Journal of Food Engineering 106 (2011) 119–126

Contents lists available at ScienceDirect

Journal of Food Engineering

journal homepage: www.elsevier.com/locate/jfoodeng

An RFID application in the food supply chain: A case study of convenience stores in Taiwan

I-Hsuan Hong [a,*,1], Jr-Fong Dang [b], Yi-Hsuan Tsai [b], Chen-Shen Liu [c], Wang-Tsang Lee [c], Ming-Li Wang [c], Pei-Chun Chen [c]

[a] Institute of Industrial Engineering, National Taiwan University, 1 Section 4, Roosevelt Road, Taipei 106, Taiwan
[b] Department of Industrial Engineering and Management, National Chiao Tung University, 1001 Ta Hsueh Road, Hsinchu 300, Taiwan
[c] Industrial Technology Research Institute, 195 Section 4, Chung Hsing Road, Hsingchu 310, Taiwan

ARTICLE INFO

Article history:
Received 5 January 2011
Received in revised form 20 March 2011
Accepted 9 April 2011
Available online 22 April 2011

Keywords:
Radio frequency identification (RFID)
Food traceability system
Supply chain

ABSTRACT

Food hazards can appear at any stage of global food supply chains, making it essential to define critical control points to capture the data about ingredients, manufacture and dates-certain (sell-by, use-by), etc., and provide it in a transparent manner to supply chain participants and consumers. The government of Taiwan has appointed a non-profit research organization to conduct a pilot project to launch a potential national-wide food traceability system to increase the intangible value of purchased food and to enhance food safety. This paper discusses a financially viable business model for a Radio Frequency Identification (RFID) application to a food traceability system. We conduct a case study of RFID implementation in the chain of convenience stores in Taiwan. The Taiwanese experiment may have implications for policy-makers, industry and public health officials elsewhere.

1. Introduction

Concerns about food safety have grown over the past decade (WHO Media Centre, 2007). After the outbreak of bovine spongiform encephalitis (BSE, or mad-cow disease) in the United Kingdom in 1985, the Euro-Retailer Produce Working Group (EUREP), a private party consisting of several European supermarket chains and their major suppliers, developed GLOBALGAP (Good Agricultural Practice; formerly EurepGAP) to set voluntary standards for the certification of agricultural products around the world (GLOBALGAP, 2009). In 1997, several major European retailers responded to food scares such as BSE by banding together to develop new global guidelines for sales of meat, fruit, and vegetables throughout Europe.[2] The scandals in China involving contamination of infant formula and pet foods further heightened concern. As countries issued product recalls (BBC News, 2009), the public learned that current industry practices were inadequate to *track forward* and *trace back* throughout global food distribution channels. Articles in the popular media, such as "Live Chat: Who makes sure our food is safe to eat?"[3], "Council to report on New York's Food Industry, From Seed to Compost"[4] and "UK: Listeria scare forces Waitrose recall"[5] reveal the extent of the problem. Recently, the US Senate passed the Food Safety Modernization Act that intends to improve food safety procedures and controls over the nation's food supply chain.[6]

Participants in a typical food supply chain may include primary producers, manufacturers, transport and storage firms, subcontractors to retail and food service outlets, producers of equipment, packaging, cleaning agents, additives, ingredients, etc. (Frost, 2005). Currently, participants rely on two informational methodologies. One *manages* food supply chains via standards or certifications, e.g., ISO 22000 (the International Organization for Standardization), HACCP (Hazard Analysis and Critical Control Point) and food GMP (Good Manufacturing Practices). The second *records* logistics operations and production processes via a food distribution traceability system that provides transparent trace back and track forward information. To achieve the ambitious goal

* Corresponding author. Tel.: +886 2 3366 9507, fax: +886 2 2362 5856.
E-mail address: ihong@ntu.edu.tw (I-H. Hong).

[1] The corresponding author holds a joint appointment with Department of Mechanical Engineering, National Taiwan University, Taiwan.

[2] The article can be found at http://www.flex-news-food.com/console/PageViewer.aspx?page=14843.

[3] The article can be found at http://www.theglobeandmail.com/news/national/time-to-lead/global-food/safety-and-traceability-in-the-global-food-market/article1806207.

[4] The article can be found at http://www.nytimes.com/2010/11/22/nyregion/22food.html.

[5] The article can be found at http://www.just-food.com/news/listeria-scare-forces-waitrose-recall_id99476.aspx.

[6] The article can be found at http://whitehouse.senate.gov/newsroom/press/release/?id=1942135E-B40A-43B8-8F4D-7BF52E9BAF57.

0260-8774/$ - see front matter
doi:10.1016/j.jfoodeng.2011.04.014

of recording the associated information of interests in a food supply chain, industry has turned to Radio Frequency Identification (RFID), an automatic identification technology that uses wireless sensors to identify items and gather data without human intervention. An RFID system is based on tags and readers (Tajima, 2007): the tag is a microchip and an antenna that stores and transmits identification data, and the reader communicates with the tags, delivering the information in a digital format to a database. In addition, retailers may equip kiosks for consumers' inquiries about the food distribution information.

The government of Taiwan has appointed a non-profit research organization to develop a pilot project to improve food safety. If the pilot is successful, the associated technology, learning and management skills will be transferred to an application service provider (ASP) which will consult with the parties intending to launch a food traceability system. The aims of this paper are to analyze the profitability and benefits incurred in establishing the ASP and to propose a financially viable business model of a food traceability system. Although RFID technology is a powerful records tool for food supply chains, barcodes are most commonly applied due to cheaper pricing. The current status of the pilot project is still at the interview/analysis stage. The aim of the pilot project is to provide industry practitioners and government regulators with a cost-benefit analysis such that associated firms in food supply chains may be willing to implement a food traceability system in the future. We hope to contribute significantly to the ongoing discussion among industry, regulators and consumers.

