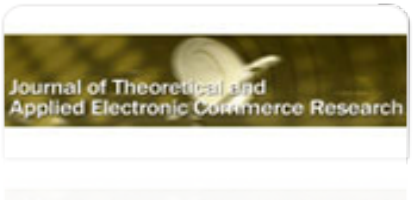

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The National Livestock Identification System: The Importance of Traceability in E-Business

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Abstract

This paper aims to explore how Radio Frequency Identification (RFID) can be utilized on dairy farms to enhance total farm management. There is a growing worldwide trend for countries to implement whole-of-life traceability systems for livestock, and RFID is clearly the dominant technology being chosen to achieve this aim. In line with this global trend, and to meet the requirements of key trading partners (such as the EU), Australia has implemented the National Livestock Identification System (NLIS) to provide whole-of-life traceability for livestock– a system based on the use of RFID devices. As such, it is proposed that dairy farmers utilise RFID so as to not only comply with NLIS requirements, but to extend the use of RFID onto their farms so as to provide additional benefits for themselves through subsequent enhancements in farm management practices.

Key words: Radio Frequency Identification, Livestock, Traceability, Total Farm Management

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VOL 2 / ISSUE 1 / APRIL 2007 / 49 - 62

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1 Introduction

Radio Frequency Identification (RFID) is becoming globally recognized as the technology to implement animal identification, and has become a mandatory form of livestock management in many countries (such as Canada and Australia), while other countries have begun trials of the technology (such as the United States of America). In the current global livestock environment, awareness, fear and recognition of animal borne diseases such as 'mad cow disease' have driven calls for reliable and effective systems for individual identification and tracking of livestock throughout the animals' entire lifecycle. Such systems empower authorities with rapid and precise information (such as the animals' farm of origin, cows it has been in contact with etc.), aiding them to take prompt and direct action to reduce the possibility of a disease outbreak. Considering this global trend towards the use of RFID for individual whole-of-life animal tracking, it appears that farmers will soon be utilising this technology, whether by choice or to meet a mandatory/obligatory requirement. RFID is increasingly being touted as a technology solution that will help users achieve business process optimization through automatic identification and location services, and the field of agribusiness is no different to any other industry. As such, it is important that research be undertaken to identify how the electronic identification technology of RFID may be utilized to enhance total farm management, derive additional benefits and maximise return on investment for the farmer.

2 Background

2.1 What is RFID?

RFID is defined as "… a system that transmits the identity (in the form of a unique serial number) of an object or person wirelessly, using radio waves" [34]. This technology is commonly implemented using a system of reusable and programmable RFID tags (also known as transponders) and readers (also known as interrogators). These tags can be attached/built-in to virtually any good/object and provide a storage capacity of up to 2 kilobytes of data [34]. This allows more than just a unique identifier to be stored on the tag, but may also allow additional information pertinent to the object to be stored (such as expiration date, manufacture date, owner information etc.). The receiver can be a mounted or hand-held computer-controlled device, and when a tag is brought within the reading range of a receiver, the receiver captures the data stored on the tag and forwards this to the host computer [6], [34], [42].

2.2 Characteristics of RFID – Active vs Passive Tags

There are two main forms of RFID tags – active and passive. The primary difference between the two is that active tags have their own power source (typically a battery), and also incorporate a transmitter to enable communication, whereas passive tags do not. This power source provides active tags with a greater and more reliable read range, as well as greater data storage and transfer capacity than their passive counterparts. Active tags however, are significantly larger than passive tags (currently, the smallest active tag is approximately the size of a coin) and also come at a much higher cost. Active tags usually operate at frequencies of 455 MHz, 2.45 GHz, or 5.8 GHz, and have a typical read range of about 20 to 100 meters [36].

Instead of utilising their own power source and transmitter, passive tags generate enough power from the RFID reader's signal to transmit their information. They do this by manipulating the energy (radio waves) sent from the reader, simply reflecting the energy back to the reader in a manner that the reader can interpret into data. Not incorporating a power source or transmitter enables passive tags to be much smaller (in 2004, the smallest commercially available device was 0.4mm x 0.4mm and thinner than a sheet of paper) and also dramatically cheaper. Sacrificing the power source however, means that these tags have a shorter read range, and cannot store as much information [22], [6], [35]. Passive tags operate at a range of frequencies, primarily low frequency, high frequency, and ultra-high frequency. Low frequency tags operate at 124kHz, 125kHz, or 135kHz, and have a read range up to 0.33 meters. High frequency tags operate at 13.56MHz and have a read range of up to one meter. Ultra-high frequencies operate anywhere from 860MHz and 960MHz, providing a read range of up to 3.3 meters [35].

2.3 Advantages of RFID

RFID provides many advantages over other electronic identification technologies such as barcodes. These advantages include the ability to store more information, strong machine readability, fast read speed, and having no operating costs once implemented. Further, as their usage relies upon radio waves rather than line-of-sight technology, RFID tags do not need to be visually seen to be read – they simply must enter the scanning field of the reader. This therefore dramatically increases ease of use, as well as providing greater reliability in light of general wear and tear, and environmental elements such as dirt and dampness [16]. Such elements may render other line-of-sight identification technologies such as barcodes unreadable. Consequently, RFID systems have a wide range of applications in a number of industries.

Journal of Theoretical and Applied Electronic Commerce Research
ISSN 0718–1876 Electronic Version
VOL 2 / ISSUE 1 / APRIL 2007 / 49 - 62

This paper is Available online at
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2.4 Animal Identification and RFID

Animal identification is one of the most common applications of RFID technology, and one that has been pioneering the technology for almost 20 years [2], [16]. Focusing on the livestock industry, there are four main ways in which RFID can be used for animal identification – attaching a transponder to the collar, attaching a transponder in a tag form to the animals ear (similar placement to current ear tagging however utilized vastly differently), injecting tiny glass transponders under the animal's skin, or via a 'bolus' where the RFID transponder is mounted within an acid resistant, cylindrical housing which is inserted permanently within the animals stomach [16].

