7-18-2009

Research on the establishment of food supply chain traceability systems

Jianmin Zhang

WORLD MARITIME UNIVERSITY
Shanghai, China

RESEARCH ON THE ESTABLISHMENT OF FOOD SUPPLY CHAIN TRACEABILITY SYSTEMS

By

ZHANG JIANMIN
China

A research paper submitted to the World Maritime University in partial Fulfillment of the requirements for the award of the degree of

MASTER OF SCIENCE
INTERNATIONAL TRANSPORT AND LOGISTICS

2009

DECLARATION

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

…………………….

…………………….

Supervised by

Professor LIU Wei

Shanghai Maritime University

ACKNOWLEDGEMENT

First and foremost I would like to thank my advisor, Professor Liu Wei for his patient guiding, mentoring and support that he has given to me through to the completion of this dissertation. He has not only been an excellent advisor but also a role model and a true friend.

Now I need to thank a very important friend in my life. He is Mr. David Weekley from New Zealand. For me, he is not only a friend, but also a tutor in my life. Without his help, I couldn’t imagine what kind of life I have. I want to give my best regards to him and thanks for his help and encouragement.

Lastly, I think I should thank my best friends: Petros and Shawn. To both of you, I want to say it’s my honor to have you two as friends.

ABSTRACT

Title of Dissertation: Research on the Establishment of Food Supply Chain Traceability Systems

Degree: Master of Science in International Transport and Logistics

Abstract: Due to food safety issues, traceability is becoming a method of controlling food safety and connecting the suppliers and consumers. This dissertation builds up a food supply chain traceability system. It chooses the Structured Query Language (SQL) Server 2008 as a database center for the whole traceability system. Additionally, some basic information collection technologies such as radio frequency identification (RFID) technology and bar code identification technology are also selected to support the database center. Then this thesis uses the failure mode and effect analysis to assess key indicators of the system and the largest risk priority number (RPN) is the precision risk of information. Moreover, we use the fuzzy synthetic evaluation model and intensity weighted average method to rank the importance of the three factors of the food supply chain traceability system and know that the depth is the most important factor of the three. Lastly, we use a case of Green Pork Company to calculate economics facts. According to the result of calculation, the system causes the price of pork to increase by less than 0.1Yuan/kg.

Keywords: Traceability, Food Supply Chain, Food Safety, Failure Mode and Effect Analysis Model, SQL Server 2008, Fuzzy Synthetic Evaluation Model

TABLE OF CONTENTS

List of Figures

List of Tables

List of Abbreviations

BSE	Bovine Spongiform Encephalopathy
COOL	Country of Origin Labeling
EAN-UCC	European Article Numbering-Uniform Code Council
EU	European Union
FDA	Food and Drug Administration
FMEA	Failure Mode and Effect Analysis
GAP	Good Agricultural Practice
GPC	Green Pork Company
ISO	International Organization of Standardization
NLBC	National Livestock Breeding Center
NLIS	National Livestock Identification System
PDF	Portable Data File
RFID	Radio Frequency Identification
RPN	Risk Priority Number
SQL	Structured Query Language

CHAPTER 1 Introduction

1.1 Background

According to ISO, traceability means "ability to trace the history, application or location of that which is under consideration". In 2007, ISO explained that "A traceability system is a useful tool to assist an organization operating within a feed/food chain to achieve defined objectives in a management system" (ISO, 2007)

Traceability includes two basic activities: tracking and tracing (A.Bechini et al., 2005). The term "tracking" is usually used to specify the ability to follow the downstream path of a product along the whole supply chain. The other concept "tracing" is related to the ability to determine the origin and characteristics of a particular product. Traceability systems establish the path of information on food origins, attributes, and production and processing technologies from 'farm to fork', thus increasing transparency in the food chain. It has been applied in food supply chains to control food safety hazards for more 10 years[1].

In the United States, the food traceability system is largely voluntary and driven by consumer demand. Because of BSE (bovine spongiform encephalopathy or mad cow disease), threats of bioterrorism etc. producers and consumers were induced to use the traceability system in the beef market (Maria L. et al., 2007). Compared with the American market, the system in the European Union (EU) is more developed (Liddell and Bailey, 2001). They use regulations to enforce the implementation of the traceability system in the food supply. Australia is one of the earliest countries to track beef by a traceability system in the European market (WANG Bo et al., 2007).

In recent years, many food safety incidents occurred in China. A typical event is the San Lu Milk Powder Event in 2008. It precipitated a halt in the buying of Chinese milk powder. Examples like this illustrate the necessity of setting up a food supply chain traceability system for monitoring and controlling food safety issues for public

1 EU and American began to use the traceability system in food industry for Bovine Spongiform Encephalopathy (BSE) since 1997.

safety.

