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ABSTRACT

In many countries, food safety crisis can negatively impact public welfare as well as political stability. In over the past tow years, three government agencies and major food companies in South Korea have implemented a Radio Frequency Identification (RFID) project intended to explore and investigate the opportunities and challenges of RFID technology in the areas of instant food manufacture and supply management. This article reports on the successful practices and lessons learned of such project and antecedents of both enablers and inhibitors of acceptance and usage of the system through structured group interview. Among the findings are that item level tagging requires detailed and customized guidelines; standardized system development procedures among stakeholders is critical to the success of RFID implementation; information quality and information related system quality are more important than technical system quality in adopting the systems; factors that have been treated as enablers are identified as inhibitors in this context.

Keywords

Radio Frequency Identification (RFID), RFID Application, Food Safety, Information Success Model, Enablers and Inhibitors.

Adoption of RFID for Enhanced Food Safety Management: A Qualitative and Explorative Approach

INTRODUCTION

Regulations for edible products in many countries are becoming increasingly stringent due to a series of accidents. In 2006, the outbreak of E. coli bacteria tied to fresh-bagged spinach affected over 200 U.S. citizens, caused 3 fatalities, and resulted in an economic disaster for the agricultural industry in California (Nall and Hoffman, 2006). The previous year, the Bird Flu pandemic affected countries throughout Asia. In each case, there was a lack of an effective tracking system to monitor the circulation of affected food either within or across countries. In addition, an effective food safety management solution not only can ensure consumer's health benefits but also ease the political issues.

Country	Food Threats
Russia	In Russia, over 400 victims suffered acute intestinal infection after consuming products of a milk factory believed to have been poisoned by a factory worker. The company suffered huge financial losses.
European countries	In an effort to damage Israel's economy in 1978, citrus fruit exported to several European countries was contaminated with mercury, which led to significant trade disruption.
Chile, USA, Canada	An alleged contamination of Chilean grapes with cyanide in 1989 led to the recall of all Chilean fruit from Canada and the USA, leading to a boycott by American consumers. The damage amounted to several hundred million dollars, and more than 100 growers and shippers were going bankrupt.
USA	In 1998, a company in the USA recalled 14 million kilograms of frankfurters and luncheon meat potentially contaminated with Listeria.
USA	In 2004, Salmonella outbreak, traced to tomatoes, sickened over 400 people in 9 states. Federal investigators traced the tomatoes to a Florida packing house.
USA	In 2006, E. coli-contaminated prepackaged spinach that killed 3 people and sickened more than 200 in 26 states was traced to a California's Salinas Valley farm.

Source: Gessner, G. H., Volonino, L. and Fish, L. A. (2007). One-Up, One-Back ERM in the Food Supply Chain. *Information Systems Management*, 24(3), p. 215.

Table 1. Food Terrorism, Sabotage, and Accidental Contamination Incidents

In Table 1, a global review of serious food safety outbreaks is provided. These incidents illustrate the need for effective solutions to assist in food safety administration. One candidate technology to help address these issues is Radio Frequency Identification. The Food and Drug Administration (FDA) in U.S. has called for RFID usage in the drug industry to enhance drug safety levels and to counter potential threats from bioterrorists and counterfeiters (Chater, 2006). RFID has also demonstrated its potential to improve the supply chain management of the drug industry by tracking and handling the products delivered to consumers (Shim, Varshney, and Dekleva, 2007). Over the last two decades, the benefits of RFID have received increasing attention as the business process diversifies. The total RFID market value in 2007 across all countries is expected to reach $4.96 billion us dollars. The number will approach $10 billion before 2010. While U.S. is the leading country in adopting RFID technology with a global market share of 58.4%, Europe accounts for 33% of the market (Das and Harrop, 2007).

