

# When food quality control in China meets mobile and wireless technology: Interactions, potentials and pitfalls

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## ABSTRACT

With the fast economic development and industrial evolution in China, the surge of product quality and safety control issue has become one of the top concerns country wide in recent years. On one hand, citizens, academics and nonprofit organizations urged government to further refine product quality supervision strategies and install new food safety monitoring mechanisms (Qu, 2009). On the other, because of the popularity of wireless sensor systems and mobile data collection and transferring technologies in goods production, transferring and processing worldwide, they quickly gained their popularity among Chinese national quality control administration (Ruiz-Garcia et al, 2009; Jiang, 2008). The purpose of this paper is to conduct a comprehensive review of China's newly installed mobile and wireless quality control system based on the analysis of both first hand and second hand data. Specifically the study focuses on how changes in monitoring and tracing technologies interact with the current quality control and food safety administration, goods production and supply, and inspection systems. The paper concludes that although China's food quality control administration did attempt to bring new technology to enforce quality control code, the current implementation of mobile and wireless monitoring tools still demonstrates a highly reactive nature. In addition, the distribution of mobile and wireless monitoring device is still very uneven when it comes to different types of food. This to certain extent prevents the government from employing the new tools to their full extent to establish a meaningful monitoring system for further food quality crisis prevention.

## Categories and Subject Descriptors

H.4.1 [Information systems]: Information systems applications – Office automation

## General Terms

Management, Performance, Economics, Reliability, Experimentation, Human Factors, Standardization

## Keywords

Food Safety, Monitoring technology, Mobile and wireless technology

## 1. INTRODUCTION

With the fast economic development and industrial evolution in China, the surge of product quality and safety control issue has become one of the top concerns countrywide in recent years. The death of six babies and hospitalization of 0.29 million others after consumption of a top milk powder brand name and the high-speed train tragedy, shocked the whole country (Xinhua, 2008). Citizens and nonprofit organizations urged government agencies to further refine product quality supervision strategies and install new food safety monitoring mechanisms (Qu, 2009). A new initiative aiming to scrutinize operations of vendors nationwide was initiated by multiple government agencies (Zhang, 2008). In about one month, five new national, provincial and local regulations and policies on quality watch and monitoring were issued (Zhang, 2008; Qu, 2009). Because of the popularity of wireless sensor systems and mobile data collection and transferring technologies in goods production, transferring and processing worldwide, they quickly gained their popularity among Chinese manufacturers and national quality control administration (Ruiz-Garcia et al, 2009; Jiang, 2008).

However, a toxic substance was found in cartons of milk from the biggest Chinese dairy company in the end of 2011 (Xinhua, 2011). With this new discovery, efficiencies and effectiveness of wireless sensors and mobile monitoring devices were called into question. The goal of this paper is to conduct a comprehensive review of China's quality control system. Specifically the study focus on how changes in monitoring and tracing interact with the current quality control and food safety administration, goods production and supply, and inspection systems.

## 2. MOBILE AND WIRELESS TECHNOLOGIES IN FOOD SAFETY CONTROL: ROLES OF TECHNOLOGIES AND THE STATE OF THE ART

## 2.1 Major Mobile Technologies Used in Food Quality Control

### 2.1.1 Wireless Sensor Network (WSN)

WSN is a system composed of radio frequency (RF) transceivers, sensors, micro-controllers and power sources (L. Ruiz-Garcia et al, 2009; N. Wang et al, 2006). Instrumented with a variety of sensors, WSN monitors and transmits data on temperature, humidity, light, moisture, sound, solar radiation, soil temperature, wind speed, and seismic movement. It can exchange data with other networks and external users of Bluetooth and Zigbee. Comparing to traditional wired networks, WSN can operate in a wide range of environments and prevail in cost, size, power, flexibility. Currently WSN is widely employed in precision agriculture (Li et al, 2008), fish quality control (Crowley et al, 2005), supply chain management (Fu, 2008), and food packaging (Tan et al, 2007)

### 2.1.2 Radio Frequency Identification (RFID)

RFID is another major application of mobile technology in food supply chain management. Some scholars define RFID as a technology relying on radio frequency for object identification. It is a system comprised of tags, readers, and computing database and information management software (L. Ruiz-Garcia et al, 2009; R. Chena et al, 2008). The RFID tag part includes a microchip that is attached to an antenna. The antenna enables the chip to transmit the identification information to a reader. The reader converts the radio waves into digital information that can be passed on to database and information system (T. Kelepouris et al, 2007).

RFID has been applied to intelligent and smart packaging (S. Otles & B. Yalcin, 2008; Kit L. Y. et al, 2005), food sale management (E.W.T. Ngai et al, 2008), food logistics and supply chain management processes (L. Ruiz-Garcia et al, 2009) and food product traceability (K. Sugahara, 2009; A. Mousavi et al, 2002; A. Regattieri, 2007; A. Mousavia et al, 2005).

### 2.1.3 Geographic Information System (GIS)

GIS technology is a geographic information system designed to capture, store, manipulate, analyze, manage, and present all types of geographically referenced data (K. E. Foote and M. Lynch, 2000). It is also a powerful tool used to capture, integrate, model, analyze, visualize data and assess public health risks (L. H. Beni et al, 2011).