The remainder of the paper is organized as follows. Section 2 reviews the relevant literature on RFID development and food traceability systems. The participants in a food traceability system and the implementation procedures required to install a traceability system are introduced in Section 3. Section 4 discusses a proposed promotion scheme and pricing strategy. Section 5 presents a case study of RFID application to convenience stores in Taiwan. Section 6 presents our conclusions and suggestions for future research.

2. Literature review

RFID technology developed for several decades, with successful applications for access control systems, airport baggage handling, livestock management systems, and automated toll collection systems, especially in logistics and retail businesses (Ergen et al., 2007; Agarwal, 2001; Hou and Huang, 2006; Kelly and Erickson, 2005). For example, a construction industry application using RIFD in an automated traceability system of pipe spools and buried assets is another successful application of the technology (Domdouzis et al., 2007). Tajima (2007) suggests that adopting RFID in supply chain management may reduce management costs and increase the efficiency of product flows. McMeekin et al. (2006) state that the use of RFID technology enables the food industry to increase the accuracy and speed of gathering source information about foods in traditional retail environments. Wamba et al. (2008) show that using RFID in a retail industry can improve shipping, receiving and put-away processes corresponding to suppliers, distribution centers (DCs) and retailers, respectively. Gandino et al. (2007) propose a traceability system based on RFID technology for a fruit warehouse. Meuwissen et al. (2003) indicate the importance of the traceability system and analyze its potential costs and benefits by applying RFID technology to the British livestock industry. These and other research demonstrate that RFID technology helps retail companies both enhance product availability and improve a chain's end-to-end visibility.

Table 1
Literature on food traceability systems.

Category	Author	Scope of study
System design	Gandino et al. (2007)	Agriculture food chain
	Regattieri et al. (2007)	Expensive cheese
	Bevilacqua et al. (2009)	Vegetable products
	Thakur and Hurburgh (2009)	Bulk grain supply chain
	Ruiz-Garcia et al. (2010)	Agricultural batch products
Industry overview	Prater et al. (2005)	Grocery supply chain
	Jedermann et al. (2007)	Temperature monitoring
	Lin (2009)	An integrated framework
Benefit analysis	Karkkainen (2003)	Perishable grocery supply chain
	Bertolini et al. (2006)	Pasta production
	Martínez-Sala et al. (2009)	Grocery supply chain

Table 1 summarizes the key studies categorized by "system design", "industry overview" and "benefit analysis". The research related to system design demonstrates that a typical traceability model in food supply chains can establish a secured food distribution system (Gandino et al., 2007; Ruiz-Garcia et al., 2010; Thakur and Hurburgh, 2009; Bevilacqua et al., 2009; Regattieri et al., 2007; Martínez-Sala et al., 2009). General situations of food traceability systems have been conducted by Jedermann et al. (2007), Lin, 2009 and Prater et al. (2005). Benefit analysis studies indicate how a traceability system can enhance food safety (Karkkainen, 2003; Bertolini et al., 2006; Martínez-Sala et al., 2009).

Several studies indicate that RFID brings more advantages than the barcode system for food traceability (Jedermann et al., 2009; Tajima, 2007). Regattieri et al. (2007), who analyze the economic advantages of alphanumerical codes, barcodes and RFID in a product traceability system, show that although RFID is relatively more expensive, it is still very promising because it does not require physical contact or particular alignment with RFID readers and the reading phase is very fast and fully automated. The most commonly mentioned advantage of RFID over barcodes is supply chain visibility, which enables fast and automated processes at the supply chain level, such as exception management and information sharing (Tajima, 2007). Li et al. (2006) propose an innovative planning model which utilizes RFID technology to identify the product quality status for a perishable food supply chain. Their model considers the product value for consumers instead of merely reducing the costs. Jones et al. (2005) analyze the benefits of RFID, i.e., greater speed and efficiency in stock operations and better tracking throughout the chain, from the retailer perspective. Kelepouris et al. (2007) study the requirements of a traceability system in which RFID technology provides excellent opportunities for effective and efficient system design and makes the traceability feasible and easily deployable across a supply chain. However, this is typically considered a long-term benefit because realization of visibility requires popularized adoption, trading partner collaboration and technology infrastructure for information sharing. Recently, several solutions for implementing food traceability systems by RFID technology are found in (Abad et al., 2009 and Wang et al., 2010). Lin (2009) develops the approach to construct an integrated framework of the RFID promotion procedure to implement the technology in logistics and supply chain management. As expected, RFID becomes a popular technology, but most applications are restricted to a single process or single division (i.e., a particular product such as vegetable, cheese, etc.). In reality, few large-scale applications have been implemented in food supply chains. Thus, implementation of an RFID-based food traceability system throughout an entire food supply chain is a daunting challenge.

Table 2
The participants in Taiwan's pilot food traceability system with RFID implementation.

<table>
<tr><th>Planning and Development</th><th>Pilot Testing</th><th>Implementation</th></tr>
<tr><td colspan="2">← Government →</td><td></td></tr>
<tr><td colspan="2">← Non-profit Research Organization →</td><td></td></tr>
<tr><td colspan="3">← Members in Food Supply Chains →</td></tr>
<tr><td colspan="3">← RFID Hardware and Software Developers →</td></tr>
<tr><td></td><td colspan="2">← Certification Organizations →</td></tr>
<tr><td></td><td></td><td>← Application Service Provider →</td></tr>
</table>

3. Introduction to the traceability system

3.1. Food traceability system

The implementation of the food traceability system suggested for Taiwan follows three stages: planning and development; pilot testing; and implementation. In the planning and development stage, the government underwrites a non-profit research organization to develop the technology for integration of required software, hardware, etc. In the pilot testing stage, lessons learned are used to customize and refine the traceability system depending on the parties' requirements. After the system is developed maturely, the government transfers the associated intellectual properties (IP) to an ASP which operates the system. In the implementation stage, the ASP provides the members with consulting services, e.g., technical support and data analysis. Table 2 shows the three stages.