RFID applications improve the performance of supply network by allowing rich information exchange and achieving higher accuracy of delivery process (Straub and Rai, 2004). Such improvement in supply network realizes a quick turnover of stock in stores, which leads to some other consequential benefits such as lower operational cost and fewer transportation errors. To harvest those benefits, Wal-Mart required some of its suppliers and intermediates to implement RFID through their reengineering processes and planned to gradually increase the number of RFID enabled products. Despite the difficulties lying in the process of quantifying Return of Investment (ROI) of RFID deployment, Boeing, whose 80% component parts are provided by contracted suppliers, decided to use RFID to track products from manufacturers to installation, from repair to maintenance (Manufacturing Business Technology, 2006).

In response to the need for more powerful food safety assurance and control mechanism, South Korean public agencies and private sectors launched the Food Safety Information Management Systems (FSIMS) project in 2006. In addition to traceability, this project also was intended to explore the potential of RFID in a ubiquitous environment that contains other communication technologies (e.g. hand-held PC). The participants in the project have tested technological and operational feasibility of RFID applied food information management systems.

However, the project has overly emphasized the technological aspect of the systems and has not considered user requirements of the systems. The failure to meet the requirements of users has been led to inappropriate or inefficient system designs and reported as common reason for system failure (Avison and Fitzerald, 2003; Wixom and Watson, 2001).

The antecedents for technology acceptance have been broadly researched and significant models such as TAM and UTAUT have determined critical factors such as perceived usefulness. Cenfetelli (2004) points out that we need to consider the negative perception of a technology or systems, leading to discourage the usage as well as positive beliefs held by users to draw comprehensive explanation on technology acceptance. Antecedents of technology acceptance can be grouped into positive beliefs on technology called enablers and negative perceptions called inhibitors (Cenfetelli, 2004). Enablers are predictive of adopting and encouraging the usage of the systems whereas inhibitors are predictive of rejecting or discouraging the use of the system as well as continuous usage (Cenfetelli, 2004).

This research aims at identifying the positive and negative antecedents of the adoption of FSIMS. We employ qualitative research method because inhibitors are contextualized variable and inseparable of the context within which the technology is used. It is expected that the research findings can provide meaningful base for developing quantifiable scale for inhibitors and enablers specified to FSIMS.

The research first provides the description of FSIMS with its essential components and structure of RFID applied information systems in food industry. FSIMS project is a pilot system whose goal is to identify problems and opportunities through the test of its feasibility and potentials as well as its challenges. Next we focus upon identifying the enablers and inhibitors to affect the usage of the system based on group interviews on the basis of framework developed by DeLone and McLean (2003). As Cenfetelli (2004) argues, enablers and inhibitors are independent and have their own antecedents and effects. It is critical to investigate the two different determinants for explaining and predicting the adoption of information system as well as its post-adaptation.

DESCRIPTION OF RFID APPLIED INFORMATION SYSTEMS FOR FOOD INDUSTRY

A Successful Case of RFID application: the FSIMS project

Some of South Korean RFID projects are collaborations between government agencies and private sector companies. One, the Food Safety Management Information Systems (FSMIS) project, the focus of the remainder of this paper, suggests a comprehensive infrastructure for food safety insurance through tracking analysis of incidents coupled with the development of responsive actions. The system provides a common platform for food manufacturers, logistics, and retailers to access and share relevant information. The project reflects the concept of a previously conducted research of vigilant information systems in that the system integrates information from different stages of supply chain to detect change, analyze the problem, and initiate an alert. The coordinator of the FSIMS project is the Korean Food Industry Association (KFIA), while public agencies such as Ministry of Information and Communication (MIC) and National Information Society Agency (NISA) offer their respective contributions in the area of public administration. The project received substantial supports from the leading industrial companies including Nong-shim, Mega Mart, Dongwon Industries, Dongwon F&B, C&J Group, and Paris Baguette.

System Design: Interfaces & Key Components

The RFID-based information system for food safety is highly incorporated with wireless technology and mobile device. The consumer and supplier can track down the product information in both forward (destination) and backward (origin) directions. Additionally, RFID tags allow for food manufacturers and retailers to quickly be notified and retrieve contaminated product. The overall design of the FSIMS is presented in Figure 2.