2.5 RFID for Traceability and Farm Management

There is currently a worldwide trend towards improving traceability systems within livestock industries, and RFID is the primary technology of choice. Spurred by disease incidents from around the world, such as the Bovine Spongiform Encephalopathy (BSE, more commonly known as 'mad cow disease') outbreaks in the late 1990's, countries such as those within the European Union (EU) have enacted policies to ensure livestock can be traced through their entire lifecycle [7]. Programs such as these are designed to minimise or eliminate the spread of disease as authorities are able to trace origins of diseases, identifying farms and animals that may have been affected and subsequently they are able to take direct appropriate action to minimise further spread [17]. Other countries such as Canada have enacted electronic identification legislation requiring all livestock to be tagged with approved RFID devices by September 1, 2006 [11], while America is currently operating voluntary trial operations utilising RFID tags as they consider a full individual animal identification proposal [7], [21].

2.6 The Importance of Traceability in E-Business

Traceability in the food chain has always been a major issue, however it would appear never more so than in the current global environment. As identified, governments of countries such as Australia, Canada and those in the EU are introducing laws requiring whole-of-life traceability for animals, while food traceability standards are also being upgraded. Quality assurance in food traceability means that a technology such as RFID can be used for the end-to-end tagging, tracking, and tracing of food. The food chain is analogous to any supply chain with the distinct difference that food safety is a global issue. In many countries like Australia, product integrity in red meat and dairy products is non negotiable. The introduction of the NLIS places Australia at the forefront of livestock traceability in the world, while also satisfying the demands of key trading partners and desires of consumers. E-business, even in agribusiness, is fast becoming the way for nations to trade with one another. Governments demand that farmers provide proof of their day-to-day practices, and consumers likewise demand more information about the source of their food. RFID systems can provide that level of granularity.

2.7 Focus Benefit of RFID

An important benefit of the NLIS is that of offering producers improved herd management options. As the global push towards mandatory RFID identification and whole-of-life traceability systems continues, it is proposed that farmers should take advantage of this situation, and extend the usage of this technology to enhance farm management practices. This research will investigate this concept.

3 Methodology

3.1 Objective

The objective of this paper is to conduct a literature survey on electronic identification for animals, with a view to identifying key methods of application (including the positives and negatives), subsequent management practices enabled, and possible future uses of such technology. The main strategy that will be used to conduct this study is a qualitative literature survey.

This research project investigates and documents dairy farm management practices with varying degrees of electronic animal identification integration, subsequently highlighting achievable benefits derived from such practices. The research also provides a value proposition for traceability that may serve as a long term goal for the dairy industry to maximize benefits from further integration of individual electronic animal identification with farm management practices.

3.2 Relevant Literature for the Survey

Online and hardcopy resources were used to explore the theme of "RFID", "benefits" and "farm management". It was found that specific reference to traceability systems using RFID was scant, despite an abundance of RFID books on various application areas. The researcher began with searching informatics online databases like the

Journal of Theoretical and Applied Electronic Commerce Research
ISSN 0718–1876 Electronic Version
VOL 2 / ISSUE 1 / APRIL 2007 / 49 - 62

This paper is Available online at
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Communications of the ACM, and *IEEEXplore* but with little success. While "RFID" and "supply chains" feature widely in the literature, the idea of tagging livestock has only recently become significant with changes to government regulation. The search for literature quickly widened to include more academic style online databases like *Springerlink*, however results indicated a need to continue searching online using mainstream search engines. The acronym "NLIS" was used to recover industry-specific and popular trade documents pertaining to Australia, as a means to guarantee material that was relevant. Descriptive research provides a detailed, highly accurate picture of specific details of a situation, social setting or relationship. The suitability of this approach is further evident when considering that this research attempts to address 'what' and 'how' questions.

3.3 Scope

This research project is focused on dairy farms located in the geographical area of the South Coast of New South Wales, Australia. However, as dairy farm practices are expected to be similar throughout the whole of Australia (and possibly the world), it is expected that this research will be relevant to the whole dairy farming industry of Australia, despite it's original limited geographical area of study. Similarly, it is expected that this research may be adaptable and useful to other countries in which electronic animal identification is being explored or is mandatory.

Further, this research is specifically focused upon the dairy industry. Other farming industries such as beef, sheep, pigs and the like may find some relevance and derive some usefulness from this research, however they are not the primary focus group.

3.4 Justification

RFID is becoming globally utilized for implementing individual whole-of-life identification and tracking systems for livestock. Such technology and systems are now mandatory in many countries such as Canada and Australia, while countries such as the United States of America are currently trialing the concept. Whether by choice or to comply with a regulatory requirement, it appears evident that farmers will soon be investing in, and utilizing the technology of RFID for the purpose of individual livestock identification. Considering this, it is important that research be undertaken to identify ways in which farmers can derive additional advantages from their utilizing this technology. This research has been undertaken to address this need.

4 Literature Survey

An abundance of literature is available regarding the technology of electronic identification, with its application for animal identification included as a topic in much of this literature. Entire websites such as RFID Journal [36], AIM Global (the Association for Automatic Identification and Mobility) [3], RFID News [37], RFID Times [38], and many more sites are dedicated to electronic identification, providing an abundance of information, international news stories and developments regarding both the technology and the industry, including its applications for animal tracking. Authors such as Finkenzeller [16] and [20] devote entire books to the subject of electronic identification and RFID, while Finkenzeller [16] also briefly demonstrates its usage for the purposes of animal identification and tracking.

The major authors in this field are Geers et al. [19], who devote an entire book to electronic identification, monitoring and tracking of animals. Providing information on current animal tracking technology, how they work, current applications, and possible future direction, Geers et al. demonstrate the growing awareness and importance of electronic identification for farm management. Considering improved disease and fraud controls, combined with the desirable and dominant cost-benefit ratio that can be derived from the utilisation of electronic identification for farm management, Geers et al. provide a clear message that electronic identification is the likely path of animal identification in the future.