The pilot project plans to operate an RFID-based traceability system that offers the services listed in Table 3: information service; technical support; and educational training. The information service includes information sharing to the members. Technical support includes software and hardware installation. Educational training is given in the design, development, and implementation of traceability systems.

3.2. Operations in the food traceability system

The three participant groups (food manufacturers, DCs, and retailers) proceed through the three steps illustrated in Fig. 1 below, where each step indicates a particular control point in the group's operations. At the producing step, the processing food is electronically labeled on an RFID tag to record its production data (e.g., manufacturing date, ingredient contents and weight). Manufacturers pack products into cartons and label them with RFID tags as well. In the packaging step, the identity of products specified by the corresponding carton and pallets holding the cartons are also tagged. All associated information is uploaded to the traceability system and made immediately available.

The second group involves the operations in a DC, including receiving and stocking, picking, and repackaging and shipping. As

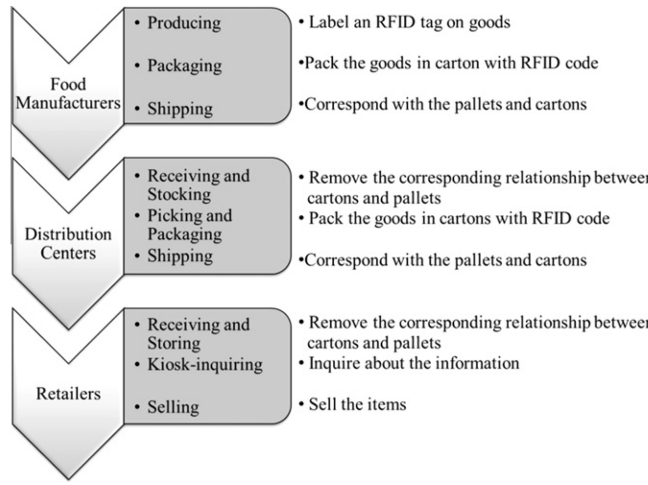


Fig. 1. Operations of a food traceability system.

the goods pass through the RFID reader, the stocking and the merchandise data are recorded. At the same time, the corresponding relationship between the cartons and pallets is removed since the goods are allocated to other cartons at the next step. The operators in the DC place the cartons on tagged pallets and upload the shipping data to the traceability system.

Retailers, the third group, receive and store, handle kiosk inquiries and sell goods via an RFID-POS (point of sale) system which records sales information. When retailers receive goods from DCs, the corresponding relationship between cartons and pallets is removed. Retailers then write their own merchandise data and use the RFID reader to record specific stocking data and sales of goods gathered by their RFID-POS system. Typically, each retailer has an in-store kiosk for use by consumers inquiring about food distribution information.

Table 3
Major services and features of a food traceability system.

Information service
– Provide members with food distribution information
– Analyze food consumer behaviors based on the recorded data, e.g., data analysis
Technical support
– Establish hardware and software for members
– Develop innovative applications
– Design packaging, e.g., tag-embedded bottles
– Lease hardware, e.g., kiosks and readers
Educational training
– Assist in implementation of complete traceability system

4. Financial plan of implementing the RFID

4.1. Implementation of RFID in food supply chains

We apply the innovation diffusion theory (Kotler, 1994) to predict the number of adopters of RFID technology in food supply chains. Innovation diffusion theory is widely used to understand technology adoption in organizations (Ranganathan and Jha, 2005; Lee and Shim, 2007; Sharma et al., 2008). Rogers (1995) indicates that it follows an S-shaped cumulative curve where the number of members adopting a new technology is plotted over time on a frequency basis. The S-shaped curve rises slowly when there are few adopters at initiation and accelerates to a maximum when half have adopted the new technology. The S-shaped cumulative curve then increases at a slower rate as fewer remaining members adopt. In practice, the logistic distribution returns a nice-looking S-shaped cumulative curve with a relatively simple mathematical formula (Stockute et al., 2006).

The cumulative function of the logistic distribution is used as a growth curve (Balakrishnan, 1992). Let $F(x)$ denote the cumulative distribution function (cdf) of the logistic distribution with variable x (see Stockute et al., 2006).

$$F(x) = \frac{1}{1+e^{-x}}, x \in \mathbf{R} \tag{1}$$

The probability density function (pdf) of the standard logistic distribution is given by

$$f(x) = \frac{e^{-x}}{(1+e^{-x})^2}, x \in \mathbf{R}. \quad (2)$$

The variance is

$$Var(x) = \frac{\pi^2}{3}. \quad (3)$$

The plants of each food manufacturer and the DCs install the RFID hardware at initiation, followed by a large number of retailers. Because time is needed to promote RFID technology to the entire food supply chain, we assume that retailers will adopt RFID following an S-shaped cumulative curve in T periods according to the innovation diffusion theory, which has been applied in (Norton and Bass, 1987 and Schmittlein and Mahajan, 1982). Therefore, let M, N, and L denote the total numbers of food manufacturers, DCs, and retailers, respectively. Assume l_t retailers adopt the RFID technology in t period. To estimate l_t, we use the standard logistic distribution with a commonly used three-standard deviation and let $R(t;T)$ denote the proportion of retailers who adopt the RFID technology:

$$R(t;T) = F\left(-1.5\sigma + \frac{t}{T}3\sigma\right), t = 1, \ldots, T. \quad (4)$$