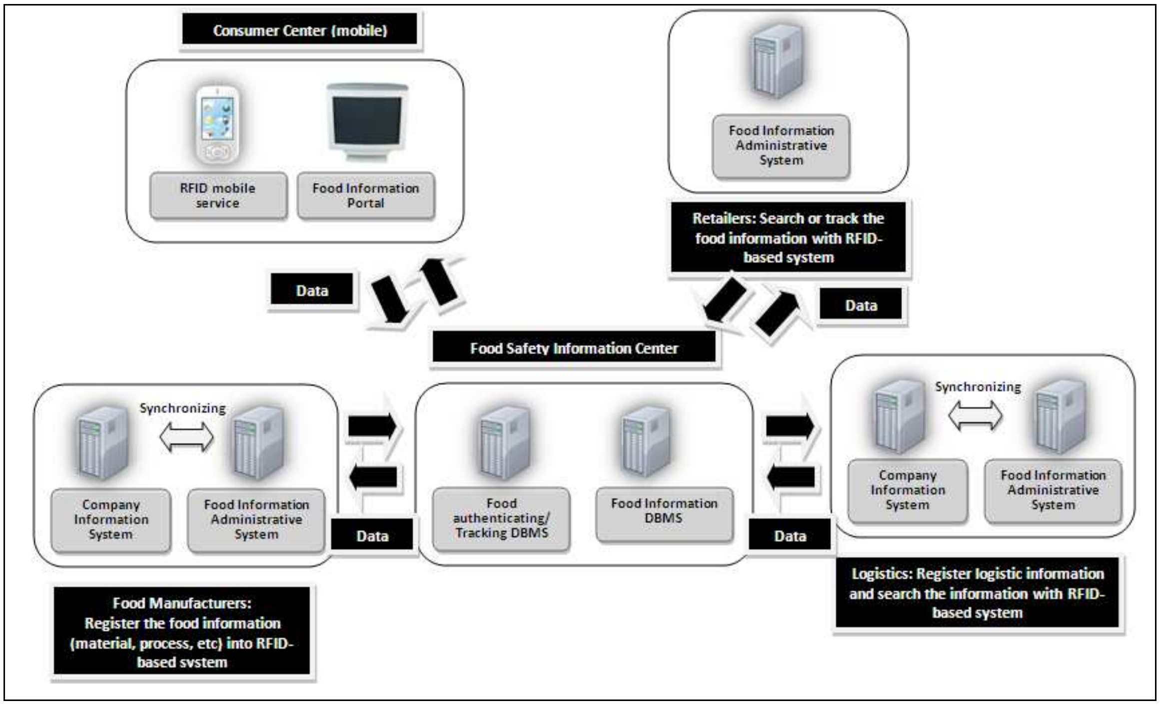

Figure 1. Components and Design of FSIMS Project

In Figure 2, the functionalities of *Food Safety Information Center* and *Consumer (Mobile) Center* can be further articulated as the following:

- Food Safety Information Center - Developing the RFID code contained tag; developing the mobile link module; developing mobile query interfaces.
- Consumer (Mobile) Center - Developing exterior RFID reader for mobile device; developing the wireless platform; developing the interface for mobile phone.

The project is composed of the following key components:

1) *Product Registration and Tracking System* is designed and implemented to realize product authentication and registration. It also conducts information search and tracking service which enhance the process of retrieving problematic products and handling customer complaint.
2) *Standardized Product Information Administrative System* involves tag administration, RFID devices installation, management of warehousing, and synchronizing the systems with the intermediate systems of outsider companies.
3) *Information Portal for Food Safety and Mobile Service* provide consumer-end product information searching and tracking service, builds food safety information center and mobile-related service that store/disseminate relevant information such as safety alert and product commercials etc.
4) *Public Relation Department and Information Strategy Planning (ISP)* accommodate legal issues, communicate the RFID definition, code system, and project design, and publicize the project with Video on Demand (VoD) that introduces and promotes the RFID-attached products.

To illustrate how projected systems should work, we describe the operational model in Figure 3 using company Paris Baguette as an example. Figure 4 describes how stakeholders of the project interact with each other.