GIS's leading contribution in food quality control is its wide use in food contamination impact analysis system (L. H. Beni et al, 2011). GIS captures data from different sources, stores them in a database, analyzes and processes these data before providing an interface for simulation tools and visualize results in two dimensions. Integrated in the simulation tool, combining with data on locations of contaminated food and other attributes such as volume and concentration, a dynamic risk is estimated considering numbers of contaminated items and local population size. The GIS technology provides more accurate and real time information for threat evaluation in food contamination emergency response (L. H. Beni et al, 2011). Another use of GIS technology is to analyze local food supply chain characteristics and develop a coordinated distribution system (T.G. Bosona & G. Gebresenbet, 2011).

## 2.2 Advantages of Employing Mobile and Wireless Technology in Food Quality Control System

Mobile and wireless technologies and devices demonstrated clear advantages in consistent monitoring, collection and distribution of real time information along the product life cycle, and flexibility for information transmission. Many countries have approved mobile technologies use in food safety and quality control and surveillance (L. Ruiz-Garcia et al, 2009; P. Kumar et al, 2009; N. Wang et al, 2006). However, differences in architecture of mobile and wireless technology defined their application in different scenarios.

By constant data monitoring, WSN is able to record key operational data and events for supply chain management (Zhibo Pang et al, 2011). While WSN comprised of sensor modules can be employed in varieties of contexts, current use of this system can be found in agriculture production and livestock management (N. Wang et al, 2006).

According to Xuemei Li et al (2008), WSN supports precise control of environmental conditions for green house management. The real time information from the fields will provide a solid base for farmers to adjust farming strategies at any time (L. Ruiz-Garcia et al, 2009). In fish product and aquaculture industry, temperature data transmitted by WSN is a constant indicator used to measure and control fish quality. In addition, WSN allows information collection for future query from all stakeholders and supports appropriate actions taken according to changes in temperature parameters (K. Crowley et al, 2004; K. Crowley et al, 2005; D. He et al, 2011).

Similarly, wireless sensors for temperature and humidity control are used to provide precise information on the crop and help predicting problems such as pests in the wine industry (M. Connolly & F. O'Reilly, 2011). Location sensors are widely used in livestock industry to track animal movement in the pasture and each animal's grazing habits (T. Wark et al, 2007). Also soil moisture sensors functioned to increase awareness of the state of the plants for in-time irrigation.

Compared to wired network, WSN can be installed almost anywhere associated with relatively high network robustness. The cost of installation and maintenance is not very high either (N. Wang et al, 2006). It is an effective way to collect dynamic information for food safety and efficient storage and transportation management (D. L. Brock, 2003; W. Fu et al, 2008).

Because RFID has high capacity in data storing and remote reading, it is popular first in food supply chain management (L. Ruiz-Garcia et al, 2010). The use of RFID makes it possible to track food circulation process automatically with a low cost (G. Lao & Q. Wang, 2008). It facilitates food quality control in transportation by transmitting accurate, timely, complete, and consistent data (A. Regattieri et al, 2007; D. Li et al, 2006). RFID with biosensors can also be found in intelligent packaging for product tracing and environmental indicator monitoring (S. Otles & B. Yalcin, 2008) where it provides real-time traceability information on products (E. Abad et al, 2009; P. Kumar et al, 2009).

## 2.3 Challenges in Applying Mobile Technology

Despite the fact that the great potentials of this technology have been recognized by many, adoption of wireless sensor technology has not been as rapid as one would imagine (N. Wang et al, 2006).

### 2.3.1 Technical problems

One of the problems constantly associated with RFID tags is the system's fragility in water (Y. Hsu et al, 2008). Power supply is also a great concern for wireless systems (N. Wang et al, 2006). Though the cost of a RFID tag is not very high, the implementation of an RFID system is still relatively expensive. It mandates major investment in hardware, application software, middleware, tags, integration cost, consultancy fees, and employee training (E.W.T. Ngai et al, 2008; P. Kuma et al, 2009; K. Crowley et al, 2004). Problems can also emerge with reading range and accuracy. Most of the low frequency RFID systems have a limited reading range which constrains its capability for information transmission (P. Kumar et al, 2009). Furthermore there is no uniform technical standards and global regulations in terms of frequency allocation and data formats (Y. Hsu et al, 2008; P. Kumar et al, 2009; A. Regattieri et al, 2007; N. Wang et al, 2006; E.W.T. Ngai et al, 2008). The reliability of data connection and communication between wireless equipment is constantly questioned as well (M. Connolly & F. O'Reilly, 2011). Foods packaged in metal cans pose a unique challenge because metals can short out tags by reflecting signals (P. Kumar et al, 2009).

### 2.3.2 Non-technical problems

RFID tag recycling can be challenging. How to minimize excess contamination caused by RFID tag use is an issue widely discussed (P. Kumar et al, 2009). While security and privacy can be a challenge for all data collectors, users, and decision makers, overwhelming and unstructured data collected can provide limited value (N. Wang et al, 2009; W. Fu et al, 2008)(N. Wang et al, 2006).