1.2 Literature Review

EU General Food Regulations which have applied since 1 of January 2005, define traceability as the “ability to trace and follow a food, feed, food-producing animal or substance intended to be, or expected to be incorporated into food or feed, through all stages of production, processing and distribution”[2]. Supermarkets in Europe, such as Carrefour, use traceability systems to control the quality system of the goods (Diogo M. and Julie, 2009). This system can mitigate the risks of food safety. If something happens to the food in the market of Carrefour, they just need to check the system to find out where food is from and how many products constitute the origin. Someone called this information system the “F-F” system. That means it tracks and traces from ‘farm to fork’ (Dickinson et al., 2002).

Europe is the one of the biggest beef consuming markets. Every year, Australia exports thousands of tons of beef to European countries (WANG Bo et al., 2007). In order to ensure the quality of the beef, the whole traceability process includes suppliers, manufacturers, retailers and consumers. Even though the cow is cut into many pieces, consumers just need to keep the label code and can trace the origin of the beef on the internet very quickly.

For other agricultural foods, Europe’s Good Agricultural Practice (GAP) protocol for fruit and vegetables has evolved from its initial defensive role in trying to be an environmentally-friendly pesticide standard, into setting standards for traceability systems. If something happens to the vegetables or fruit, the authorities can track and trace theses goods through the supply chain immediately. During the period between 2000 and 2005, the European Union had passed traceability legislation (Alessandro Arienzo, Christian Coff and David Barling, 2008). At the same time, some advanced technologies are used in the track and trace system in EU, for example, Trenstar and Scottish Courage Brewing Companies from UK use the Radio Frequency Identification (RFID) technology to track wine containers (DU Wei, 2007). Some other technologies such as DNA technology, protein analysis technology, etc, are also

2 Regulation (EC) no. 178/2002 of the European Parliament and of the Council of Jan. 28, 2002. (Chapter V).

used in food supply chain traceability in Europe (SHI Xi-ju et al., 2006)

According to Elise and her colleagues (2003), traceability systems had developed a substantial capacity among the food firms in the food supply chain of United States. Here it is different from the European countries. The traceability systems are motivated by economic incentives instead of government regulations. But because of the threat of bioterrorism, the Food and Drug Administration (FDA) issued a regulation to compel the people who produce, process, pack, transport, distribute, receive or store in America, to establish and maintain records (Arni Petersen, 2004). These records must be available to FDA when they need - to inspect and copy. Some additional other acts and rules in United States are as follows: Country of Origin Labeling (COOL): The COOL affects the labeling of beef, pork, lamb, fish, shellfish, etc. Under the COOL, these records for exported products to United States must be kept for 2 years.

There are many other acts to be observed for food safety. So in America for beef, from farm to slaughter, from processing to distribution, every stage can be tracked and traced (LIU Ying and CHEN Li-cheng, 2003).

Since January 2004, many food safety hazards occurred in the US, for instance BSE, avian influenza and Newcastle Disease (P. Cheek, 2006), which caused the largest red meat recalls in the history of this country. If they didn't use a traceability system, the social loss would have been much larger.

Now let's turn to Canada. In January 2004, one of the biggest Canadian pork process companies began to use a pork traceability system (GUAN En-ping and ZHANG Yi-bing, 2006).This system can track and trace the pork within an hour to get the information of the pork from origin to the end. They use DNA technology as the detection method to implement the system.

As I mentioned above, Australia is one of the earliest countries to track and trace beef in the world. This traceability system is mandatory and they set up a National Livestock Identification System (NLIS) which can track and trace the livestock from birth to slaughter (MA Han-wu and WANG Shan-xia, 2006).

In New Zealand, every cow which is slaughtered has an ear tag (GUAN En-ping and

ZHANG Yi-bing, 2006). This ear tag identifies the cow. Cows which are from the same farm will have the same code. When the cows are shipped to the factory to be slaughtered, they will input the code into the computer. When the cow is slaughtered, cut into many pieces and weighed, the computer will give to each piece a unique label which includes a great deal of information such as; the code of the farm, weight, slaughter date, the code of this piece of meat, the type of livestock, etc. The factory will pass the information to a platform—E-cert system of New Zealand Food Safety Department. When these pieces are transported to the supermarkets or exported to other countries, we just need to input the label code into computer through the E-cert system, and then we can get information about the piece of meat. Nowadays, people begin to put computer chips into the stomach of cows instead of ear tags. This new technology is much better than the ear tag, which is easily lost or destroyed. So in Australia and New Zealand, the track and tracing system is very advanced.

In Asia, Japan is very famous for its food research. Because of BSE, the Cattle Traceability Law was issued in June 2003. (Roxanne Clemens, 2003). Consequently, a traceability system was also employed in December 2003 (Katsuaki Sugiura and Takashi Onodera, 2008). The Japanese government also enacted the cattle traceability Law over the whole country. Under this law, the cattle, including all bovine animals which are born in Japan, should be covered by the cattle traceability system. This system can not only trace the same batch, but can also trace their baby cattle within 24 hours. At the same time, it also can provide information about the journey from distributor to consumer. The law also provides an obligation for the cattle owners, importers, exporters and other people who are involved in the food supply chain to track and trace the beef. The technology and information used in the traceability system is the same as that in Australia and New Zealand. Using the ear tag with a unique identification number, we can track and trace the cattle or a piece of cattle through the platform which is provided by a National Livestock Breeding Center (NLBC) of Japan.