Source: KFIA, Food safety information system based on RFID final report, 2006

Figure 2. Operational Model of FSIMS Project

Among the interfaces within FSIMS system, mobile link output interface deserves most of the development attention. Such interface is important in that it interacts with the components of *Information Portal for Food Safety* and *Mobile Service*, and they together play a key role in communicating with actual customers.

The shopper scans the merchandise item using his/her hand-held device (e.g. cellular phone), which transfers consumer's request through data transmission infrastructure (e.g. public cellular network). The network service provider (e.g. AT&T in the United States and SK in Korea) forwards such request using the routing table that contains identifier and destination information which is carried in the request packet generated by shopper's hand-held device. The destination of the routing process is a Food Information Database that stores, updates, and organizes relevant data entries provided by manufacturers. After locating the desired data records, the information will be processed and transmitted backward to user end.

THE DETERMINANTS OF USER ADOPTION

Interview Process

Quantitative research methods such as survey or experiment are inappropriate to explore the inhibitors because the variable is context bounded. The qualitative methods are useful not only in exploring the potential relationship underlying social phenomena and obtaining in-depth knowledge (Jean Lee, 1992; Fitzerald and Howcroft, 1998) but also in investigating phenomenon when the boundaries between phenomenon and context are blurred (Yin, 2002). Among the qualitative research methods, interview method is employed because the technology is not introduced in real world yet and observation and documentation method are infeasible. Specifically, structured group interview method is used in order to control the interview process efficiently.

The phases of group interview process included: 1) selecting research framework in order to develop structured interview questions, 2) designing of interview process, 3) creating specific interview questions based on the framework, and 4) selecting interviewees.

1. Identifying Research model and Constructs

Researchers in IS discipline have developed IS distinct models to determine the constructs of IT artifact usage. Representative models include Technology Adoption Model (TAM) (Davis, 1989), TAM 2 (Venkatesh and Davis, 2000), Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al, 2003), and Information System Success model (DeLone and McLean, 1992; 2003). Since it is not the goal of this research to develop our own models or hypotheses, we employ DeLone and McLean's (2003) model, which is extended version of information systems success model developed by DeLone and McLean (1992) as a framework for developing structured interview questions. We pay attention to information system success model developed by DeLone and McLean (2003) because it not only distinguishes the system quality from information quality delivered by the system but also expands its boundary by adding a new construct, service quality.

Service quality has been controversial due to its lack of validity in measurement instruments. Van Dyke and Kappelman (1997) describe the problems of service quality instruments: lack of discrimination validity between concepts, weak consistency in service dimensions, and low reliability of instruments due to indirect measurement.

However, Jiang, Klein, and Carr (2002) argue that empirical evidence demonstrates that service quality instruments equip adequate reliability, convergent validity, and discriminant validity.