Michael's thesis [29] further supports this view, providing an in-depth review of a wide variety of electronic identification technologies (including smart cards, barcode and biometrics). A section of chapter seven, regarding animal identification using RFID demonstrates that traditional forms of animal identification are considered inferior in comparison to RFID technology, while the application of RFID identification to improve farm management practices is also touched upon. Karnjanatwe [28] provides an insight into an actual application of RFID technologies used to enable enhanced farm management of pigs, such as automating the feeding process and regulating how much each pig eats. Ishmael [24] tells of the economic benefits achieved by a group of farmers resulting from utilising RFID technology to provide individual identification and subsequently enhanced farm management operations on their beef farm in America. James [27] states how electronic identification can be used to reduce the labour required for the milking process, providing large cost savings, while Davies [13] demonstrates the ability to improve the quality of milk yields through controlled feeding processes based on electronic identification. This literature demonstrates the rising recognition of electronic identification for animal identification and farm management practices, while also demonstrating that it does have practical applications for farm management and the ability to provide economic benefits for farmers.

Journal of Theoretical and Applied Electronic Commerce Research
ISSN 0718–1876 Electronic Version
VOL 2 / ISSUE 1 / APRIL 2007 / 49 - 62

This paper is Available online at
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5 Benefits of using RFID for farm management

5.1 Financial and Managerial Benefits for the Farmer

The first reason is for increased profitability for the farmer, and assistance with managerial procedures on the farm. Geers et al. [19] note that despite electronic identification of farm animals being more expensive than traditional forms of identification, it allows for a faster payback on investment through exploiting a wider range of possible applications. Identification can be used to facilitate control activities on farms, including "... follow-up of premiums, milk-record control, tracing back of transit and disease prevention, progeny testing and herdbook administration, electronic feeding stations, automatic gating in group housing facilities, accountability to markets and slaughterhouses, animal health control, public health control, animal welfare surveillance, prevention of fraud, tracing back of stolen stock, facilitating trade, central database facilities" [19].

Geers et al. [19] continue, stating that in the modern farm environment, farming needs to manage more animals to be cost-effective. Consumers also have an impact on what farm management should be, and subsequently, management processes become increasingly difficult for the farmer. Electronic identification can strongly aid a farmer in their managerial efforts, while also deriving financial benefits from exploiting an increased range of possible applications.

5.2 Worldwide Trend for Traceability

A second primary driver for the move to RFID for farm management is to conform to the current worldwide push to introduce individual whole of life tracking programs for livestock.

In the wake of recent disease outbreaks amongst livestock (such as 'mad cow disease' and foot-and-mouth disease), countries around the world are implementing policies and procedures to ensure individual whole-of-life traceability for all livestock. RFID is the technology of choice for these solutions. Countries such as those within the European Union have enacted policies to ensure livestock can be traced through its entire lifecycle [7], Canada has enacted legislation requiring all livestock within Canada to be tagged with an approved RFID device by September 1, 2006 [11] and America is currently operating voluntary trial operations utilising RFID tags while considering a full animal identification proposal [7], [21]. Rizoli [39] notes that trials of RFID technology for identification and tracking of livestock have been taking place in America since 1998, when the National Farm Animal Identification and Records (National FAIR) pilot project was launched.

5.3 Purpose of the Programs

These whole-of-life traceability programs are designed to record and present accurate and up-to-date information regarding all cattle movements. Such systems enable authorities to rapidly trace the origins of any cattle diagnosed with a serious contagious disease (should one ever occur), identifying farms and animals that may have been affected, or even been the source. Subsequently, they are able to take direct appropriate action to minimise further spread [17]. Rizoli [39] further notes that such traceability systems are required so as to reduce the possible impacts of a terrorist attack upon the livestock industry. Rizoli quotes National FAIR Director Robert Fourdraine as stating in regards to terrorism that "One outbreak of disease (among livestock) can be isolated and contained… But if someone were to introduce foot-and-mouth disease in several different places at once it would shut down the food supply". This viewpoint is also recognized by Nagl et al. [31], and raises an interesting point and benefit of the current systems being implemented.

5.3.1 Infeasibility of Traditional Identification Methods

Geers et al. [19] notes that traditional identification methods certainly could not provide the reliability and accuracy being sought by current requirements. Traditional ear tags are reported to be lost 5 to 60% [1] of the time, while brands or tattoos on cattle can be damaged or fade away. A further key drawback of such traditional systems is that they require visual detection and must be recorded manually, which can easily introduce human errors, while the labour cost of such a practice is also high. Reading errors are estimated to occur in six of every 100 animals processed via traditional mechanisms, while electronic devices are estimated to produce only one error for every 1000 animals [8]. From such estimations, it is blatantly obvious that electronic identification provides dramatic advantages and enhancements that traditional farming identification technologies can not provide.

The need to control disease outbreaks is obvious, and it is no surprise to see many of the authors describing the systems being put into place as being from Government departments. This aids to demonstrate the recognition within Government of the requirements and issues currently involved in RFID for livestock. Authors Rizoli [39] and Nagl [31] make an interesting point regarding terrorism, which is not something immediately obvious within livestock, however, upon consideration it appears entirely possible that such an attack could take place. Subsequently, their points regarding the requirement for RFID traceability programs so as to reduce the threat or impact of a terrorist attack appear quite valid.

Journal of Theoretical and Applied Electronic Commerce Research
ISSN 0718–1876 Electronic Version
VOL 2 / ISSUE 1 / APRIL 2007 / 49 - 62

This paper is Available online at
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5.3.2 Cost of Implementing Nationwide

Forster [18] provides an estimate of how much it would cost to implement a whole-of-life electronic identification system in America. The cost of implementing such a system is estimated to range from $US2 to $US10 per head of cattle. Considering the 96 million head of cattle in America turning over a rate of approximately 35 million a year, top of the range chips are expected to cost about $US350 million per annum. Administering and maintaining the national database of information on each animal will provide a further cost, and understandably, debate over who will pay for such a system is quite intense. Considering such costs, it is likely that similar debates will be ongoing in many countries in the near future.