The Story in China is totally different. Almost every year in China, there is some food safety events that occur, for example, the San Lu Milk Powder Event in 2008.

More than 1200 babies got ill with kidney stones. This news shocked China. When they tried to track and trace the tainted milk, it was extremely difficult, because there is no traceability system for milk in China.

In May 2004, the Chinese government issued the aquatic product traceability regulation (GUAN En-ping and ZHANG Yi-bing, 2006). Although we have bar codes on most of products in China, the bar codes are not for tracking and tracing and only identify the name of the manufacturing factory and name of the product.

In recent years, lots of Chinese scientists have begun to research and try to establish a theoretical traceability system for China. LIN Ling and ZHOU De-yi (2005) give a theoretical construction of a food quality and safety traceability system in their research paper-Principals of Constructing and Benefits of Establishing a Traceability System - they provide a lot of detail about the system. YANG Tian-he and CHU Bao-jin (2005) also tried to set up a control system of food safety, which can be used for tracking and tracing in the food supply chain of China. In 2007, ZHANG Bing, HUANG Zhao-yu, et al., designed and implemented a vegetable quality and safety traceability system. In this paper, they used the network technology and European Article Numbering-Uniform Code Council (EAN-UCC) system to construct a traceability system for vegetables. YU Ping-xiang (2008) and his colleagues did some research on the food safety traceability system which is based on the Radio Frequency Identification (RFID) technology. They talk about how this technology is applied in manufacturing, processing, storage, transportation, etc, and how it brings advantages and convenience for quality control and management.

Now, in some cities like Shanghai and Beijing, consumers can track and trace pork on the internet if they use the food safety traceability code. When they input the code on the platform, they will know about the pieces of pork they buy - from which farm and which factory. Compared with the traceability system in EU, US, Australia, New Zealand, etc, the Chinese food traceability system is much less advanced (YANG Tian-he, CHU Bao-jin, 2005). The pork traceability system can only be used in some cities, and different cities have different traceability systems. This results in a waste of resources and less communication between different cites. They can not share the information.

1.3 Methodology

In this dissertation，the main work is to establish a framework for a national food supply chain traceability system. We will use some system models to design this traceability system. When we finish the design, we need to do an assessment of the traceability system. Then the failure mode and effect analysis model will be chosen to judge it. We just select some key indicators for a traceability system to be assessed in this model. At the same time, fuzzy synthetic evaluation model and intensity weighted average method will be used to rank the importance of these indicators. Lastly, a case study of the Green Pork Company will be used for the application of a food supply chain traceability system. In this case study, we will set up a pork tracking and tracing system for this company. Then we will calculate the total costs to establish a food supply chain traceability system in practice.

1.4 Structure of Thesis

There are six main chapters in this dissertation. The first chapter is an introduction to this system. Chapter 2 is about the necessity and importance of establishing a traceability system. The third chapter is about the establishment of a framework for the food supply chain traceability system. The main content in this chapter is looking for the right technology for a tracking and tracing system. Chapter 4 is about assessment of the traceability system. The main indicators: breadth, depth and precision will be tested by the failure mode and effect analysis (FMEA) model and ranked by fuzzy synthetic evaluation model[3]. Chapter 5 is the case study of the Green Pork Company in Shanghai. The case is a practical test to set up a traceability system for a company. Then we will give conclusions and suggestions in Chapter 6.

1.5 Restrictions

The thesis focuses on the idea of establishing a traceability system to ensure the food safety, but the biggest restriction is that we can’t put this idea into practice. Although we use the FMEA model to test the traceability system, the best way to check it is to practice in the real environment.

---

[3] The three main indicators are from E. Golan and her colleagues (http://www.ers.usda.gov).

CHAPTER 2
The Necessity and Importance of Establishing a Food Supply Chain Traceability System

2.1 Food Safety Incident

According to research by WHO (World Health Organization), millions of people fall ill every year and many die as a result of eating unsafe food. Taking diarrheal diseases as examples, they kill about 1.8 million children every year in the world, and most of these illnesses are caused by contaminated food or water. There are more than 200 diseases are spread by food[4]. Some experts of UN (United Nations) say that food safety is an issue for every country and all food consumers. Food safety incidents can be caused by many factors. They could be microbiological in origin, chemical, processing faults, product deterioration, etc.

As we introduced in the literature review, Australia and New Zealand, have a very advanced food supply chain traceability system. Every year, they have lots of food recalls. These next figures show the number of food recalls in these nations.