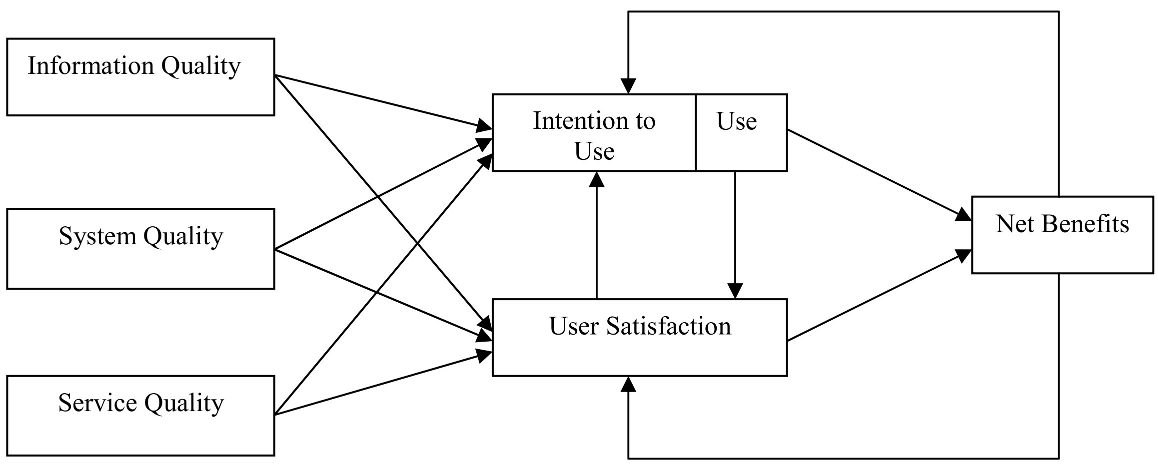

Figure 3. Updated D&M IS Success Model

Source: DeLone, W. H. and McLean, E. R., (2003), The DeLone and McLean Model of Information Systems Success: A Ten-Year Update, Journal of Management Information Systems, Spring 19(4), p.24.

However, some constructs in the model are inapplicable to the food information systems because the information systems are on test phases and interviewees have no chance to use and evaluate the system. Thus two constructs, user satisfaction and net benefits are not considered in the interview. The constructs in gray area in following figure are used in the research

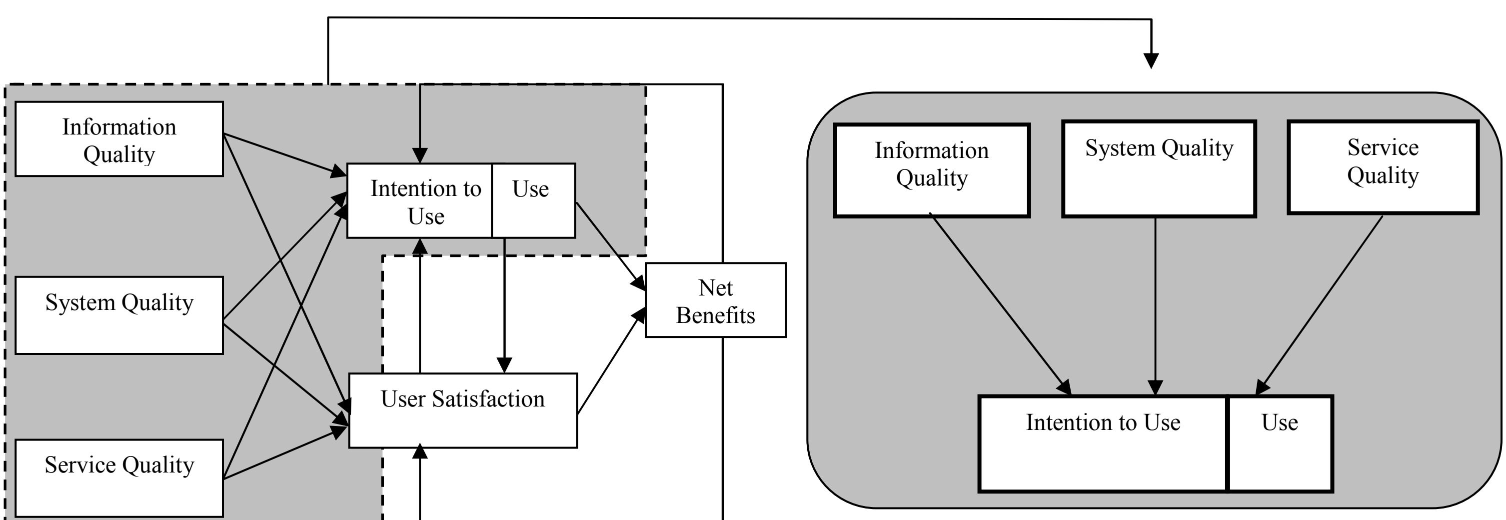

Figure 4. The constructs used in this research

2. Designing the Interview Process and Interview Questions

The deductive structured interview process is used because interviewees have a little background knowledge for food information systems. Thus, the interview is designed to begin with general questions such as shopping behavior, concerns for food quality, and perceived usefulness of information technology to release the concerns. The interview process is thrilled down to specific questions related to perceived system and information quality of FSIMS.