Expertise employment and personnel hiring need to be taken into consideration as well when mobile technology systems are implemented. How many skillful RFID professionals should be hired for short term installation and long term maintenance is always a constant debate among all stakeholders (N. Wang et al, 2009; E.W.T. Ngai et al, 2008). With existing wired network and computing infrastructure, hardware and legacy system, how to integrate new mobile technology is another major concern (K. Crowley et al, 2004; N. Wang et al, 2006). Consumers' concern for privacy and information security is a major barrier for mobile and wireless technology use in food quality control where public support is greatly needed (P. Kumar et al, 2009; P. Bernardi et al, 2007., Sugahara, 2009 ). Some studies also argued that to ensure the successful use of mobile technology system in food quality control, commitment of private enterprise is mostly needed (E.W.T. Ngai et al, 2008).

## 3. RESEARCH DESIGN AND METHODOLOGY

## 3.1 Theoretical Framework: Structuration Theory

"Structuration" theory is a meta-theory. Its principal goal is to connect human actions with a structural explanation in social analysis (Giddens, 1979; Reily, 1983). Though structuration approach has not yet been explicitly used to study interactions between mobile/wireless technology use and quality management, structuration approach has been widely applied to study applications of Information and communication technology (ICT) and its influence on institutional, organizational environments as well as individuals' behavior related to ICT use (Orlikowski and Robey, 1991; Rose, 1998).

Thus an exploratory, qualitative research based on structuration approach was taken in this study, seeking to understand the interactions between mobile, wireless technology use and quality management efforts in China. The study specifically focused the investigation on the two research questions below. By combining these different dimensions, we hope to achieve a comprehensive understanding of China's quality management system with regard to the use of mobile and wireless technology use:

Research Question 1: What mobile and wireless tools have been employed in quality control systems, including food safety monitoring and merchandise quality control in China in the past decade?

Research Question 2: What roles are mobile and wireless technologies playing in the national quality control and food safety watch system?

## 3.2 Data Analysis Guided by Grounded Approach

Data analysis and theory development in qualitative research have always been the point of discussion and sometimes, where critiques are originated (Strauss and Corbin, 1998; Glaser, 1992). Comparing to classical theories, some of which have been delivered deductively, the grounded approach is derived inductively, a methodology comprising a number of single techniques. Its main purpose is to bridge the gap between theoretically uninformed empirical research and empirically uninformed theory (Frank and Riedl, 2004). Emphasizing new discovery and "focusing on the process of generating theory rather than a particular theoretical content (Patton, 2002, p125)", grounded theory is often used in areas where little is known or to put existing knowledge into a new perspective (Goulding, 1999).

Beginning with basic descriptions, Grounded theory moves to conceptual ordering ("...organizing data into discrete categories 'according to their properties and dimensions and then using description to elucidate those categories,'" (p19)) and then theorizing ("...conceiving or intuiting ideas --concepts--then also formulating them into a logical, systematic and explanatory schemes," (p 21)) (Strauss and Corbin, 1998).

Thus the research team decided that techniques based on grounded theory are instrumental for studying interactions between mobile/wireless technology and food quality management system. This would help to challenge presumably sound knowledge, and to avoid a tunnel-viewed perspective on a particular phenomenon. We aim to develop and fine-tune theories about the use of quality management systems and administration behavior in China that are supported by mobile and wireless

technology. Guided by these two approaches, our data collection and analysis thus started.

### 3.3 Second Hand Data Collection

Drawing on secondary source data included in formal publications since 1990, we included two types of data:

- 1) Academic papers published in leading Chinese academic database since 1990
- 2) Official reports produced by the Chinese government and international organizations and a number of government databases.

### 3.4 Data Sources and the Filtering Process

#### 3.4.1 Selection of Journals and Databases

This paper relies on high-quality government reports and Chinese papers about the use of mobile and wireless ICT for quality management in China. For academic publications, we chose the largest database of China, the China National Knowledge Infrastructure (CNKI, www.cnki.net), which contains 6642 types of domestic academic journals, including 2460 types of core journals and important databases. This database contains 99% of all the journals published in China and 99.9% of the papers written in the Chinese language. Given the completeness of this database, we chose core journals in this database as the main source for academic publications to further investigate.<sup>1</sup> In this research, core journals particularly refer to journals listed in the on the list “Main list of the Chinese core journals” which has been developed and published by Peking University Library every four years. Google Scholar was also employed to search for English papers by scholars centering on mobile and wireless ICT use for quality management in China.

To collect government reports, we searched websites of major government agencies involved in quality management. The specific government websites we browsed, searched and downloaded relevant reports include websites of:

- 1) The State Council
- 2) Ministry of Science and Technology
- 3) State Food and Drug Administration
- 4) State Administration of Work Safety
- 5) State Administration of Coal Mine Safety
- 6) Ministry of Agriculture
- 7) Ministry of Environmental Protection
- 8) General Administration of Quality Supervision, Inspection and Quarantine
- 9) Ministry of Commerce
- 10) Ministry of Health

#### 3.4.2 Selection of papers and reports

To narrow and secure core papers that can directly inform our study, we searched for papers and reports published since 1990 in

the databases, search engines and websites mentioned above. Combinations of different key words we used included “Mobile and Wireless Technology AND Quality Management”, “Mobile Technology AND Quality Management”, “Wireless Technology AND Quality Management”, “Mobile and Wireless Technology AND Quality Control”, “Mobile Technology AND Quality Control”, “Wireless Technology AND Quality Control”.