The figures quoted in this article are from 2003, and considering the trend of RFID costs to decrease over time, it can be considered that the costs for the present time will be less than the values specified in this article. The amount of cattle may also have changed, rendering the already wild estimate further unreliable. However the figures do provide a good example of the large costs involved in implementing such an RFID system.

6 Australia's Traceability System

The Australian dairy industry is valued at approximately $8 billion [13]. In 2004, this industry was composed of 9,611 registered dairy farms, hosting an estimated 2,028,000 dairy cows. Internationally, Australia ranks third in terms of world dairy trade [13]. Thus, it can be seen that the Australian dairy industry is certainly large and valuable.

6.1 The National Livestock Identification Scheme (NLIS)

In order to maintain trading relations with major customers and competitors (primarily the EU), Australia has developed its own individual whole-of-life traceability program for livestock – the National Livestock Identification Scheme (NLIS). This system is a "… permanent whole-of-life identification system that enables individual animals to be tracked from property of birth to slaughter for food safety, product integrity and market access purposes" [29]. Utilizing RFID tags, this system is designed to record and communicate all movement of cattle from a property (whether it be from farm to farm or throughout the livestock chain) to the central NLIS national database. This system will not only ensure compliance with the EU trading standards (and likely any other countries who may develop similar standards for whole-of-life traceability in the future) [29], but the NSW Department of Primary Industries – Agriculture [32] states that,

> "Permanent identification will benefit the livestock industries by:
> - improving livestock traceability to reduce the impact of livestock disease and residue incidents;
> - making access to overseas markets more secure;
> - maintaining consumer confidence in Australian beef and dairy products;
> - offering producers improved herd management options; and
> - providing better proof of ownership to reduce stock theft."

6.2 Devices Utilized in the NLIS

There are currently only two types of devices approved for use in the NLIS – a rumens bolus or ear tag utilising a low frequency RFID transponder. Both of these devices may be read while attached to the animal. No microchips (RFID devices placed under the animal's skin) have been approved for use in the NLIS as yet.

6.3 State Control but National Scheme

This system is coordinated at a state level, and has been compulsory in the state of Victoria since 2002 [7]. New South Wales then enacted legislation to ensure state compliance with this system by the 1st of July 2005 [32], the same date that Queensland initiated the first of three phase-in stages [33]. All states within Australia have agreed that the NLIS will become compulsory, and are all at various stages of implementing this system [41].

6.4 New South Wales NLIS regulations

The following information pertaining to the NSW NLIS database (including approved NLIS devices and costs section) is drawn from the NSW Department of Primary Industries – Agriculture [32] information website for the NLIS. Under the current NSW arrangements,

> - For the "phase in" year to 30 June 2005, cattle born from 1 July 2004 will have to be identified before they leave their property of birth.
> - From 1 July 2005, all cattle, irrespective of age, will have to be identified before they leave any property.
> - From 1 July 2005, saleyards will be required to notify the NLIS database of all cattle being sold. Abattoirs will be required to notify the database of all cattle slaughtered.
> - From 1 January 2006, all movements of cattle between properties must be notified to the NLIS database."

Journal of Theoretical and Applied Electronic Commerce Research
ISSN 0718–1876 Electronic Version
VOL 2 / ISSUE 1 / APRIL 2007 / 49 - 62

This paper is Available online at
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Once fully implemented, all cattle that leave a property for any reason must be identified with an RFID tag and notification of the movement must be provided to the NLIS. Cattle that stay on their property of birth (as may happen for dairy cows) are not required to be identified, however the department states that the identification process may still be used if farmers wish to use the NLIS system for management purposes or to help with the recovery of cattle should they ever be stolen.

6.5 Moving Cattle and Who's Responsible

When cattle leave the farm, even if on the way to an abattoir, they must be tagged and registered. From the 1st of July 2005, if cattle move to a saleyard or abattoir, it is up to the saleyard, agent, or abattoir to notify the NLIS of the movement of the cattle. From 1st of January 2006, if cattle move directly between properties for any purpose, it is the responsibility for the owner or person in charge of the cattle at the receiving property to notify the NLIS database of the movement.

6.5.1 Approved NLIS Devices

To be approved for use in the NLIS, RFID devices must move through a process of examination and authorisation by a standards committee. This committee is charged with ensuring that proposed devices are of the correct electronic type, and meet national standards for quality and data retention. Approved NLIS devices are clearly identifiable as they feature the NLIS logo printed on them. It is an offence to use an unapproved RFID device, and also illegal to remove a functioning NLIS tag from an animal.

RFID identification devices (tags or boluses) are mandatory under the NSW NLIS scheme, however other available RFID components, such as readers, are not. Use of these additional components is left to the farmer's discretion.

6.5.2 Pricing and How to Purchase the Devices

Currently, all devices are available for purchase from Rural Lands Protection Board (RLPB) or from the farmer's rural merchant. The cost of an NLIS approved ear tag is approximately $3.50 per tag, while rumen boluses are slightly more expensive. There are no price estimates available for microchips as none have been approved to date.
The above information is provided by the NSW Department of Primary Industries – Agriculture [32]. As such, it is the most credible source of information for the NSW NLIS, and provides a comprehensive wrap-up of the key issues and questions in implementing this system.

6.6 International Recognition of the NLIS

RFID vendor Aleis International speak highly of Australia's NLIS, stating that "[t]he eyes of the world are firmly fixed on Australia as it continues to pioneer cutting-edge traceback and integrity management systems… It [the NLIS] is the largest and most sophisticated livestock database and management system currently in the world" [4]. Carrying such glowing statements through international markets will surely aid to promote Australia's ability for RFID adoption and disease-free animals throughout the world.