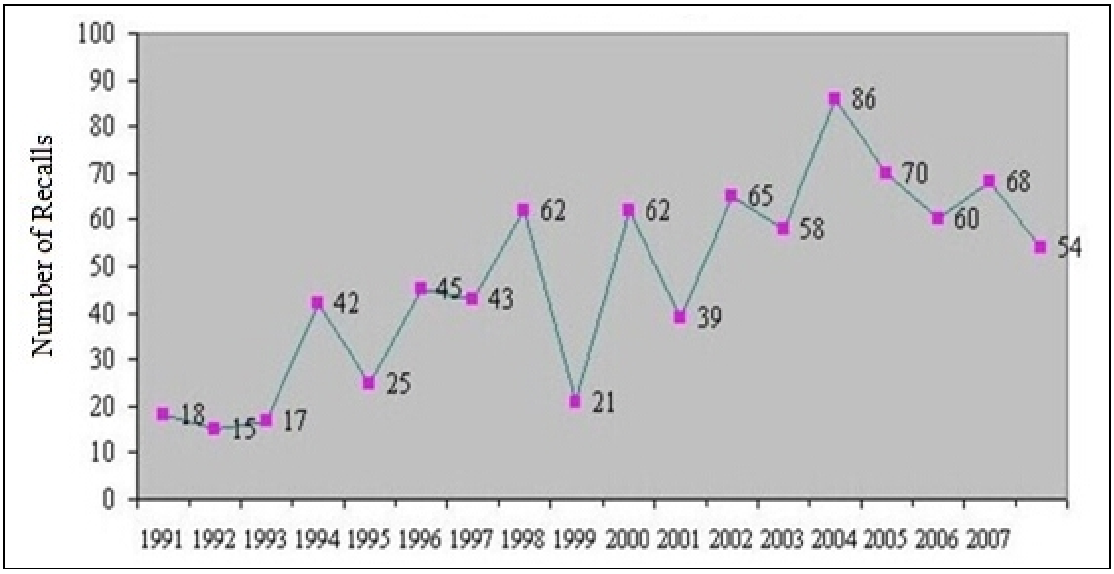

Figure 1. The Number of Food Recalls from 2001 to 2008 in Australia
(Source: Food Standards Australia and New Zealand)

4 The statistical numbers are from WHO website (http://www.who.int/topics/food_safety/en/).

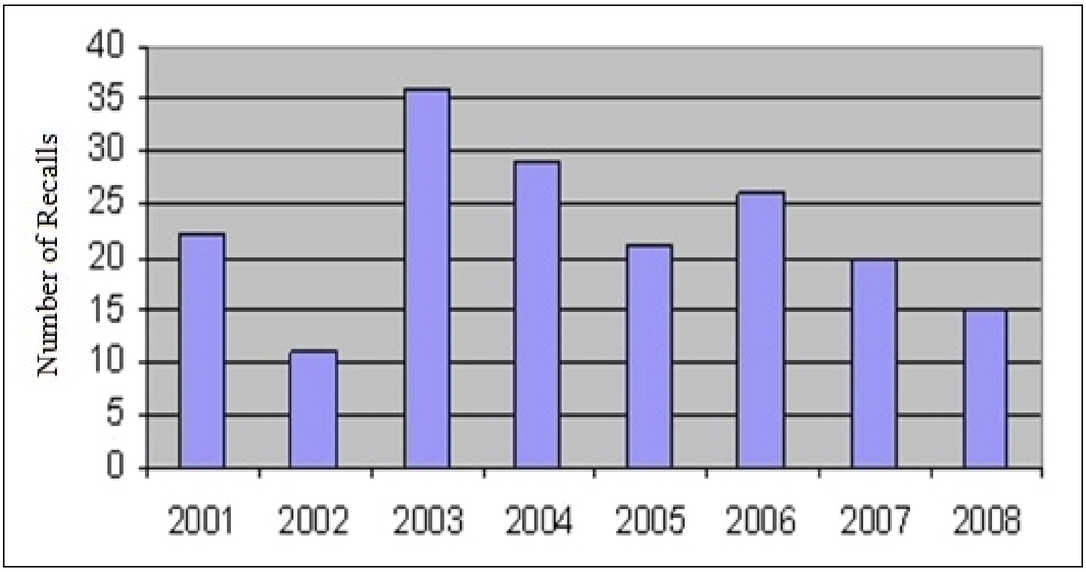

Figure 2. The Number of Food Recalls from 2001 to 2008 in New Zealand
(Source: New Zealand Food Safety Authority)

From the figure 1, we can see that the number of food recalls have been increased a lot. The number of recalls in 2007 is 54 which is 3 times as much as in 1991(18 recalls). Compared with Australia, the situation in New Zealand seems better. But we shouldn't forget the population in New Zealand is much smaller than Australia. The population in Australia is about 4 times larger than New Zealand, but in 2007 the number of food recalls in New Zealand was nearly half of Australia's.

The aim of this dissertation is to establish a framework of a food supply chain traceability system in China. So let's turn to Chinese food safety incidents in the recent years. The large Chinese food safety events recorded in this article are based on news reports. It is somewhat a general estimate, shown in figure 3. These big events include Soy sauce made from human hair event in 2004, Sudan I Red Dye in 2005, San Lu Milk Powder Events in 2008, etc. The number of food safety incidents has a tendency to increase. Although the number in 2008 shows a decline, the influence of these events is more powerful than before. San Lu Milk Powder Event caused a milk tsunami in China[5]. It greatly affected the milk consumption confidence of customers; it bankrupted San Lu Company directly. Then almost every milk company in China suffered large a loss in the fourth quarter of 2008. It gave all of the

[5] San Lu Milk Powder Event is also called the San Lu Contaminated Milk Event.