For the first round of documents search we retrieved a total of 5167 papers and reports (Agriculture:1529; Industrial safety:1515; Environmental protection: 225; Medical Safety:194; Transportation: 164). After the initial search, results demonstrated that many researchers and government reports are not very relevant. Most of the non-relevant publications discussed the impact of a specific type of mobile/wireless ICT such as RFID or wireless sensor systems on quality management, rather than the impact of mobile/wireless ICT in general. We refined our search strategy and combinations of keywords, replacing Mobile and Wireless Technology with a specific mobile/wireless ICT. Additional searches using twenty keywords combinations such as “GIS AND Quality management” and “GIS AND Quality Control” were again conducted. This second round of search helped us further narrowing down number of relevant documents. In filtering papers and reports published on the topic of quality management in agriculture using mobile and wireless ICT, for example, the second round of search offered 739 papers and reports that are closely related to use of mobile/wireless ICT for quality management in China. We further improved our search relevance level by deleting one-page newsletters, low relevance papers and advertisements, totally 96 high-quality academic papers and reports on Mobile/wireless ICT use for quality management in agriculture were secured for further analysis.

The same filtering procedure was performed on papers and reports published in the area of Industrial Safety, Environmental Protection, Medical Safety and Transportation. A total of 264 papers and reports meet the criteria of our selection and thus selected for study. The research team then coded each paper separately according to the classification schemes to be explained later. During the coding process, we re-evaluated each paper for its relevance to Mobile/wireless ICT use for quality management in China. After the coding process, the research team met to discuss the validity of the coding scheme, and to brain-storm on and refine it.

### 3.5 Multifaceted Coding Methods

Owing to its interdisciplinary nature, Mobile/Wireless ICT use for quality management in China encompassed an array of rich research ingredients. This required us to conduct a multifaceted coding on papers and reports selected.

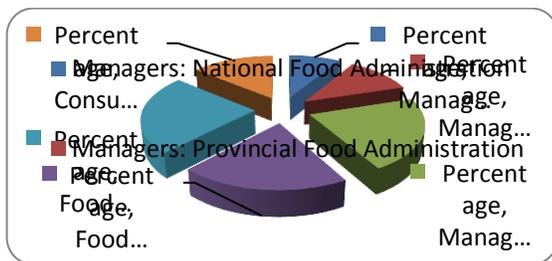
After the first round of brain-storming among the research team members, we identified various aspects and ingredients of mobile and wireless ICT use for quality management. Special attentions were paid to: the paper/report's source, the quality management and safety control issue discussed, the specific mobile/wireless ICT used, the areas to which mobile and wireless ICT was applied, the goals for adopting mobile wireless ICT, the functions mobile and wireless ICT played, the impact/effects generated by using mobile and wireless ICT in the quality management system, and the challenges. The reasons and purposes of setting these aspects and their application are as follows:

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<sup>1</sup> Core journals in China are generally referred to journals that have accumulatively published a great number of papers, and have high paper citations and high academic influence

- 1) The paper/report's source: How heavy should we rely on data extracted out of the paper/report?
- 2) The quality management and safety control issue discussed: What was the cause of the incident; Which area of quality management was discussed; What actions were taken, and What were the results of the actions.
- 3) The specific mobile/wireless ICT used: Whether mobile/wireless ICT was employed; what type of Mobile/wireless ICT was used?
- 4) The areas mobile and wireless ICT applied to: which area of quality management was discussed?
- 5) The goals for adopting mobile wireless ICT: Why was mobile/wireless ICT adopted and what was the goal?
- 6) The functions mobile and wireless ICT played: what were the functions of mobile and wireless ICT on quality management in China?
- 7) The impact/effects generated by using mobile and wireless ICT in the quality management system: what was the impacts/influence of mobile wireless ICT use on quality management?
- 8) The challenges: What were the challenges of adopting, using, and integrating mobile/wireless ICT in quality management in China? What challenges mobile/wireless ICT use brought to China's quality management system and administration?

### 3.6 Preliminary Interviews and the Structure of Interviewees



**Chart 1: Interviewee Structure**

Considering possible biases introduced by the use of second-hand data, this study also employed preliminary sets of interviews with voluntary interviewees from different levels of food administration, major food vendors and consumers. Detailed structure of interviewees can be found in chart 1 (Above).

The goals of our preliminary interview analysis included:

- To identify major projects aiming to control food quality in China involving the use of mobile and wireless technology.
- To explore with key informers on how widespread mobile and wireless technologies are currently being used in the area of food quality control in China
- To preliminarily assess challenges and barriers China's food quality control system is facing when mobile and wireless technological tools are introduced.