This glowing recommendation can be considered highly credible, as it would be expected that international RFID vendor Aleis International would be well aware of the various identification schemes adopted by various countries around the world. Being an Australian based company may pose a question of bias in their views however. This view is further supported by Australian RFID supplier Electro-Com [15] and also the Australia Lot Feeders' Association [9], who state that the "NLIS has now set the standard for all beef exporting countries and further strengthened the reputation of Australian beef in terms of food safety and reliability" [9]. Given the Australian background of these entities, their statements may not be free of bias, however they provide a consistent view, aiding to provide validity for the comments.

6.7 RFID Standards

There are two main standards that are relevant to electronic animal identification. These have been defined by the International Organisation for Standardization (ISO):

- ISO 11784 – This international standard represents the structure of the radio frequency identification code for animals. This standard allows the bits communicated by the transponder to be interpretable by the transceiver [19], [26].
- ISO 11785 – "This international standard describes the accepted protocol for transmission between the reader/scanner/interrogator and the transponder (tag)" [10]. A central aim in the development of this standard is to facilitate communication with transponders from a wide range of manufacturers with a common receiver [16].

As these are defined by the ISO, they are voluntary standards, and as such, there is no guarantee that vendors will elect to take up these standards if they feel that their own standard will achieve greater benefits for them. However, as consumer desires for compliance increase, and co-operation between vendors continues to grow it can be seen

Journal of Theoretical and Applied Electronic Commerce Research
ISSN 0718–1876 Electronic Version
VOL 2 / ISSUE 1 / APRIL 2007 / 49 - 62

This paper is Available online at
www.jtaer.com

that these standards are likely to play a dominant role in the future of RFID technologies. Currently, a large number of vendors now design their readers and transponders to conform to these standards, aiding to remove incompatibilities between manufacturers. Such companies include the popular Texas Instruments [40], and Allflex Australia [5] (who consider themselves the number one company in livestock identification). With such strong backing these standards look certain to have an impact and remain involved in the development of RFID devices for animal identification. They are also well documented, with three credible sources such as Geers et al. [19], Finkenzeller [16] and BeefStocker USA [10] all featuring the standards. As the popularity of these standards grow, those vendors that elect not to comply risk being outcast from the market, as consumers will desire the device (tags and readers) that offer the most compliance with other devices [24].

6.8 RFID Temperature Sensing (Bio-Thermo RFID)

"Temperature is the most important parameter to monitor in livestock" [23]. Higgins [23] interviews Digital Angel's CEO Randolph Geisler, so as to gain an understanding of Digital Angel's relatively new bio-thermo RFID microchip. These microchips are injected into the animal (under the skin), and provide temperature readings when interrogated by an RFID receiver/scanner. The article considers temperature fluctuations to be a great indicator of health problems in livestock.

Hostetter [24] also interviews Geisler, and subsequently provides a similar view of the technology. The article notes that if any unusual temperature readings arise, then a farmer can be notified and take appropriate actions, such as removing this animal from the rest and checking it for illness. Hostetter notes that Digital Angel is looking to advance this technology in the future, so as to possibly provide information on an animal's hormonal changes, blood pressure and even possibly disease identification. Conceding that most serious diseases may not be identifiable without extensive testing such as brain tissue, Hostetter notes that Geisler hypothesises that if someone can find a way to identify such diseases from another more measurable attribute of an animal then RFID may be the devices to perform this monitoring.

This bio-thermo technology provides a large range of benefits and possible uses. The ability to detect ill health before it progresses enough for visual signs to be evident is a highly useful device, and may be able to prevent the spread of illness through a group of livestock. These two articles are quite similar in their explanation and examples of the technology, however this is to be expected when they both interview the same person. Hostetter takes the discussion a little further however, and allows Geisler to reveal that they plan to provide further advances in livestock monitoring, which would be a great advance for RFID technology and livestock management on the whole.

7 Current RFID Farm Applications

The following are existing farm management practices that are deriving benefits from the use of electronic identification technologies. These applications provide examples of ways in which electronic identification can be used to exploit new opportunities, as stated by Geers [19].

7.1 Reducing Labor Requirements

James [27] provides an article describing direct benefits found by dairy farmers derived from the use of electronic identification. James states that ear tag recognition can be used to segregate cows as they pass through the milking parlour, reducing labour requirements on dairy units by up to £20, 000 per year. Providing a real life example of a milk producer, the article describes a farmer who fitted his cattle with an electronic ear tag costing £3 each. He utilises these tags to implement automatic segregation of cattle on their way to milking. As they head to milking, they pass through a race that contains gates to different areas, one to the milking parlour and one to another paddock. As the cattle move through the race, their electronic identification devices are read. The gate to the milking parlour will open for those cows specified to be milked on the computer, while the gate leading to the other paddock will be the one to open for the rest. To perform such a task would have previously required the farmer to hire additional labour, however this is no longer required with the use of automatic identification devices, and the farmer may continue to expand his herd.

In another example from James, a farmer utilises automatic identification techniques so as to facilitate expanding his herd size from 280 to 450 cows. Automatic identification devices are estimated to cost the farmer an additional £6,000, however he estimates that it will reduce his labour bill by approximately £20,000 a year, thus providing an excellent cost-benefit ratio.

It can be seen from this article that electronic identification is providing real savings for dairy farmers. In these examples, the savings are being realized primarily due to a reduction of labour costs. This author has obviously targeted the article towards those in the dairy industry, as she uses terminology that is specific to this industry. It would have been beneficial if she explained these concepts and terminology, especially considering it may be read from others outside the industry due to the importance of the information being presented.