Chinese people who are involved in the food value chain a good lesson.

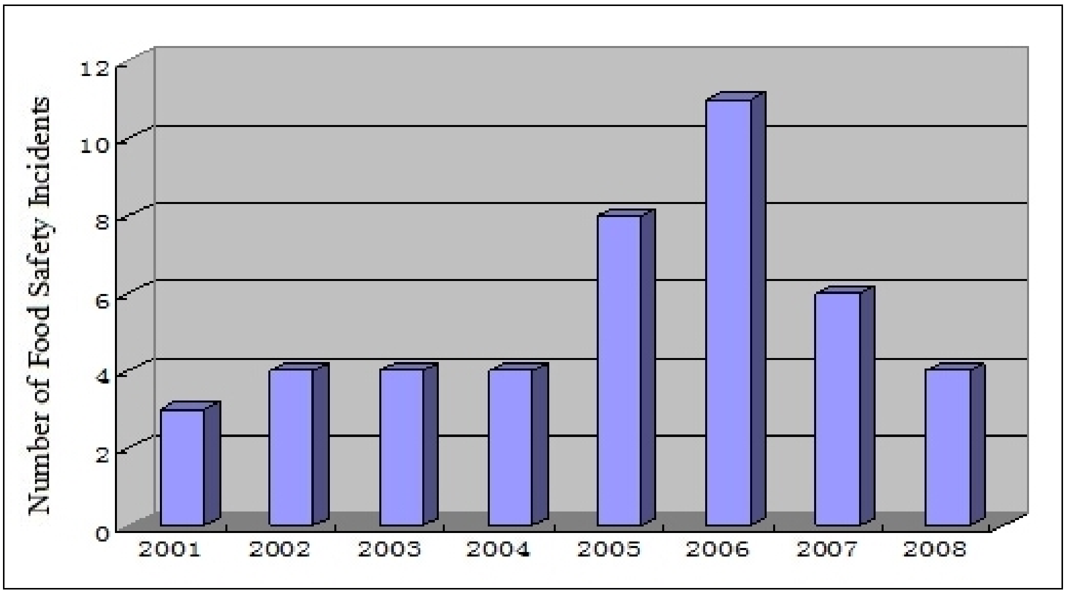

Figure 3. The Number of Big Food Safety Incidents from 2001 to 2008 in China
(Source: http://www.cmrn.com.cn/cygc/a/200811/682474.html)

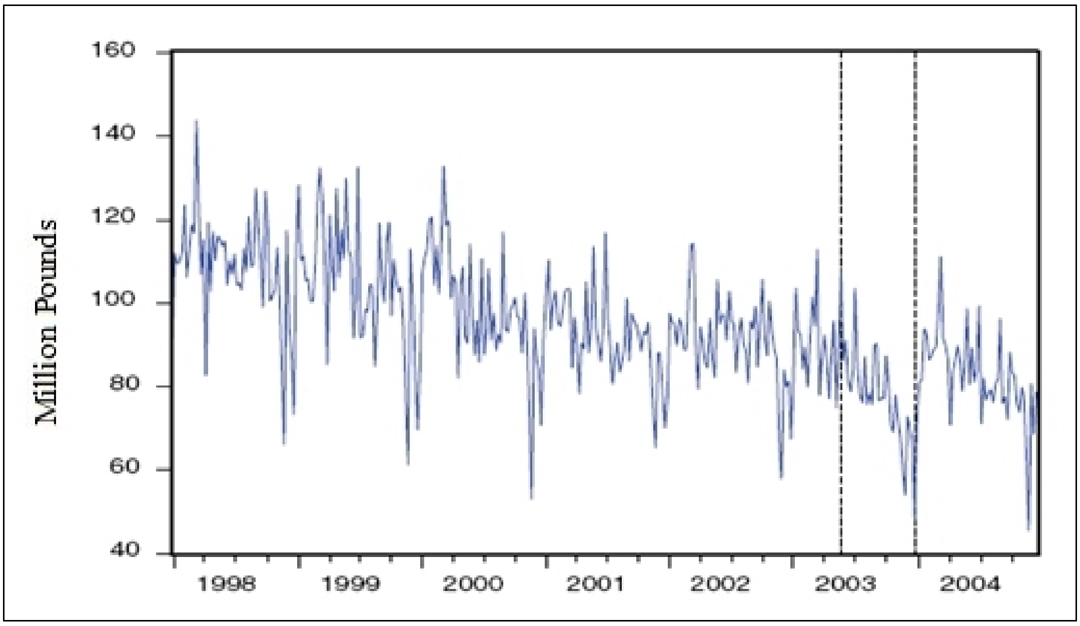

Figure 4. Weekly U.S. Purchase of Fresh Beef from 1998 to 2004
(Source: Economic Research Service/USDA)

Another typical case for this is BSE. Because of BSE, the consumption of fresh beef has dropped a lot since 1998. Figure 4 gives the weekly purchases of fresh beef in US from 1998 to 2004. Fresh beef purchases dropped by 5.2% per year between

1998 and 2004.