## 4. FINDINGS

The data showed that China started building her own food quality tracking system since late 1990s mainly relying on Personal Digital Assistant (PDA), GIS, GPS, and bar-coding technologies. The quality control administration employed mobile and wireless technologies in four specific areas: Food and Drug Safety Management, Clothing Quality Control, Housing and Real Estate Service Quality Control, and Traffic Safety Management. This reflected a traditional political belief of Confucius: Only if a government can efficiently take care of Citizens' needs in these four aspects, can they maintain a stable control of the state.

An in-depth analysis of the 11th five-year plan demonstrated that China's Food and Drug Administration (China's FDA)<sup>2</sup> invested heavily in national food quality control infrastructure. The national FDA has been conducting experiments in eight provinces and cities since 2001. The main goal was to test the reliability of China Quality Management System, and the newest mobile and wireless technology based system specifically for food quality control. A pilot project named "Golden Quality" was also introduced. Its core was created by the construction of one network, one database and three systems:

- One network, the backbone of the Golden Quality project, included all hardware, software and network platforms supporting the smooth operation of the project.
- One database, named "Quality Supervision Administration Database", was a database the public can access for information inquiry and public services.
- Three systems pointed towards the construction of three different systems for different purposes. While the Quality Supervision, Inspection, and Management system focused on quality supervision, the Quality Administrative Licensing and Management system was the main internal platform used by FDA agents for administrative licensing and filing. The Quality Inspection Information Service System acted as the main interface between Quality Control Administration and the Public.

In this paper, we only present our findings on the use of mobile and wireless technology for food quality management in China in the past decade. Four major subareas of food quality control involving use of mobile and wireless technology were identified:

- Production Safety Management,
- Logistics Management,
- Monitoring and Source Tracing, and
- Emergency Management.

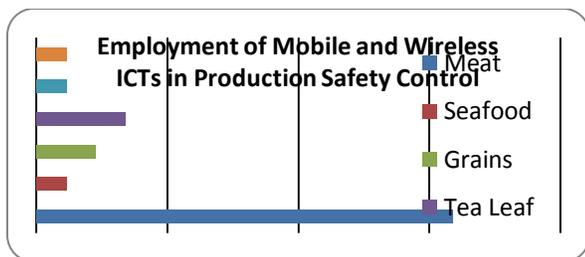
<sup>2</sup> We want to clearly differentiate terminologies in relation to FDA used in this paper. We use China's/Central/National FDA to refer to the country's Central Food and Drug Quality Control Administration. While FDA agencies refer to agencies within the China's FDA, Local FDA is Food and Drug Quality Control Administration on the local level.



**Figure 1: Use of Mobile and ICT in Major Areas of Food Quality Control in China**

#### 4.1 Production Safety Management

Our analysis shows a high concentration of research and projects on use of mobile and wireless technology in production safety control of Poultry and Meat, Tea Leaves and Grains. Projects were also launched for safety control purposes in vegetable and fruits, seafood, oil that employs mobile and wireless technology.



**Figure 2: Employment of Mobile and Wireless ICTs in Production Safety Control**

For poultry and meat, RFID and bar-coding technologies were used for quality control purpose. They generally played similar roles in recording all data from the moment chickens or cows were born, how they were fed and measures taken for animal epidemic prevention (Xiong et al, 2006). They also record individual identifier information during the reproduction process for instant PDA reading before livestock were butchered (Ma et al, 2008; Chen and Liu, 2008). It is also observed that Poultry and Meat production is the largest sector that widely implements mobile and wireless monitoring devices.

In contrast, quality control in seafood using mobile and wireless technology is more advanced. The system tracks all relevant data such as indicators of the aquaculture environment, and information on production process, packaging, inspection, transportation and marketing before seafood reach regular Chinese' dinner table. In addition, China's FDA offers regular access to seafood quality management database for citizens. Vendors, inspectors, and consumers can all access and interact on the platform. Services supporting retrospective inquiry in relation to questionable seafood, quality certification for seafood brand-names and anti-fraud against pirated brands are offered through phone, internet and SMS to citizens on a regular basis (Xie et al, 2005; Xiong, 2006; Liu, 2008; Shi, 2009; Shi and Yuan, 2010; Liu and Tang, 2010). Unfortunately the data sources for such quality management system are limited due to the fact that only a small number of fisheries on the east coast agreed to install such devices for production safety management purpose.

Although China's FDA is launching a new initiative to rely on mobile and wireless devices to track and monitor the quality of grain and oil as well, researchers and practitioners generally agree it is not easily achieved (Liu et al, 2006). Long production chain and too many tiers in transactions were suggested as the two leading reasons (Liu, 2006; Tu et al, 2010). Not to mention the unrealistic possibility of creating individual identifier for each unit of grain and oil (Zheng et al, 2009).

For vegetables and fruits, bar-coding systems and RFID tagging technologies were employed to create individual product identifiers, acting not only as real time product information collectors and distributors, but inputting mechanisms for safety warning system (Xu, 2011; Huang and Zhang, 2010; Sun et al, 2009; Li et al, 2008). Together they formed the basis for agricultural product safety management system (Zhang et al, 2010).