The number of retailers increases in proportion of $R(t;T)$ from periods 1 to $T-1$, and then achieves L in period T. The cumulative number of retailers in period t is

$$l_t = \begin{cases} L \cdot R(t;T), t = 1, \ldots, T-1 \\ L, t \geqslant T. \end{cases} \quad (5)$$

4.2. Pricing strategy and prospective profits

In this section, we analyze the costs and profits of the ASP. Since the procurement cost of the RFID hardware is simply transferred to the members installing the traceability system, the financial analysis in this paper does not consider this cost. One pricing approach is breakeven pricing. Breakeven analysis is used to identify the sales volume at a price that covers costs, where the total revenues equal the total costs of all fixed and variable costs. In (6), the breakeven point is the minimum sales that must be sold before a firm starts to make a profit.

$$\text{Breakeven Point} = \frac{\text{Total Fixed Costs}}{\text{Price} - \text{Unit Variable Cost}} \quad (6)$$

Considering a desired profit in the estimated breakeven point, the breakeven point can be further represented as (7).

$$\text{Sales Volume to Achieve Desired Profit} = \frac{\text{Fixed Costs} + \text{Desired Profit}}{\text{Price} - \text{Unit Variable Cost}} \quad (7)$$

We can set the price in (8) as a result of (7).

$$\text{Price} = \frac{\text{Fixed Costs} + \text{Desired Profit}}{\text{Sales Volume to Achieve Desired Profit}} + \text{Unit Variable Cost} \quad (8)$$

To establish a company would incur start-up costs in the beginning and operation costs which maintain the company existence. As a result, we assume the ASP incurs start-up and regular operations costs for promoting RFID technology. The start-up costs only occur in the initial period, and operations costs are considered in the following periods. The start-up costs include fixed assets costs, such as office supplies and installation of hardware, and the operations costs include rent, payroll, insurance and utilities. Let TC_t denote the total cost in period t, TSC the total start-up costs, and TOC_t the total operations cost in period t. Thus, the total cost in period 1 is the sum of the total start-up costs and the operations cost while the remaining periods (starting from period 2) only include operations costs.

$$TC_t = \begin{cases} TSC + TOC_t, & t = 1 \\ TOC_t, & t > 1. \end{cases} \quad (9)$$

In the pilot, the ASP charges an initial fee, termed $P_{initial}$, which pays for installing the RFID-related hardware to make the breakeven point of the ASP's start-up costs. Thus, $P_{initial}$ is derived from dividing the start-up costs by the total number of installers:

$$P_{initial} = \frac{TSC}{N+M+L}. \quad (10)$$

The ASP may also charge a service fee, denoted by $P_{service}$, after the first installing period. To make a positive profit, we impose a desired proportion of profits, $x\%$, on the operations costs and then divide it by the number of accumulated clients over service periods, 1, 2, …, T. Specifically, the service fee is:

$$P_{service} = \frac{\sum_{t=1}^{T} TOC_t \cdot (1 + x\%)}{\sum_{t=1}^{T}(N+M+l_t)}. \quad (11)$$

The profit is calculated by revenue minus costs and is stated as

$$\text{Profit} = P_{initial} \cdot \text{Newly Adopting Members} + P_{service} \cdot \text{Accumulated Members} - TC.$$

Food manufacturers and DCs adopt the RFID technology in period 1 followed by retailers from l_1 to l_T in T periods. We note that in each period the ASP only charges an initial fee to newly adopting members. Those adopting the RFID in preceding periods are charged a service fee in each period. The profit of the ASP in each period can be stated as:

$$\text{Profit} = \begin{cases} P_{initial} \cdot (N+M+l_t) - TC_t, & t = 1. \\ P_{initial} \cdot (l_t - l_{t-1}) + P_{service} \cdot (N+M+l_{t-1}) - TC_t, & t = 2, \ldots, T. \\ P_{service} \cdot (N+M+L) - TC_t, & t > T. \end{cases} \quad (12)$$

5. Case study

5.1. Description and data collection

Consumers expect to find fresh and risk-free food products in convenience stores. For this reason, we choose chains of Taiwanese convenience stores consisting of a set of suppliers, DCs and retailers with good experience in electronic commerce systems. Taiwan's Department of Commerce, Ministry of Economic Affairs (MOEA), plays the role of government sponsor for the pilot project and the Industrial Technology Research Institute (ITRI) plays the role of a non-profit research organization. Our case study is based upon representative data for food supply chains in convenience stores. Note that the data only apply to our research case study and clearly would differ for other industry sectors, geographic regions, and/or time epochs. The specific case study data are only given for demonstration purposes for our general framework presented in Section 4.

We must first predict the market size and the demand of RFID hardware for our particular chain of stores. Note that there are different types of RFID readers, including fixed readers, hand-held readers, RFID-POS systems and kiosks. Let firms A, B, C and D denote Taiwan's four major chains of convenience stores. The upper part of Table 4 shows the types of information collected from the stores and DCs in our case study, based on estimating the total readers, RFID-POS and kiosks required by the members in the

Table 4
Number of retailers, plants and DCs in each convenience store chain and food manufacturers.

Chains of convenience stores	Number of retailers	Number of DCs
A	4800	9
B	2300	4
C	1250	5
D	850	2
Total	9200	20
Food manufacturers	Number of plants	Number of DCs
a	6	6
b	4	4
c	2	4
d	2	3
e	2	3
f	2	3
g	4	0
h	3	0
i	2	0
j	3	2
Total	30	25

Table 5
Estimated hardware demand for the chains of convenience stores.