Journal of Theoretical and Applied Electronic Commerce Research
ISSN 0718–1876 Electronic Version
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7.2 Controlled Feeding

An article produced by 'Yoke-L' [43] – a dairy cattle feeding system designed for operation inside a feeding parlour - describes the advantages that it offers for improved management of feed for the herd through electronic identification. The Yoke-L system can identify cows and provide individual cattle their specified rations, according to their lactation 'calendar'. Many electronic identification systems can do this, however Yoke-L defines itself as being unique as it can mix forage and high protein additives. The feeding design features feed barriers with moving bail arms that provide access to the food. Mixed feed is spread along the trough or floor behind the feed barrier and supplements are added to this.

The farmer can vary the quality of the feed to each stall, placing high quality feed in some, and lower quality feed in others. This variation enables the high yielding cows to be given higher quality food whilst cheaper food can be given to those cows nearing the end of their lactation cycle, and producing less milk – obviously a more cost effective feeding system, while maximising the potential for milk production.

Yoke-L identifies and distinguishes between cows by electronic identification ear tags placed on each cow. As the cow approaches the feed barrier, the tag is electronically read, and the cow's identity number is compared with a database to derive her milk yielding value. A computer then "… decides whether she is entitled to the quality of feed at that position; if she is the bail arm opens and she can eat; if she is not, the bail arm stays closed and she wanders off to try her luck elsewhere" [43].

Despite demonstrating cost savings through electronic identification, this article is somewhat misleading. The article initially identifies Yoke-L's ability to 'mix and match' ingredients as the key aspect that gives this feeding system its advantage over others. Similar language and writing style to this leads the reader to believe that Yoke-L is actually mixing the feed for each cow and providing it in the trough as per individual requirements or rules depending on the amount of milk the cows are yielding, readable from their RFID tags. However when the reader approaches the bottom of the article it becomes apparent that Yoke-L is not mixing the feed, but rather it is essentially mixing the cattle who are allowed access to the already varied feed. It is up to the cows themselves to find a feed barrier with food behind it that is of correct quality for their current needs, and not the other way around. Coupled with the cows changing lactation cycle (and thus varied milk production output), this may be a tricky concept for them to grasp, as they may be unable to identify a pattern in feeding arrangements. Additionally, information regarding how the feeding barriers are programmed to allow or deny cows entry would have been beneficial for this article. If such a system does work however, the cost benefits of saving high quality food could be significant for the farmer.

7.3 Improved Milk Yields and Reduced Operator Stress Through Controlled Feeding

Davies [14] provides an example of how electronic identification has been used to provide measurable results in improved feed efficiency and increased milk yields. The article describes an electronic identification setup worth £9, 000 that was implemented in 1996 by large dairy RFID vendor Agricultural Technology Ltd. The system utilises individual passive RFID tags on each cow, combined with antennas at each stall within the feeding parlour. When a cow moves into a stall, these antennas interact with the tags to generate the required electromagnetic energy field, and a reader installed within the parlour receives the data. A unique piece of this design is that it utilises only one reader for the parlour, which can read data from up to 1000 antennas. The computer control unit for this system manages parlour feeding and milk yield records. Davies [14] also states that the unit can store animal health information, and can be connected to a standard personal computer, thus enabling two way data exchange.

Under this system, cows enter the feeding parlour, and must enter the feeding stall directly beside the cow in front (which they apparently learn to do very quickly). Once they enter the stall, feed will only be released if the stall in front of them is occupied, and that occupant has been identified by the system and fed. Once this occurs, a predetermined amount of feed is automatically released to the newly identified cow. The farmer notes that the investment into electronic identification wasn't a luxury, but rather a necessity, so as to reduce his stress levels and provide improved feeding accuracy. He states that measurable benefits have been realized, as, "Before the change rolling average yield was 6500 litres a cow, of which 1932 litres came from forage. It is now 7300 litres, including 3000 from forage. Margins over purchased feeds have increased from £1300 a cow to £1438. Milk quality has also improved" [14].

Obviously this demonstrates significant benefits gained from the usage of electronic identification. The farmer also claims he is much happier since the technologies introduction, and the cows are also more relaxed. However, he doesn't attribute all of these benefits to electronic identification, as he states that his farm is trying hard to improve all areas of management, but this system certainly assists as at least they know that the cows are receiving the right amount of feed every time.

It is certainly obvious from this article that significant gains were realized due to automating the feeding procedure through electronic identification. However, Davies [14] leaves a lot of gaps in the article, and many assumptions have to be made to gain a comprehension of it. Davies [14] doesn't provide any information regarding how the system determines what feed to be released, hence it is assumed that the user enters the amount of feed for certain cows

Journal of Theoretical and Applied Electronic Commerce Research
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VOL 2 / ISSUE 1 / APRIL 2007 / 49 - 62

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into the computer controlling the RFID system. The specified amount of food and concentration is then provided to each cow depending on the individual specifications. The article also fails to identify the unit of measurement for the average amount of milk yielded from each cow. It is blatantly obvious that 6500 litres cannot be drawn from a cow in one milking session, leading to the assumption that the rate is measured per annum, however this is not confirmed anywhere in the article. Nor does the article explain the concept of the increased margins over purchased feed, or what has caused the rise in margins (other variables such fluctuating prices could achieve this). Mid-way through the article Davies [14] also states that the system is capable of storing health information on the animals, however he doesn't define what health information this may be, or how it is derived and stored – perhaps manual entry or some automated process of detection and storage. The benefits identified look appealing, however a full comprehension of how these benefits are derived and their true significance cannot be achieved due to the brevity of this article.

7.4 Pig Farm Feed Management

An article by Karnjanatwe [28] explains a pig farm feeding system similar to those discussed above. Utilising electronic tags on individual pigs, automatic feeding stations are placed in the pen. When a pig approaches the feeding station through a one-way gate, an RFID reader will detect it and receive information from the tag. This will check the pigs ID, and gain it's characteristics including it's age and weight. The system will also determine if the pig has already eaten that day. If it is found to have already eaten, the gate to the feeding station will remain closed, however if the pig has not yet eaten, the system will open the door to the feeding station and deliver the desired amount of food based on the pigs age and weight. When the pig has finished its food, an exit gate will open and the pig will exit. This technology is now a few years old however, and Karnjanatwe notes that maintenance costs are rising for the owners. As such, they are looking to update their RFID technologies.