While wireless sensors provided instant access to real time data for fruit and vegetable quality inspection, GIS facilitated a more vivid presentation of production environment (Zhang et al, 2010). After compiling all these information in the mobile tracking system and databases, China's FDA was expecting to create a clearer line of circulation. By documenting origins of fruits and vegetables, how they circulated between suppliers to supermarkets or vendors before reaching individual customers, FDA in China is hoping to establish clear trails of fruits and vegetables and quickly determine individuals and companies that are accountable in cases of fruit and vegetable emergencies.

#### 4.2 Logistics Management

Inefficient supply chain management has been frequently recognized as the main reason for food poisoning outbreak in China. It is especially true for agricultural products that are highly perishable. Most researchers and practitioners agreed that monitoring mechanisms during food transportation must be improved to ensure food quality (Chang, 2010; Wang et al, 2010). The advantage of mobile and wireless technology is thus highly appreciated in this area. Chang (2010) pointed out that new mobile tracking technologies offered a new way of managing supply chain based on real time information flow where all stakeholders can access the same type of product information. This way, the uncertainty and blindness of traditional agricultural product delivery dropped greatly.

Wang and his colleagues (Wang et al, 2010) also suggested that RFID, GPS, GIS and RS (remote sensing) have become four leading mobile technologies utilized by both government agencies and private vendors in food supply chain management. During transportation, RFID tags are attached to the surface of each item. Inspectors can easily pull out all relevant information by reading the tag using RFID readers without even scratching anything. They hope advantages of RFID tagging which makes recording, revision, accessing and encryption of product data relatively easy make this technology more attractive to many Chinese companies, supermarkets and inspectors.

For inspectors and supply chain managers, Shen (Shen, 2007) argued, dynamic tracking--the combination of RFID and GPS--could considerably decrease the workload of monitoring, tracking, and random inspection of products on the way. Customers and logistics companies can access and check the status of food and fruits in transportation at any time. Additionally, inspectors on the border do not have to open the containers for their routine check

any more. Instead, these tasks can now easily be done by reading the tags using RFID readers.



**Figure 3: Employment of Mobile and Wireless ICTs in Logistics Management**

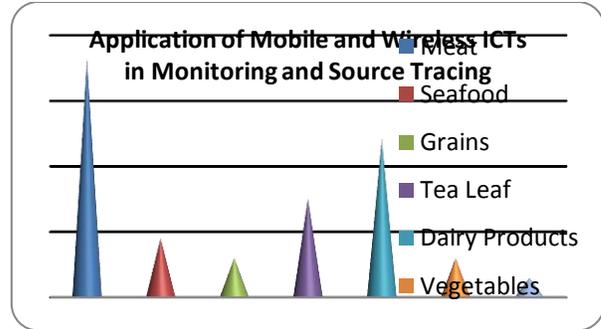
However though FDA officials generally agreed that applications of GIS and GPS in agricultural product supply chain definitely helped locating vehicles and products and optimizing distribution and delivery routes. However, these technologies are still relatively unstable and expensive. How to ensure their reliability and widespread use in China's food quality control system is still a question to be answered.

### 4.3 Monitoring and Source Tracing

Comparing to production and logistics, citizens generally are more concerned with how government agencies monitor product quality (Zheng et al, 2009). In the past several years, China's FDA invested heavily to develop a national database for food and drug source tracing. In creating this database the FDA goal was to collect, accumulate and compile accurate data on raw material origin, purchase, processing, storage, transportation and sales information (Zha, 2010). These data serve as input for decisions that the FDA makes about its service of certification and anti-fraud in addition to its monitoring efforts. The public can access the database and check on the quality and relevant information of products they purchased any time (Deng, 2008). Multiple access points are available through cell phones, landlines, PCs, Mobile terminals and Touch Screens at the supermarkets.

Local governments also made efforts to control food quality in certain parts of the Country. Combining GPS and GIS, Sichuan provincial government, for example, built a regional source tracing and quality management system. By compiling sizable e-maps and inputs from GPS and PDA/mobile terminals, this system marked the precise locations of all food manufacturers in one city on one e-map. Different manufacturers are marked with different colors (green, yellow, red and black) to differentiate how they are monitored by the city FDA office.

When clicked, all relevant data on quality control for one manufacturer will be expanded and displayed on the map. This significantly reduced the city FDA's workload in collecting information for each company. Traditionally before FDA agents made any decision, they have to repeatedly collect information on each company's registration, quality control data, inspection history, and location data. Right now, all these information is just one click away.



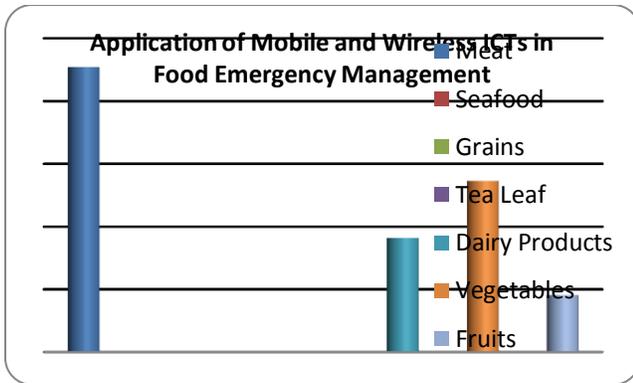
**Figure 4: Employment of Mobile and Wireless ICTs in Monitoring and Source Tracing**

Interestingly, for perishable food such as seafood and fruits where heavy monitoring is needed, fewer monitoring and source tracing devices were installed. This may reflect a lack of strategizing and planning when introducing mobile and wireless technology to the domain of quality monitoring and source tracing.