	Fixed reader	Hand-held reader	RFID-POS system	Kiosk
Unit cost (NTD)	100,000	70,000	80,000	130,000
Food manufacturers	60	30	N/A	N/A
DCs	90	45	N/A	N/A
Retailers	N/A	9200	18,400	9200
Total	150	9275	18,400	9200

chains. Similarly, the lower part of Table 4 summarizes the associated large food manufacturers and their DCs.

We interview several industry experts who work for ITRI, all of whom are involved in the research and development of RFID technology in food supply chains and have abundant experience with its implementation in a food supply chain or other sectors. From interviews with industry experts, each retailer is equipped with at least one hand-held reader to record inventory, two RFID-POS systems at two checkout counters and one kiosk per store for customers to inquire about goods. Each food manufacturer has at least one hand-held and two fixed readers to record production and transportation processes and each DC has one hand-held and two fixed readers. We suggest that the estimated total quantities in Table 5 should give RFID component manufacturers strong incentives to develop hardware for this potentially large market.

We also take samples from five different retailer locations to estimate the consumption of RFID tags. Consumers' purchase data is captured from both morning (10:30–11:30 a.m.) and evening (7–8 p.m.). We record the number of four typical product categories available in convenience stores: beverage, instant, packaged and frozen. Table 6 summarizes the results.

The cross-out marks for 132, 104, 76 and 42 are the outlier statistics (the highest and lowest numbers of morning and evening time periods, respectively) which we omit from our analysis. It is easy to estimate the day-consumption of tags in each retailer by

$$(64 + 112 + 71 + 47 + 100 + 84)/6 \cdot 24(\text{h}) = 1912(\text{tags/day}).$$

Thus, the total consumption of the annual number of tags can be approximated as

$$\begin{aligned} &1912(\text{tags/day}) \cdot 365(\text{days}) \cdot 9200(\text{retailers}) \\ &\quad = 6420{,}496{,}000(\text{tags}). \end{aligned}$$

5.2. Promotion scenarios

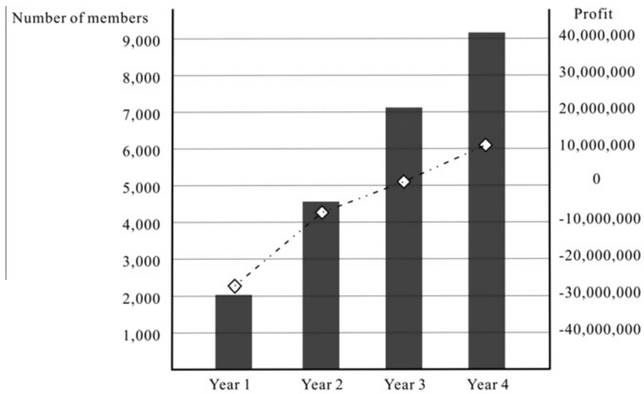
The next sections discuss 4- and 6-year promotion schemes for the pilot project. To record the complete data throughout the food supply chain, the manufacturers and DCs may need to adopt RFID technology at the onset of the 4- or 6-year promotion scheme. We assume that food manufacturers and DCs install RFID hardware in Year 1 and retailers participate in Years 1–6. The number of installing retailers follows the standard logistic distribution presented in (5). Figs. 2 and 3 illustrate the 4- and 6-year promotion schemes.

5.3. Cost and profit analysis

We estimate the annual expenditure including start-up and operations costs. The major part of operations cost is salaries. We

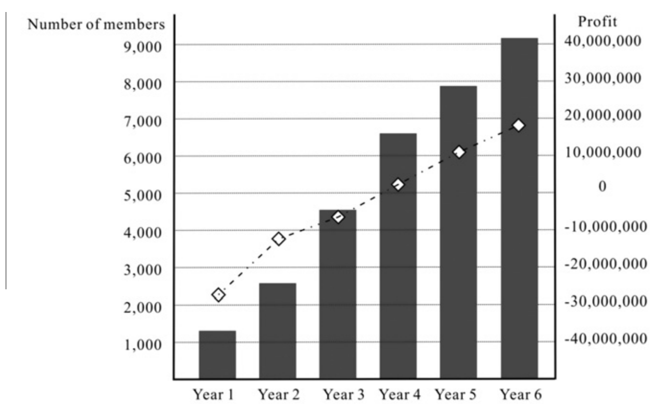
Table 6
Records of tags consumption from five retailer locations.

Category	Location 1		Location 2		Location 3		Location 4		Location 5	
	a.m.	p.m.	a.m.	p.m.	a.m.	p.m.	a.m.	p.m.	a.m.	p.m.
Beverage										
Plastic bottles	11	29	48	48	25	12	17	63	20	16
Metal can		3		9	1	17	2		1	17
Glass bottles		2	1	15	1			4	2	
Retort pouch	24	34	35	19	18	31	16	12	9	37
Milk	7	12	5	11	6	3		8		2
Instant food										
Rice ball	7	11			1				1	
Sandwich	5	8			8		2	2	2	
Dessert	1	4							1	
Bread	7	13	3	5	3		4	4	4	
Packaged food										
Snack		4	6	1	3	5	2		2	5
Instant noodles	1	2	1		1	3		1		3
Crackers		4	2	1		5	2	4		4
Candy		4	3	2	4		2	2		
Frozen food										
Frozen food	1									
Ice, Popsicle		2		1						
Total	64	~~132~~	~~104~~	112	71	~~76~~	47	100	~~42~~	84



	Year 1	Year 2	Year 3	Year 4
◇ Profits of ASP (in thousands)	-28,707	-7,206	824	11,297
■ Retailers	2,000	4,600	7,200	9,200
■ Distribution centers	45	45	45	45
□ Plants of food manufacturers	30	30	30	30

Fig. 2. Four-year promotion scheme.