When the effect of the San Lu Milk Powder Event had gradually abated, another event - milk tainted with antibiotics - occurred in April, 2009. So we see that the war between consumers and food safety will never end. As WHO propounds on its website, one of key global food safety concerns is to have strong food safety systems in most countries to ensure a safe global food chain. The best way to achieve this is to have a food supply chain traceability system to track and trace the food for customers.

2.2 The Necessity and Importance of Establishing a Traceability System

ISO gives the definition of traceability as the "ability to trace the history, application, or location of that which is under consideration." The traceability system can help companies to control internal and external problems related to safety or quality of products. Some countries like America, Australia and New Zealand have their own food traceability systems to ensure the food safety.

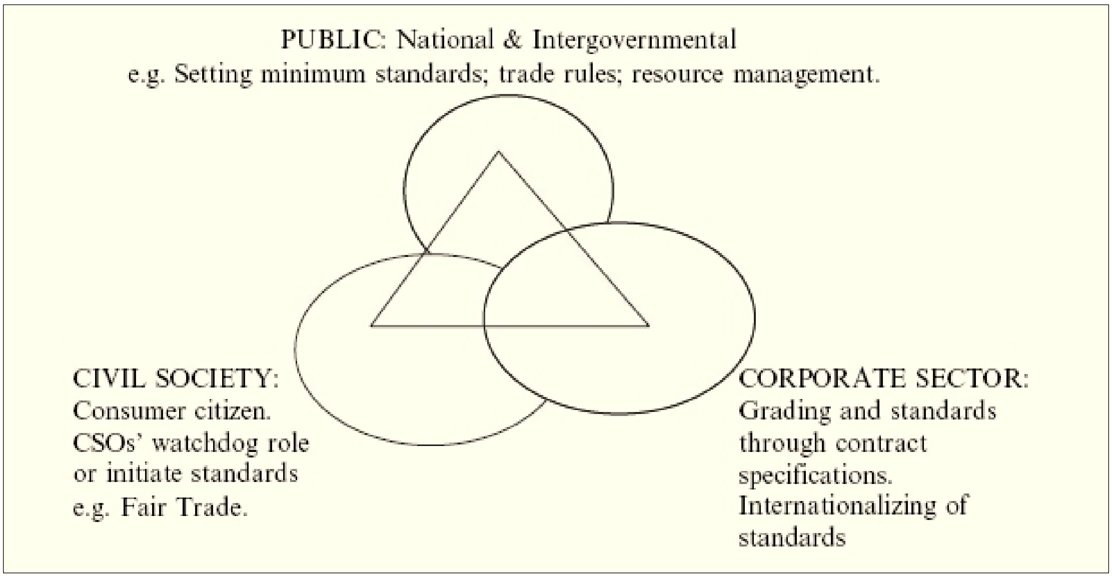

Figure 5. Food Governance – Overlapping Form
(Source: David Barling, 2008)

According to David Barling (2008), food safety should be governed by public, corporate and civil society sectors. The overlapping forms are shown in figure 5. So the traceability system should be the product of cooperation of the three sectors. So for food safety, the traceability is the key. We should use this key well to ensure the food safety. Some big supermarkets like Walmart, Tesco, etc, have used the traceability system back to their suppliers for many years. Since January 1, 2006, Walmart has tracked all its suppliers. The reason that they do this is to make sure the food they get and sell is safe for everybody.

More and more people are aware of the food safety issue. Every time there is a food safety incident, people just solve the particular problem at hand. This is not a sustainable way to control food safety. What we need to do is to find an effective way to prevent the food incidents. The food supply chain traceability system is just the right product for this. For external environments, the food supply chain traceability system can track and trace food between two nations. For internal traceability, it can track and trace the products from the farm to fork. Additionally, from the research of David M. McEvoy & Diogo M. Souza-Monteiro (2008), traceability systems can decline the total costs of a food safety incident by detecting the cause of the problem quickly.

So many food safety incidents occur in China. It is necessary to set up a food traceability system to give confidence to people to consume. So we need to establish a framework of a food supply chain traceability system to ensure food safety

CHAPTER 3
Establishment of a Food Supply Chain Traceability System

3.1 The Framework of a Food Supply Chain Traceability System

A food supply chain traceability system is a management process. This system will not only protect public health but also will provide other benefits that will increase consumer confidence. Depending on different kinds of food, we need to divide the food into different groups. They are as follows: fruit and vegetables, milk and eggs, meat. For different foods, we need to choose different technologies to track and trace the food from farm to fork. At the same time, we need to collect different information from different food groups. The method of applying food supply chain traceability systems to different groups from the beginning to end is almost same. When we establish these systems, we choose the same structure for those traceability systems.