Benefits of this system include increased efficiency as staff will know which pigs are fed and which are not, thereby reducing repeat consumption, while each pig has enough food for its needs. It was designed to subsequently reduce labour costs, while improving accuracy of the food quantity delivered to the pigs and to reduce food spillage that often occurred when food was distributed manually. This article provides a good description of this system, allowing the reader to gain a solid understanding of the systems operation. While the article is not directly related to dairy farms, the concepts of operation can be considered applicable to a dairy farm context.

7.5 Improved Management Options Generating Large Savings

Three brothers who own a beef farm in the United States of America claim to have dramatically increased their profitability as a direct result of utilising RFID to track and manage cattle on an individual basis rather than groups. Ishmael [24] reports that by using electronic identification tags to identify individual cattle, then sifting through the data using a specialized information system (AgInfoLink's 'Beeflink'), they believe they are saving between $US35-$US60 per head of cattle. "We're already using this to our advantage to make money. This isn't a theory; we've done it", states Tigh Cowan (one of the three brothers). They perceive the savings to be mainly related to the information they now have access to and can utilise to manage the farm. For example, they can get rid of poor performing cattle and keep the good ones, tell which paddocks have the most nutrition, evaluate mineral supplements in feed etc. These management capabilities, as well as possessing actual data relating to the cattle's life and development, have enabled the farmers to gain a higher than average price for their cattle at auctions. Treg Kusserz, another farmer utilising RFID states that "The more information you have, the better decisions you can make".

While Ishmael's [24] article relates to the beef industry, it bears strong relation to the management operations of dairy farms also. It can be seen from this article that there is certainly money to be made from the use of electronic identification technology for improving farm management practices. However, this article simply provides the reader with an overview of the benefits these farmers are receiving. The article does not detail precisely what the farmers are looking for in the data, how they gain the data, what ways they use the data etc. This crucial information remains unrecorded.

8 Alternative Approaches

Attempting to move beyond basic identification, Nagl et al. [31] undertakes a project for the design of a remote health monitoring system for cattle. In this system, Nagl et al. attempt to use a range of sensors to constantly monitor cattle state of health, communicating biological information wirelessly to a base station through the use of Bluetooth technology. Nagl et al. identify the fact that at the time of writing, America had no mechanism in place to track animal identity in the fashion that Canada did, nor did they have any means to assess past or present animal health. The system they develop attempts to provide the ability for the livestock industry to react to and predict disease onset and spread, whether from natural or terrorist events.

Through the use of a GPS (Global Positioning System) unit to gather location and movement data, a pulse oximeter to measure blood oxygen saturation and pulse rate, a core body temperature sensor, an electrode belt to monitor pulse rate, a respiration transducer, and an ambient temperature transducer [31], the project developed a wearable unit for cattle. This unit was designed to extract the biological information of the animal and communicate it to a base

Journal of Theoretical and Applied Electronic Commerce Research
ISSN 0718–1876 Electronic Version
VOL 2 / ISSUE 1 / APRIL 2007 / 49 - 62

This paper is Available online at
www.jtaer.com

station via Bluetooth technology (which supports a ten metre read range) where it could then be analysed for any patterns that may indicate illness in the animal.

This project was obviously an investigatory undertaking, with numerous limitations in the unit developed. These included the size of the unit being quite large, and the battery life of various components of the unit. Some interesting results were drawn however, and for most components, solid results were evident. Nagl et al. recognise the issues that arose, and state in their conclusion that there is a lot of research and development to be done on this topic, including the all-important ability to minimise the size of the wearable device and reduce power consumption to prolong battery life. The early prototype proposed by Nagl et al. is currently physically impractical and far too expensive for use, however the results of the project provide interesting prospects for cattle monitoring and tracking in future applications. Perhaps someday it may possibly integrate this project's device with RFID devices should the desire for this in-depth health monitoring arise.

It is immediately striking that the authors related their project to the need for animal identification in America, and noted the Canadian RFID tracking system. However, they did not utilise RFID for individual identification in their project, nor did they attempt to state why their system is preferable or what advantages it provides over the rapidly growing RFID system. They also alluded to the desire to track animal identities in the introduction (a specialist function of RFID technology), however failed to demonstrate how their system would provide this unique identification capability. Inclusion of RFID tags for individual identity tracking (at a minimum) appears quite possible however, and it would have been useful to see this integrated into this project. An alternative approach such as this does hold some intrigue and possibility for the future, however RFID remains the dominant technology of choice for providing individual cattle identification.

9 Discussion Points

9.1 Maximising Productivity

It is believed that the use of RFID will assist farmers to maximise their productivity – an important aim in the modern competitive dairy industry. It is expected that the new farm management practices enabled by RFID will allow farmers to increase the volume and possibly the quality of milk output from their herd. The use of RFID for automation will also aid to minimise labour inputs, thus allowing each farmer to cater for more cows, or enabling farmers to have more time to spend on other activities – either way, maximising results from their input.

9.2 RFID Adoption to Continue

Considering the potential benefits offered by the implementation of RFID on dairy farms, combined with the global push for RFID to be utilized for livestock tracking, it is believed that the development and adoption of RFID technology on dairy farms will continue for quite some time. This adoption rate may even grow as the benefits of such implementations become more widely recognized, and correspondingly the costs of the technology lower with expected economies of scale. This adoption may continue to the point where the use of RFID becomes a mandatory aspect to survive in the future dairy market.

9.3 Increase in Farmer IT Literacy

As a consequence of the RFID adoption within the dairy industry, it is likely that farmers will become more involved with IT (Information Technology) generally. Traditionally, farmers have had little use for computers, however with the introduction of the NLIS, the potential benefits of NLIS etc., it is likely that computers will become a central part of farm management. Subsequently, this is expected to raise the level of IT literacy amongst the industry.