	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
◇ Profits of ASP (in thousands)	-29,874	-11,759	-7,635	2,211	10,892	17,292
■ Retailers	1,300	2,600	4,600	6,600	7,900	9,200
■ Distribution centers	45	45	45	45	45	45
□ Plants of food manufacturers	30	30	30	30	30	30

Fig. 3. Six-year promotion scheme.

approximate the personnel plan and total payroll as shown in Table 7 (the numbers are in New Taiwan Dollars (NTD)). According to industry experts, 20 employees are expected to be recruited in Year 1, 28 in Year 2 and 35 in Years 3–6. From interviews with industry experts, we assume a firm with 35 employees is established for promotion and operation in the ASP.

Table 8 details the start-up costs, which are 15,452,500. We apply the pricing method illustrated in Section 4.2 to determine the initial fee and service fee, respectively. In (10), we take the value of the total start-up costs *TSC* as 15,452,500, the number of food manufacturers *M* as 30, the number of DCs *N* as 45 and the number of retailers *L* as 9200, respectively. The initial fee is

$$P_{initial} = \frac{15,452,500}{30 + 45 + 9200} = 1666.$$

The ASP also charges an annual service fee after installation. The pricing strategy of the service fee for both promotion schemes is discussed below.

5.3.1. ASP service fee during 4-year promotion scheme

We summarize the estimated expenditure of the ASP in Table 8. Note that the technology transfer fee comprises the maximum part in Year 1. The ASP's total expenditure includes the start-up and operations costs in Year 1 and only the operations costs thereafter.

According to (9) and the estimated expenditure in Table 8, the estimated total costs are

$$TC_1 = 15,452,500 + 16,712,500 = 32,165,000$$
$$TC_2 = 20,695,000$$
$$TC_3 = 24,137,500$$
$$TC_4 = 24,137,500$$

Note that the total cost is 24,137,500 after Year 3. Suppose that the ASP is expected to earn a 20% profit. Given that the accumulated numbers of installing clients are 2075, 4675, 7275 and 9275, the service price, as shown in (11), is

$$P_{service} = \frac{(16,712,500 + 20,695,000 + 24,137,500 \cdot 2) \cdot (1 + 20\%)}{2075 + 4675 + 7275 + 9275} = 4413.$$

As mentioned, the members implementing the RFID pay an initial fee $P_{initial}$ = 1666 in Year 1 and an annual service fee $P_{service}$ = 4413 thereafter.

5.3.2. ASP service fee during 6-year promotion scheme

Since the 6-year promotion scheme eventually serves the same number of clients, we let it adopt the identical personnel plan. The total cost in Years 5 and 6 are the same as the cost in Year 4 of the 4-year promotion scheme. Again, suppose that the ASP is expected to earn a 20% profit. Given that the accumulated numbers of installing clients are 1375, 2675, 4675, 6675, 7975 and 9275, the service price is

$$P_{service} = \frac{(16,712,500 + 20,695,000 + 24,137,500 \cdot 4) \cdot (1 + 20\%)}{1375 + 2675 + 4675 + 6675 + 7975 + 9275} = 4923.$$

Thus, $P_{initial}$ = 1666 in Year 1 and $P_{service}$ = 4923 in Year 2 and thereafter. Note that $P_{initial}$ and $P_{service}$ shown in the paper are rounded to the closest integer number so the profits may be slightly different from the demonstrated calculation in the paper.

5.3.3. Profit analysis

Next, we estimate the profits for both promotion schemes. Year 1's profit is

$$\text{Profit}_1 = 1666 \cdot 2075 - 32,165,000 = -28,707,972.$$

Thereafter, the ASP charges Pinitial = 1666 for new clients who install the food traceability system and Pservice = 4413 for the installed clients. Thus, the profit of the ASP in the 4-year promotion scheme can be summarized as

Table 7
Personnel plan of the pilot project.

	Year 1	Year 2	Year 3	Payroll (year/person) in NTD
President	1	1	1	1147,500
Vice president	0	1	1	675,000
Manager	1	1	2	810,000
IT engineer	6	9	10	607,500
Accountant	2	2	4	472,500
Sales	6	8	10	337,500
Technician	4	6	7	405,000
Total personnel	20	28	35	
Total payroll	10,192,500	14,175,000	17,617,500	

Table 8
Estimated expenditure (in thousands).

	Year 1	Year 2	Year 3	Year 4
Start-up costs				
Technology transfer fees	10,000			
Deposit for office rent	546			
Interior decoration	1800			
Office furniture and computer	3054.5			
Office supplies	52			
Total	15,452.5			
Operations costs				
Payroll	10,192.5	14,175	17,617.5	17,617.5
Insurance	2400	2400	2400	2400
Office rent	3480	3480	3480	3480
Utilities	300	300	300	300
Miscellaneous	340	340	340	340
Total	16,712.5	20,695	24,137.5	24,137.5
Total costs	32,165	20,695	24,137.5	24,137.5

Table 9
Profits of 4- and 6-year promotion schemes.