To be structured, interview questions are designed to measure the responses of interviewees into four categories: information quality, systems quality, service quality, and intention to use. Thus, the interview questions are organized as the questions to measure information quality, system quality, service quality, and intention to use in order. Regarding question type, open-end question is designed because the purpose of the research is to explore the perception of interviewees to determine the key factors of system adoption. Open-end question is very useful to obtain in-depth knowledge from interviewees.

For the purpose of increasing validity, interview questions are developed based on measurement items used in previous research. The measurement items demonstrate reliability, convergent validity, and discriminant validity and make the interview questions to be scientific inquires. We use the measurements from previous studies: Kettinger and Lee (1997), Goodhue (1998), Rai, Lang, and Welker (2002), Iivari, (2005), and Kettinger and Lee (2005).

3. Select Interviewees

Selecting interviewees is important because inappropriate selection of interviewees leads to biased output. To select interviewees, we recruited interview applicants with the condition to pay commuting fee and cash gift. Among the applicants, interviewees were selected based on the criteria of whether 1) they regularly go grocery to buy food, 2) they have purchased foods for themselves at least more than one year, 3) they usually cook foods for their family, and 4) they are house worker. With the criteria, we selected applicants who regularly go grocery and have purchased food for themselves at least more than one year. The half of interviewees was selected from the applicants who cooked for their family and half were from ones who did not. Since it is common that house keepers are women in South Korea, half of the female interviewees were selected from applicants who had job and the other half from house keepers. Considering that this interview is about information technology, we select people aged between 20s and 40s. The people in the range would be principle users for the information systems.

Gender is another issue. In South Korea, females usually go grocery shopping although the trend is changing. However, theories of technology acceptance deal with gender as a moderating variable, hypothesizing that female is passive in accepting new technology compare to males.

Among the applicants who fit to the purpose of the research, we randomly selected 11 interviewees in total due to the lack of fund. To control the gender ratio, we selected 6 females and 5 males as interviewees.

4. Interview Process

The interview has been conducted in four phases. In the first phase, the description of FSIMS was presented to the interviewees with the drawings. Characteristics and working process of the FSIMS were provided to give accurate explanation on the systems. Q&A time was followed to ensure that they had a firm knowledge on the systems. In second phase, interviewees were questioned about their shopping behaviors especially related to how they obtained and interpreted food information of food. The challenges or problems of current label information systems were investigated in this phases. Third phases focused on investigating enablers and inhibitors for adoption of FSIMS at the standpoint of users. The enablers were developed framework (figure 4) and other studies adapting the Information Success Model (DeLone and McLean, 1992). For inhibitors, interviewees were asked to present any factors leading to discourage the system after interviewer explained the concept of inhibitors. In phase four, quantifiable measurement instruments of enablers derived from the framework were distributed in order to do pilot test for later research.

INTERVIEW RESULT

1. Evaluating Current Information System (Label and bar code system)

Interviewees are found to mainly check valid date, origin of product, and ingredients of foods. Especially they pay more attention to information of foods when buying a food that used not to purchase. In case of repetitive purchase of a food they rarely check the information because they trust manufactures.

Type of food is found to affect the behavior to check food information. Interviewees rarely read information when purchasing fully processed food such as cereal or chocolate bar. However, for rarely processed food such as raw meat or fish, they are found to check the information carefully. Based on the findings, following information check behavior matrix can be created.

	Fully processed	Rarely processed
Food that used to buy	• Do not check food information	• Check food information
New food	• Rarely check food information	• Carefully check food information

Table 2. Information-seeking behavioral

Regarding of reliability of information printed in label, the perceived reliability of information is determined by brand value or size of a firm. Interviewees are found to believe that food information delivered by large sized firm is more reliable than one offered by small sized firm. They prefer to buy foods produced by large sized company because they want avoid cost or effort following information seeking activities. Thus, the interviewees are found to have very positive perception toward FSIMS because the information system is expected to reduce the cost or effort by providing convenient way to check and track food information.