### 4.4 Emergency Management

Although emergency management in food quality management in China has become a public concern, how mobile and wireless technology is facilitating in this aspect is still unclear from papers published so far. A few government projects currently available in this area still narrow their attentions towards locating the root of food quality problems and finding individuals or entities that are accountable. Learning from experiences of Japan and the US, Wang and his colleagues (2010) recommended that China FDA should encourage the design of an emergency management system specifically for agricultural product quality control. The key for the system to function well and to efficiently support government decision making is to accumulate accurate source tracing information and to redesign agricultural product emergency response procedures (Jia et al, 2006). In addition, researchers are encouraged to put in more efforts in modeling the diffusion process of contaminated food and evaluating future risk of quality control in the country (Wang, 2007).

On the government side, although many projects have been launched by different FDAs since the 2008 milk powder scandal, it is still not clear how mobile and wireless technology can be used widely for food emergency management in China. This is largely due to its uneven distribution in different areas of food quality control. There is still a great need for research in how mobile and wireless technology is impacting food emergency management in China. Comprehensive measures are to be designed and implemented so data from different sources can be collected, synthesized, analyzed and used for emergency mitigation, preparedness and recovery purposes.



**Figure 5: Employment of Mobile and Wireless ICTs in Food Emergency Management**

## 5. DISCUSSIONS

Our findings clearly present the impacts of the use of mobile and wireless technology on China's food quality control management. This impact can be divided into three vertical levels: Micro level (The use of mobile and wireless technology for daily food quality control operations, especially its impact on ways individual government employees do their work); Intermediary level (The impact of mobile and wireless technology use on work organization, division of work, communication, and agency coordination in and among food quality control agencies); Macro-level (The indirect impact generated by mobile and wireless technology use on government's role in food quality control).

### 5.1 Micro-level impacts

As the newest technology introduced to the food quality control administration, mobile and wireless technology use has forced individual government employees to improve their ability to operate and work efficiently with it. These challenges include two different independent but connected dimensions: Employees' technical operation capability and informational capability. While technical operational capability can be improved with training and frequent use, the latter is much harder to increase. Informational capability generally refers to human beings' capability to recognize, seek, identify, select, retrieve, secure, apply, and even inherit useful information to increase performance (Bharadwaj, 2000).

Before the technology was introduced, food quality administration had to rely on two traditional methods to ensure food quality: Private suppliers' self-monitoring and food quality agencies' random sampling and inspection. But after the introduction of mobile and wireless technology, especially RFID, GPS and RS technologies, FDA agents can maintain an all-time monitoring of food quality from the moment it was produced. This control of real time information empowered civil servants greatly. They are no longer tolerant information receiver and passive disaster responders. They can take a more proactive role in initiating quality check and preventing food quality problem to emerge before it is too late. When food quality emergencies do occur, they can quickly compile, analyze and identify the origin of food emergency, and take appropriate and immediate action to prevent further deterioration. Decision making quality and accuracy are also greatly improved. The new technology also helps to efficiently prevent corruptions associated with loose inspection

and quality control because information is accessible at any time and to all who are authorized.

### 5.2 Intermediary level impacts

The biggest impacts of mobile and wireless technology use on the intermediary level are the ways it has changed organizational communication, division of work, information sharing and agency coordination. A flatter hierarchy is also slowly emerging. Before the technology was widely used for food quality monitoring purpose, individual public employees were each assigned and took charge in a specific subarea such as seafood production line supervision or grain & oil transportation monitoring. These individuals each operated on their own with lack of meaningful communication with others. But once real time monitoring devices, transmission systems and common data warehouses were in place, the traditional wall of communication was automatically torn down. Individual agents were not constrained by traditional division of work. Instead, they were equipped with convenient learning tools and channels to communicate and collaborate with colleagues from other offices. Especially during food emergencies, different offices can quickly align and cooperate in identifying roots of the problem and entities or individuals that are accountable.

Outside government, the use of mobile and wireless technology in monitoring food quality also improved the relationship between private food suppliers and the FDA in China. Traditionally for farm products, especially perishable food--such as milk, vegetable, and meat--private food suppliers had great difficulty in monitoring food quality especially when they collaborated with sub-vendors. In the case of the latest milk poisoning, large private milk suppliers outsourced some of their contracts to smaller and privately-owned farms in the form of subsidy. Without installing any quality control mechanism, large private milk suppliers collected raw milk from smaller farms on a daily basis. As a report published by a leading independent investigator indicates, little quality inspection was performed before raw milk was boiled and repackaged (Zhou, 2007). Some scholars argued that large milk vendors had realized the possibility of milk poisoning long before the tragedy was fully disclosed. Instead of following legal requirements and reporting to corresponding agency, they chose to cover up and hence the tragedy unavoidably took place.