	Four-year scheme		Six-year scheme	
Initial fee	1666		1666	
Service fee	4413		4923	
	Total members	Profit	Total members	Profit
Year 1	2075	−28,707,972	1375	−29,874,198
Year 2	4675	−7206,674	2675	−11,759,476
Year 3	7275	824,191	4675	−7635,330
Year 4	9275	11,297,933	6675	2211,469
Year 5	9275	16,791,523	7975	10,892,042
Year 6	9275	16,791,523	9275	17,292,462

$$\text{Profit}_2 = 1666 \cdot 2600 + 4413 \cdot 2075 - 20,695,000 = -7206,674$$
$$\text{Profit}_3 = 1666 \cdot 4035 + 4413 \cdot 4675 - 24,137,500 = 824,191$$
$$\text{Profit}_4 = 1666 \cdot 568 + 4413 \cdot 7275 - 24,137,500 = 11,297,933$$
$$\text{Profit}_t = 4413 \cdot 9275 - 24,137,500 = 16,791,523, t > 4$$

Similarly, the profit of the ASP in the 6-year promotion scheme is

$$\text{Profit}_1 = 1666 \cdot 1375 - 32,165,000 = -29,874,198$$
$$\text{Profit}_2 = 1666 \cdot 1300 + 4923 \cdot 1375 - 20,695,000 = -11,759,476$$
$$\text{Profit}_3 = 1666 \cdot 2000 + 4923 \cdot 2675 - 24,137,500 = -7635,330$$
$$\text{Profit}_4 = 1666 \cdot 2000 + 4923 \cdot 4675 - 24,137,500 = 2211,469$$
$$\text{Profit}_5 = 1666 \cdot 1300 + 4923 \cdot 6675 - 24,137,500 = 10,892,042$$
$$\text{Profit}_6 = 1666 \cdot 1300 + 4923 \cdot 7975 - 24,137,500 = 17,292,462$$
$$\text{Profit}_t = 4923 \cdot 9275 - 24,137,500 = 21,527,032, t > 6$$

Table 9 summarizes the resulting profits. Table 9 shows a positive profit in both promotion schemes after Years 3 and 4, respectively. We note the following insights. The initial fee of the two schemes is the same, but the service fee of the 6-year scheme is higher than the 4-year scheme since the 6-year scheme has a relatively higher annual personnel cost. Because of a larger number of installing members in the beginning of the 4-year promotion scheme, its profits are greater than the 6-year scheme in Years 1–5. However, when the installing number reaches the same level for both schemes, the profits of the 6-year scheme are greater than the 4-year scheme from Year 6 onward since the 6-year scheme has a higher service fee.

6. Conclusions and future research

In recent years, more researchers have focused on food traceability systems which provide visibility of transaction processes to members of food supply chains and customers. With the implementation of RFID technology, food traceability systems can become more reliable and efficient since RFID enables a higher reading rate than traditional barcodes.

This paper proposes a framework for promoting a food traceability system and analyzes the profits and costs associated with RFID implementation for a convenience store supply chain of manufacturers, DCs and retailers. We also develop a pricing strategy in which an ASP charges an initial fee for installing RFID in the first year and an annual service fee for technical support thereafter.

Although this paper focuses solely on a proposed pilot project, many factors, not the least of which is the worrisome state of the global economy, will impact the market growth of a food market. In this paper we propose a framework for promoting a food traceability system for estimating costs and developing an appropriate price strategy. Note that the pilot project should be regarded as a demonstration and that the proposed framework allows readers or industry practitioners to change the time span, number of employees, etc., to fit their situations. We suggest that future research consider using another growth function, such as the normal distribution, to predict the number of members who might conceivably adopt RFID technology. We find that our two proposed promotion schemes can extend beyond a convenience store scenario, for example, to grocery and wholesale chains. Furthermore, global food safety policies stipulated by governments typically are followed by a series of regulations which many countries then implement due to food safety incidents and the globally complex network of food supply chains. Following this trend, the Taiwanese government is promoting and encouraging traceability throughout the stages of all food supply chains. It is expected that the government may next provide sufficient funds to launch a pilot project for developing a food traceability system for the private sector. Given the overwhelming social and environmental costs of food contamination, the Taiwanese experiment now underway should have implications for policy-makers, industry and public health officials elsewhere.

Acknowledgments

The authors thank the reviewers and the chief editor for their helpful and valuable comments to improve this paper. The authors are grateful for the generous interaction and guidance provided by many industry experts. This research has been partially supported by the National Science Council, Taiwan under Grant NSC99-2221-E-002-151-MY3 and the Industrial Technology Research Institute (ITRI), Taiwan.

References

Abad, E., Palacio, F., Nuin, M., Gonzalez de Zarate, A., Juarros, A., Gomez, J.M., Marco, S., 2009. RFID smart tag for traceability and cold chain monitoring of foods: demonstration in an intercontinental fresh fish logistic chain. Journal of Food Engineering 93, 394–399.

Agarwal, V., 2001. Assessing the Benefits of Auto-ID Technology in the Consumer Goods Industrial. Cambridge University Auto-ID Center, Cambridge.

Balakrishnan, N., 1992. Handbook of the Logistic Distribution. Marcel Dekker, Inc., New York.

BBC News, 2009. Timeline: China milk scandal. Available from: <http://news.bbc.co.uk/2/hi/7720404.stm> (accessed 18.12.2009).

Bertolini, M., Bevilacqua, M., Massin, R., 2006. FMECA approach to product traceability in the food industry. Food Control 17, 137–145.

Bevilacqua, M., Ciarapica, F.E., Giacchetta, G., 2009. Business process reengineering of a supply chain and a traceability system: a case study. Journal of Food Engineering 93, 13–22.

Domdouzis, K., Kumar, B., Anumba, C., 2007. Radio-Frequency Identification (RFID) applications: a brief introduction. Advanced Engineering Informatics 21, 350–355.