The essential problems of current label printing system are identified:

- Low readability due to small size of font and label
- No standard for permissible level of specific ingredient.
- Possibility of fabrication or forgery of information label
- Difficulty of reading information printed in label due to the use of technical terminology
- Restricted information delivered

Interviewees reach the agreement that the most critical problems of current label system lie in the lack of information delivered and difficulty of reading information on label. Current label systems have its limits in providing information because of its spatial restriction and the use of technical terminologies.

As the concerns about food safety have been soared, it is demanded to increase the amount of information printed in label to enhance the 'right-to-know' of customers. However, the amount of information is restricted by label space and enlarge of the label size is not preferred by companies due to design purpose of products. Thus, the instant and 'easy' way to respond to the demand is to decrease the font size. With smaller sized font, companies are able to provide more information without enlarging the size of label. However, the prescription has been a fatal to readability and causes most customers to stop reading information on label. Actually, interviewees present that they do not read information because of the small font size and required time to read it.

Second issue is about the use of technical terminology. The interviewees propose two problems: concept and meaning. Interviewees are found not to read food information because they have no knowledge on the terms printed on label. For example, some of the interviewees read that a food contains 'oligosaccharide' from the label. But the information is useless to them because they do not have the concept of the term, 'oligosaccharide.' Another problem related to terminology is that the information is still no worth nevertheless they have concept of the term. For instance, interviewees know what 'sodium' means but they could not judge whether 'sodium 15%' means good or bad for health. In the sense, the data printed on the label need to be processes to give a benefit to customers.

The final and most important issue is a lack of information about food. Interviewees want to know more about food: who produce, when produce, who deliver, how long it takes to deliver, what ingredients are used, where the ingredients come from, and etc. Under the current systems, such information is stored at bar code and managed by information systems consist of bar code, readers, and software/hardware. Asif and Mandviwalla (2005) point out weaknesses of bar code systems:

- Easily become soiled, dirty, torn, marked over, hidden in frost
- Need line-of-sight orientation
- Requirement of extra human intervention to make barcode readable.
- Restrictive data storage capacity

In conclusion, interviewees show strong intension of adopting the FSIMS if the systems are perceived to solve the problems of current systems.

2. Determinants of FSIMS Adoption: Enablers and Inhibitors

1) Enablers

The latent constructs used in DeLone and McLean's (2003) model are measured by instruments reflecting its different aspects of the construct. The latent variables affecting the adoption of the FSIMS are information quality, system quality, and service quality. And reflective concepts of each construct are indicated in following table.

Latent construct	Measurement	Description
Information Quality	• Right data • Right level of detail • Accuracy • Currency	• The data are right and critical for my need • Appropriate or detailed data • Accurate data • New and ad hoc data
System Quality	• Compatibility • Locatability • Accessibility • Flexibility • Meaning • Assistant • Ease of use • Perceived usefulness	• Compatibility between different platforms • Ease access to the systems anywhere • Easy and quick access to data • Ease of changing data format • Ease of determining the meaning of data • Ease of getting help when in trouble • Free of effort in using the systems • Usefulness to improve my task
Service Quality	• Reliability • Responsiveness • Assurance • Tangibility • Empathy	• Systems reliability • Availability of the systems • Right and detailed system services • Visible features of the systems • Emotional expectation toward the systems

Table 4. The description of measurements

Interviewees are required to pick important aspects of FSIMS to accept and use the systems after hearing the concept of each measurement. Different from quantitative research, qualitative research method has no mathematical or statistical way to estimate parameters. Thus interviewees discuss one another and reach to the conclusion without intervene of interviewer. Following table presents critical factors in acceptance and usage of FSIMS in interviewees' perspectives.