With the use of RFID and GPS, both private vendors and the FDA can accumulate accurate data on the relation among production, transportation, temperature control, optimal supply chain design and cost reduction. This helped reduce to certain extent costs attributed to natural wear and tear of perishable food. For the FDA, the installation of monitoring devices in both smaller, privately-owned farms and large milk vendors broke the control of information by large vendors. Authorized FDA agents can directly access monitoring devices and data warehouse to check on food quality data. Warning system was setup and alert sent out when certain indicators of food quality dropped to a dangerous level. This forced large milk vendors to collaborate with FDA agents in monitoring milk quality and taking social responsibility. In cases of disagreement among vendors when it comes to sharing responsibility in a food emergency, the FDA can always rely on system data for concrete decision making and confrontations.

### 5.3 Macro-level impacts

On the macro level, mobile and wireless technology use changed roles played by the Chinese government in food quality control.

Traditionally FDAs mainly played the role of agreeable inspector and mediators. They could not maintain a comprehensive supervision of the whole food quality control system. Instead they had to rely on random inspection to maintain a weak control on food vendors. It was not infrequent that private vendors intentionally distorted food quality data and manipulated gray area in the food quality control system. But due to lack of actual data, FDA constantly failed to precisely articulate the origin of problems and to identify people or entities that were accountable. This in turn stimulated a high level of public distrust in the government with regard to food quality control.

With the facilitation of mobile and wireless technology, government agencies such as the FDA started building up foundations to take the control back. Backed up by data accumulated in mobile and information systems, FDA agencies started providing quality control information service to the general public. According to a Statement by China's General Administration of Quality Supervision, Inspection, and Quarantine, the clear goal of Quality Information Service is to update and share with the general public the most authentic quality control statistics and information throughout more than 30 provinces and cities in the nation (China Quality Control Information Service System, 2007). In this sense, China's FDA is trying to shift its role from a distant authority to a service provider aiming to regain the trust of the general public.

In addition, some local FDAs are collaborating to launch a national project in employing authentic data to support legal actions against private vendors. This will mandate accurate and comprehensive data input from all stakeholders involved in quality control and supervision. While some local government agencies are regulating companies and food producers to install mobile and wireless tracking system, others are motivating them with tax-reduction policies or refunding mechanisms. Unfortunately there are no national policies or laws yet to demand private vendors to conform in this area.

However even with all benefits associated with mobile and wireless ICT use for food quality control purposes, challenges faced by China's FDA are still enormous. First, on the individual level, data quality and accuracy in the mobile and wireless monitoring system is still an issue. While automatic data provided by remote sensors or satellites are less biased, they only form a basis for information accumulation and further analysis. Individual public employees' efforts are still highly needed to improve the agency's performance and decision making. But these are still largely hindered by individuals' different familiarity with the system, willingness to share information and power, and capability to absorb information for accurate decision making.

Second, from the perspective of private food vendors, it is not surprising that most of them lack the motivation to install mobile and wireless monitoring devices for quality control purpose. Cost saving and reluctance to share with the government key quality control information are the two leading reasons. While concerns about data privacy and security are publicly offered as an issue for most private enterprises, an anonymous insider explained that if current milk quality control regulations were enforced, no current milk vendor would be able to reach the criteria set up by the government (Private communication in 2011). Thus, how to balance the public's living standard with enterprise's needs to survive is definitely an issue faced by local FDAs. Especially when in disruption with local government's chase for higher GDP,

local and central FDAs are left with little space for taking action. China's Central FDA's decision to drop quality criteria and adjust inspection items this year is a clear sign of compromises made.

In relation to this is a loose legal and regulatory environment for food quality control currently existing in China. At present, most FDAs are still heavily relying on regulations drafted by different agencies to contain private vendors' wrongdoings (Qian et al, 2009). Except for several capital cases that have experienced national outcries, most of the offenders can successfully and quickly escape criminal charges with financial fines. Some scholars are calling for government agencies, law makers, and the public to collaborate in making better laws and taking stronger control of the situation. However, little progress has been made in this aspect so far.

## 6. CONCLUSION

In conclusion, we found that mobile and wireless technology has been widely used for food quality control purposes in China. However, due to the lack of central planning and strategizing, these projects were separately launched by different FDAs for different purposes. This resulted into on one hand the repetitive construction of similar projects thus a waste of taxpayers' money. On the other hand, for those areas that are heavily in need of production monitoring, source tracing and emergency management, little progress has been made because of the distributed style of decision making without communication and collaboration. Although our analysis suggests that influences of mobile and wireless technology use can be found on three different levels, more progress on the individual, organizational, cross-organizational, and legal environment still needs to be made before mobile and wireless technology can unleash its full potential in helping improve the general quality control system.

## 7. ACKNOWLEDGMENTS

We want to thank multiple funding agencies for their generous support that made this research possible: China National Social Science Foundation (Project ID: KRB3056068), Shanghai Pujiang Program (Project ID: KBH3056609), New Faculty Member Start-up Programs, China Ministry of Education (Project ID: JJH3056008), Fudan 985 Program (Project ID: 2011SHKXZD013), Shanghai Municipal Advisory Committee of Decision Support, and The Dr. Seaker Chan Center for Comparative Political Development at Fudan University (Project ID: CCPDS-FudanNDKT13035).

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