9.4 Third Party Opportunities

The current and predicted continued uptake of RFID technology on dairy farms provides a large opportunity for the involvement of third parties. This may include existing vendors diversifying into this industry, or new enterprises opening and developing products to specifically suit the industry, consultants opening up to provide advice on dairy layouts, how and what devices to implement, third-party distributors and intermediaries etc. Considering that many traditional farmers may not have a great deal of technological experience or are comfortable with radical changes, such third party involvement may be considered more of a requirement than an opportunity. In Australia's case, the state or national government may wish to commit more resources to provide support and information on the technology and its possible uses for the dairy industry, especially considering the mandatory regulation of NLIS.

Additionally, it may be possible for labour agencies to provide temporary milking operators for a brief or extended term to aid in operating a dairy farm. On farms with advanced RFID automation systems in the future, there may be little need for operators to have extensive knowledge of a farm or herd to conduct milking, as the machines will assist them and provide them with each cows information etc. Being able to hire such personnel could provide a temporary

Journal of Theoretical and Applied Electronic Commerce Research
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VOL 2 / ISSUE 1 / APRIL 2007 / 49 - 62

This paper is Available online at
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employee in the case of unexpected absence of a milking operator, or may enable the usual operators to take time away from the farm (holidays, family occasions etc.).

10 Principal Conclusions

There are a number of conclusions that can be drawn from this research. The first is that RFID is currently being utilized on dairy farms in Australia and around the world, and development of RFID hardware and software is continuing. Secondly, size does matter when it comes to benefits derived from the use of RFID on dairy farms. The larger the herd size, the greater the benefits are likely to be. Additionally, the larger the adoption of RFID the sooner economies of scale will be reached for the technology. Thirdly, RFID expands management capability through the information and automation capabilities, and finally it is concluded that legal requirements around the world have become a driving force behind the adoption of RFID on dairy farms.

10.1 Currently Used and Continuing Development

It has been seen that RFID is being utilized currently on dairy farms, both in Australia and around the world. While there is currently a large disparity in the scale of use from farm to farm, the level of interest in this technology and its applications is providing a solid base for future development of this technology within the dairy industry. Both hardware and software continues to be designed and enhanced to specifically cater for the needs of the dairy industry and its adoption of RFID technology.

10.2 Size Matters

The size of a farm's herd will be a large factor in determining the value of the benefits realized through utilizing RFID. On farms with relatively small herds, farmers are likely to have intimate knowledge of the herd through their own interactions with the animals, and additionally, farm labour is unlikely to be in constant demand. Thus, the abilities of RFID to provide information storage, manipulation and easy retrieval, or dairy automation possibilities are unlikely to add significant value, and thus may be perceived as an unnecessary cost. On the other hand, with large herds, whereby farm labour is virtually on constant demand, and an intimate knowledge of each cow in the herd is difficult or impossible to achieve, RFID technology provides the ability for dramatic benefits to be realized. Thus, it is concluded that generally, the benefits provided by RFID are directly proportional to the size of the herd.

Similarly, the rate of RFID uptake will be a determining factor in the cost of the technology in the future, as it is believed that economies of scale will be realized for this technology. i.e. The greater the market and purchases of RFID devices, the lower the cost will be in the future. Additionally, it is expected that the market for RFID devices for dairy farms will expand, subsequently increasing competition between vendors, which will further drive prices down for this technology.

10.3 Expanding Management Capability

The use of RFID certainly provides the ability to enhance farm management practices. This technology provides the farmer with the ability to gain a far greater depth and accuracy of information on their individual cows and overall herd, thus enabling them to make more informed decisions. Furthermore, this wealth of information can be stored, manipulated, and viewed with unprecedented speed, accuracy and ease, undoubtedly providing the potential for massive benefits in the manner in which farm management is conducted.

Furthermore, RFID technology provides the capability to automate certain farm management practices. This includes the likes of automatic feed dispensing units, automatic calf feeding, automatic drafting etc. – all of which can dramatically save labour requirements, provide more reliable and accurate operations, and enables farmers to spend more time managing the vast array of other activities involved in operating a dairy farm. Additionally, these automation practices may aid the development, health and overall milk production of cows, thus providing further benefits for the farmer.

10.4 Legal Requirements a Driving Force of RFID Within Dairy

Until recently, RFID has had only limited application within the dairy industry. However, external forces, such as worldwide regulations attempting to provide whole of life traceability for livestock have been a catalyst for a dramatic growth in the interest, abilities and use of RFID technology within the dairy industry. The use of RFID for livestock identification and tracking is now mandatory in Australia (and likely many other countries in the near future) – subsequently, this is encouraging even those farmers who may be more technologically conservative to investigate and embrace the opportunities presented by this technology.

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10.5 Conclusion

Despite the fact that RFID technology has been in existence for many decades, is only now maturing, and the time for mass adoption of RFID is nearing. Considering the worldwide trend towards whole-of-life identification and monitoring systems for livestock, it appears inevitable that RFID will have one of the biggest impacts on the livestock industries both in Australia and around the world. Considering the likely cost of implementing such a system ($3.50 per tag alone in NSW), it is important that farmers utilise this technology to derive additional benefits and return on their investment through exploiting new opportunities for farm management.

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Identification of livestock has a long history. Hot-iron branding may have been used to identify ownership of animals among the ancient Egyptians. Brought to North America in 1520 by the Spanish, it was carried into the Southwest with Coronado in 1540 and continues to this day as a form of owner and premises identification. Similarly, individual animal identification has long been accomplished by ear notching or other simple marking methods. Current government and industry interest in new methods of individual animal identification arises from a confluence of events.Â If the NAIS becomes mandatory, all these premises would eventually be registered in the system, each with a unique premises number. Livestock Identification in the U.S.