Latent construct	Measurement	Interviewees' responses
Information Quality	• Right data	Yes
	• Right level of detail	Yes
	• Accuracy	No
	• Currency	Yes
System Quality	• Compatibility	No
	• Locatability	No
	• Accessibility	No
	• Flexibility	No
	• Meaning	Yes
	• Assistant	No
	• Ease of use	Yes (Overlapped with accessibility)
	• Perceived usefulness	Yes
Service Quality	• Reliability	No
	• Responsiveness	Yes
	• Assurance	Overlapped with right data and level of detail
	• Tangibility	Yes
	• Empathy	No

Table 5. Selected influential factors in adopting FSIMS by interviewees

The implication is clear. Interviewees put more emphasis on information quality (e.g., right and detailed data) and information related system quality (meaning, ease of use and perceived usefulness) than pure system quality such as compatibility, accessibility, and flexibility. The interviewees tend to perceive FSIMS as an alternative of current systems (label and bar code). They also expect that the emerging technology, RFID, surmounts the weaknesses of current system and satisfy their increased demand for food information.

This finding provides significant practical implications and insights to current FSIMS project. Because the project seems to put a little focus upon user requirements and rarely discusses what content and interfaces are demanded.

2) Inhibitors

Regarding of inhibitors, no theoretical model or framework has been developed because the factors are contextual-embedded ones. In other words, inhibitors are variate depending on IT artifact and context in which the artifact is used. In the sense, interview is the best approach to determine inhibitors. Through the interview, following inhibitors are identified:

Item	Description	Identification
• Fee charge for service usage:	Service fee charge above certain level would discourage the usage of system	Inhibitor
• The complexity of search process:	Complicate search process or access process to data would discourage the usage of system	Ambiguous*
• Ads (e.g., Pop-up ads, flash ads, etc)	Ads above certain level would discourage the usage of system	Ambiguous*
• Use of technical terminology	Use of technical terminology would discourage the usage of system	Inhibitor
• Technical malfunction of system	Frequent malfunction of system would discourage the usage of system	Inhibitor
• Security threat	Security or privacy threat would discourage the usage of system	Inhibitor

• Locatability	Available in a few place would discourage the usage of system	Inhibitor

* The factor is answered as enabler also.

Table 6. Identified inhibitors in adopting FSIMS by interviewees

Interesting findings are that factors such as Use of technical terminology, Technical malfunction of system, and Locatability, are perceived as inhibitors not enablers nevertheless traditionally they have been treated as enablers. The identified inhibitors still have a need for thrilling down, but they would be a guideline for future research in determining antecedents of food information system adoption, especially for the quantitative study.

DISCUSSIONS& CONCLUSIONS

Challenges and issues notwithstanding, innovative technologies are extending their influences to broader areas. The FSIMS project suggests that RFID might not generate short-term economic value but may prove to be practically effective in a sense of private and public cooperation - food safety assurance and business process innovation. It can be inferred from previous research that RFID has the potential to deliver long term benefits provided that proper guidelines are framed and adhered to, careful thoughts are given to implementation plan, and vigorous teamwork among partners is realized. [Other studies have found similarities between Electronic Data Interface (EDI) and RFID in terms of industry wide acceptance. It has been discovered in EDI development that getting started early on the learning curve provides lessons of practices and first move advantages. An important caveat concerning RFID implementation is to consider the idiosyncrasy of the existing consumer-side technical infrastructure. Some of the issues cover the compatibility between user-end communication equipment (e.g. cellular phone functions) and supplier-side technology. In countries where telecommunication industry is agile in absorbing new technical advancements, it is relatively easier for consumers to adopt new solutions such as RFID. It is a no-brainer for South Korean customers to scan an RFID tag using their handheld devices whereas most of US users are left behind in this area.

The authors have found several interesting implications from the project and structured interview. First, concern over food safety threat is surging as the international trading activities grow and the distribution processes turn complicated. RFID is a promising solution to reduce the threat by allowing customers to identify who and where the food is produced and to track the distribution process. Second, information quality and information related system quality such as right and detailed data, meaning, ease of use, and perceived usefulness are more important determinants to encourage usage of system rather than pure system quality such as flexibility or compatibility. Thrid, factors that have been treated as enablers are perceived as inhibitors. The findings lead to the need of quantitative study to determine the boundary between enablers and inhibitors.

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