Ergen, E., Akinci, B., Sacks, R., 2007. Life-cycle data management of engineered-to-order components using radio frequency identification. Advanced Engineering Informatics 21, 356–366.

Frost, R., 2005. ISO 22000 is first in family of food safety management system standards. ISO Management Systems, 16–19.

Gandino, F., Montrucchio, B., Rebaudengo, M., Sanchez, E.R., 2007. Analysis of an RFID-based information system for tracking and tracing in an agri-food chain. Proceedings of the First Annual RFID Eurasia, 1–6.

GLOBALGAP, 2009. What is GLOBALGAP? Available from: <http://www.globalgap.org/cms/front_content.php?idcat=9> (accessed 10.12.2009).

Hou, J.L., Huang, C.H., 2006. Quantitative performance evaluation of RFID applications in the supply chain of the printing industry. Industrial Management and Data Systems 106, 96–120.

Jones, P., Clarke-Hill, C., Comfort, D., Hiller, D., Shears, P., 2005. Radio frequency identification and food retailing in the UK. British Food Journal 107, 356–360.

Jedermann, R., Ruiz-Garcia, L., Lang, W., 2009. Spatial temperature profiling by semi-passive RFID loggers for perishable food transportation. Computers and Electronics in Agriculture 65, 145–154.

Karkkainen, M., 2003. Increasing efficiency in the supply chain for short shelf life goods using RFID tagging. International Journal of Retail & Distribution Management 31, 529–536.

Kelepouris, T., Pramatari, K., Doukidis, G., 2007. RFID-enabled traceability in the food supply chain. Industrial Management and Data Systems 107, 183–200.

Kelly, E.P., Erickson, G.S., 2005. RFID tags: commercial applications v privacy rights. Industrial Management and Data Systems 105, 703–713.

Kotler, P., 1994. Marketing Management: Analysis, Planning, Implementation, and Control, 8th ed. Prentice Hall.

Lee, C.P., Shim, J.P., 2007. An exploratory study of radio frequency identification (RFID) adoption in the healthcare industry. European Journal of Information Systems 16, 712–724.

Li, D., Kehoe, D., Drake, P., 2006. Dynamic planning with a wireless product identification technology in food supply chains. The International Journal of Advanced Manufacturing technology 30, 938–944.

Lin, L.C., 2009. An integrated framework for the development of radio frequency identification technology in the logistics and supply chain management. Computers & Industrial Engineering 57, 832–842.

McMeekin, T.A., Baranyi, J., Bowman, J., Dalgaard, P., Kirk, M., Ross, T., Schmid, S., Zwietering, M.H., 2006. Information systems in food safety management. International Journal of Food Microbiology 112, 181–194.

Martínez-Sala, A.S., Egea-López, E., García-Sánchez, F., García-Haro, J., 2009. Tracking of Returnable Packaging and Transport Units with active RFID in the grocery supply chain. Computers in Industry 60, 161–171.

Meuwissen, M.P.M., Velthuis, A.G.J., Hogeveen, H., Huirne, B.M., 2003. Traceability and certification in meat supply chains. Journal of Agribusiness 21, 167–181.

Norton, J.A., Bass, F.M., 1987. A diffusion theory model of adoption and substitution for successive generations of high-technology products. Management Science 33, 1069–1086.

Prater, E., Frazier, G.V., Reyes, P.M., 2005. Future impacts of RFID on e-supply chains in grocery retailing. Supply Chain Management: An International Journal 10, 134–142.

Ranganathan, C., Jha, S., 2005. Adoption of RFID Technology: an exploratory examination from supplier's perspective. Proceedings of the Eleventh Americas Conference on Information Systems, 2195–2199.

Regattieri, A., Gamberi, M., Manzini, R., 2007. Traceability of food products: general framework and experimental evidence. Journal of Food Engineering 81, 347–356.

Rogers, E.M., 1995. Diffusion of Innovations, 4th ed. Free Press, New York.

Ruiz-Garcia, L., Steinberger, G., Rothmund, M., 2010. A model and prototype implementation for tracking and tracing agricultural batch products along the food chain. Food Control 21, 112–121.

Schmittlein, D.C., Mahajan, V., 1982. Maximum likelihood estimation for an innovation diffusion model for new product acceptance. Marketing Science 1, 57–78.

Sharma, A., Thomas, D. and Konsynski, B., 2008. Strategic and institutional perspectives in the evaluation, adoption and early integration of radio frequency identification (RFID): an empirical investigation of current and potential adopters. In: Proceedings of the 41st Annual Hawaii International Conference on System Sciences, pp. 407–417.

Stockute, R., Veaux, A., and Johnson, P., 2006. Paul Johnson Homepage. Logistic Distribution. Available from: <http://pj.freefaculty.org/stat/Distributions/Logistic-01.pdf> (accessed 05.05.2010).

Tajima, M., 2007. Strategic value of RFID in supply chain management. Journal of Purchasing and Supply Management 13, 261–273.

Thakur, M., Hurburgh, C.R., 2009. Framework for implementing traceability system in the bulk grain supply chain. Journal of Food Engineering 95, 617–626.

Wamba, S.F., Lefebvre, L.A., Bendavid, Y., Lefebvre, É., 2008. Exploring the impact of RFID technology and the EPC network on mobile B2B eCommerce: a case study in the retail industry. International Journal of Production Economics 112, 614–629.

Wang, L., Kwok, S.K., Ip, W.H., 2010. A radio frequency identification and sensor-based system for the transportation of food. Journal of Food Engineering 101, 120–129.

WHO Media Centre, 2007. Food Safety. Available from: <http://www.who.int/en/> (accessed 15.12.2009).