id:grai:942900000.135.24680
EPC Location Identifier (Processor) - urn:epc:id:sgln:942900.009774.xxx
RFID Reader Utilised - Motorola MC3190Z

EPCIS:

Event	AggregationEvent
Action	ADD
BizStep	urn:epcglobal:cbv:bizstep:staging outbound
Disposition	urn:epcglobal:container_closed
ReadPoint	urn:epc:id:sgln:942900.009774.CHILLER_ROOM_EXIT
BizLocation	urn:epc:id:sgln:942900.009774.CONTAINER_ON_SITE

7

Shipping Container Leaving View Processor

EPC Item Identifier (Shipping Container) - urn:epc:id:grai:942900000.135.24680
EPC Location Identifier (Processor) - urn:epc:id:sgln:942900.009774.xxx
RFID Reader Utilised – Motorola MC3190Z

EPCIS:

Event	ObjectEvent
Action	OBSERVE
BizStep	urn:epcglobal:cbv:bizstep:shipping
Disposition	urn:epcglobal:in_transit
ReadPoint	urn:epc:id:sgln:942900.009774.EXIT_GATE
BizLocation	Not Applicable

8

Container Arriving at the Port Lyttleton, Christchurch, New Zealand

EPC Item Identifier (Shipping Container) - urn:epc:id:grai:942900000.135.24680
EPC Location Identifier (Lyttleton Port) - urn:epc:id:sgln:942900.009778.xxx
RFID Reader Utilised – Motorola MC3190Z

EPCIS:

Event	ObjectEvent
Action	OBSERVE
BizStep	urn:epcglobal:cbv:bizstep:shipping
Disposition	urn:epcglobal:in_transit
ReadPoint	urn:epc:id:sgln:942900.009778.ENTRY_GATE
BizLocation	Not Applicable

9

Cartons of Venison Cuts Receipted on arrival at Hamburg Warehouse

EPC Item Identifier (Cartons) - sGTIN per carton label range urn:epc:id:sgtin:94130000.01420.1 - 99
EPC Location Identifier (Hamburg Warehouse) - urn:epc:id:sgln:4006468.00000.xxx:
RFID Reader Utilised - Tracient Padl Reader

EPCIS:

Event	AggregationEvent
Action	DELETE
BizStep	urn:epcglobal:cbv:bizstep:receiving
Disposition	urn:epcglobal:sellable_not_accessable
ReadPoint	urn:epc:id:sgln:4006468.00000.DOCK_DOOR
BizLocation	urn:epc:id:sgln:4006468.00000.CHILLER

10

Cartons of Venison Cuts loaded onto truck at Hamburg Warehouse for Delivery

EPC Item Identifier (Cartons) – sGTIN per carton label range urn:epc:id:sgtin:94130000.01420.1 - 99
EPC Location Identifier (Hamburg Warehouse) - urn:epc:id:sgln: 4006468.00000.xxx
RFID Reader Utilised - Tracient Padl Reader

EPCIS:		
	Event	ObjectEvent
	Action	OBSERVE
	BizStep	urn:epcglobal:cbv:bizstep:shipping
	Disposition	urn:epcglobal:in_transit
	ReadPoint	urn:epc:id:sgln:4006468.00000.DOCK_DOOR
	BizLocation	Not applicable

11

Cartons of Venison Cuts arrive at Retailer # 1 in Hamburg

EPC Item Identifier (Cartons) - sGTIN carton label range urn:epc:id:sgtin:94130000.01420.1 - 99
EPC Location Identifier (Retailer #1) - urn:epc:id:sgln:4023339.00000.xxx
RFID Reader Utilised – Tracient Padl Reader

EPCIS:		
	Event	ObjectEvent
	Action	DELETE
	BizStep	urn:epcglobal:cbv:bizstep:receiving
	Disposition	urn:epcglobal:sellable_accessible
	ReadPoint	urn:epc:id:sgln:4023339.00000.IN_STORE
	BizLocation	urn:epc:id:sgln:4023339.00000.RECEIVING_BAY

Table - The Eleven Step Process Design Model

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