3.1.1 The Structure of the Traceability System

For the traceability system, the main business is to deliver and record information during the different stages of the whole food supply chain. The key issue of the whole food supply chain is to track and trace products and data. The basic units of a food supply chain are pallets, packages and batches. So we define them as units of product (A.F.Bollen, C.P.Riden, N.R.COX, 2007). When we want to get information from products of a food supply chain, we need to track and trace every unit of product from suppliers, warehouses to buyers. According to the requirements of traceability, the following information needs to be recorded: where they have been; when they were shipped; how they were shipped. Paper records are easily lost or destroyed. But a database can avoid these risks. So it is necessary to establish a central database. The whole structure of a traceability system is as follows: The information such as location and name are collected and input. According to different stages of the whole supply chain, different information will be collected by this system. I will go on to talk about the information collection below.

3.1.2 The Content of the Traceability System

Figure 6 is just the main structure of the whole traceability system. Each different part of the food supply chain has many different contents supporting the chain (ZHANG Jian et al., 2008).

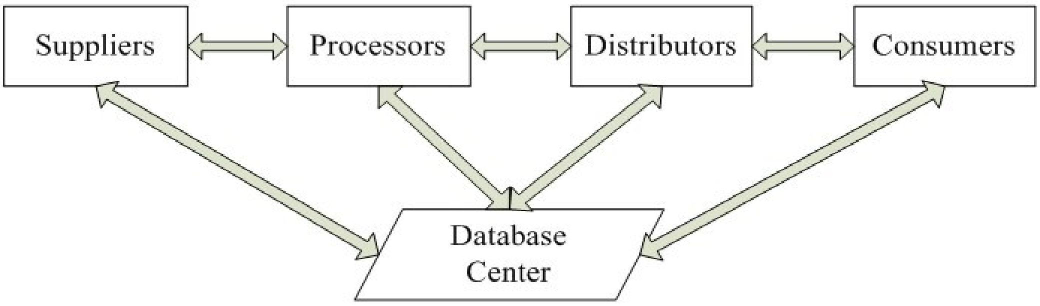

Figure 6. Basic Structure of the Traceability System

The supplier content is the starting point for the whole chain - food, like a baby that will be labeled when it comes to the earth. No matter if it is vegetable, pork or beef, it must have a farm system of inputs. This farm system is a collection of some management systems (figure7).

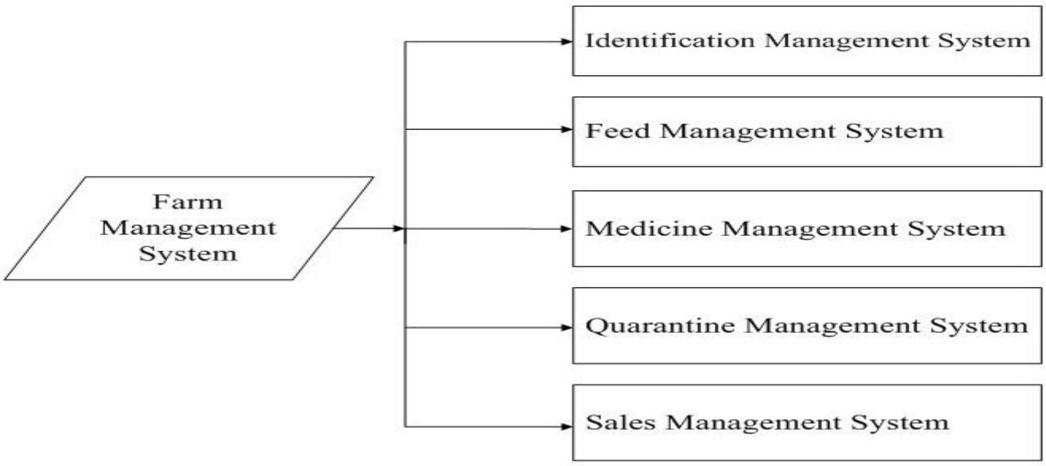

Figure 7. Main Supportive Systems of a Farm Management System

As figure 7 shows us, a farm management system contains five main supportive systems: identification management system, feed management system, medicine management system, quarantine management system and sales management system. From the farm stage, we need to assign an ID number to an ingredient. Under this ID number, we input information into the management system. This information will be passed through the whole food supply chain, even after the food is consumed the record is still kept in the system.

The processing management system is operated by a processing factory. When the ingredients arrive at a factory, they will be processed: such things as transport, washing, slaughtering, packing, etc (C.Shanahan et al., 2009). The supportive systems to the processing management system are as follows:

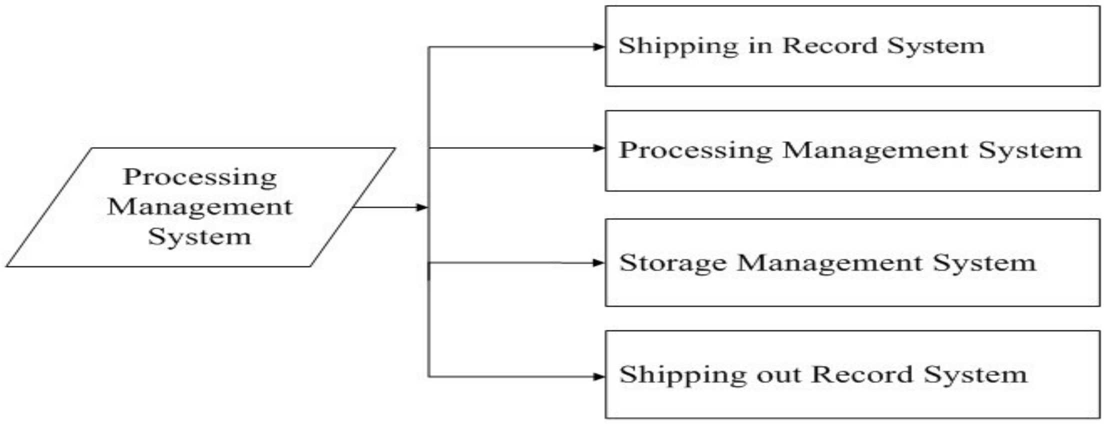

Figure 8. Main Supportive Systems of a Processing Management System

In this system, the main supportive system is the sub-management system of shipping, processing and storage. This system records what happens to the ingredients when they are shipped in and out of the processing factory.

Distribution management system doesn’t have any supportive child system, but it is a critical part of the whole food chain. It records where the processed foods come from and where they will go.

This management system is aimed at customers. The sales situation will be recorded in the system. When a safety issue happens to consumers, we can track the origin of the food through bar code or RFID chip which helps us to track the food chain. This system will tell us where the food comes from and we can control the harm swiftly at a minimum level.

3.2 Database Design for the Traceability System

Nowadays Structured Query Language (SQL) is widely applied in the supply chain database design. It is a database computer language designed for the retrieval and management of data in relational database management systems (RDBMS), database schema creation and modification, and database object access control management. So in this dissertation, the newest technology -Microsoft SQL Server 2008 will be used for the food supply chain traceability system.

3.2.1 Database Center: Microsoft SQL Server 2008

According to Microsoft Company's introduction, Microsoft SQL Server 2008 can help us to manage any data, any place and any time. It can provide the highest levels of security, reliability, and scalability. These features are needed for the traceability system. It is so close to our life and we have to make sure this system can give reliable information to the public. The platform vision of the technology is following.

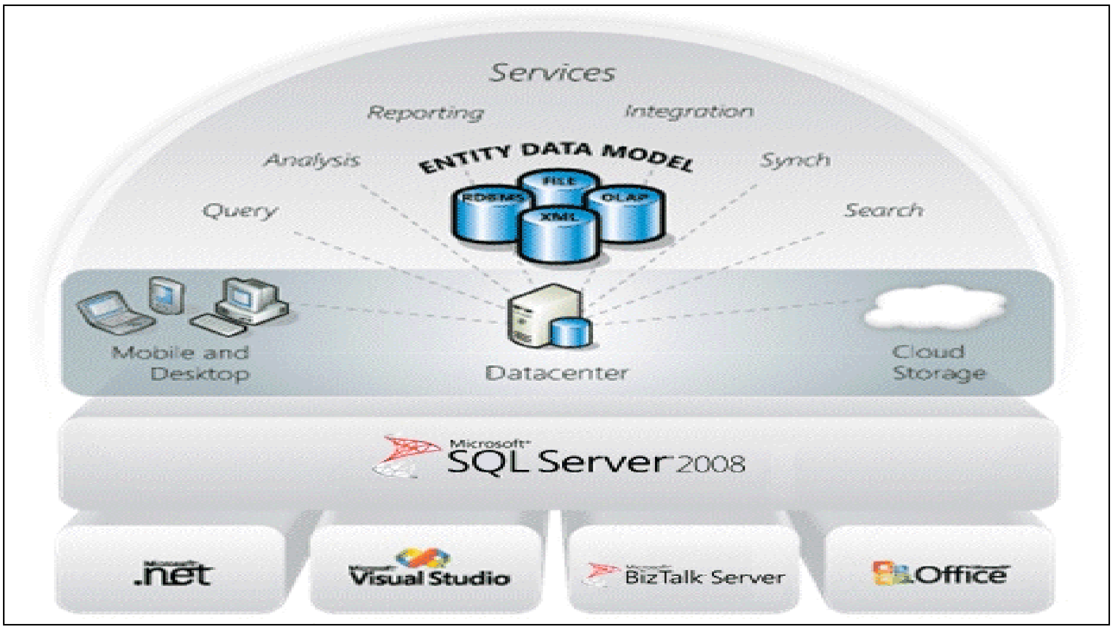

Figure 9. Microsoft Data Platform Vision
(Source: http://www.microsoft.com/sqlserver/2008/en/us/default.aspx)

This database centre not only provides internal service for users of the value chain, but also needs to provide service for external service to the public. From figure 9, we can see that it is very easy to get touch with the database centre through proven web technology which we have been using for many years.

3.3 Information Collection

The food supply chain traceability system is a system of information collection and integration. Producers or other units which are related to the food supply chain should have their information system able to connect with the database centre.

3.3.1 Brief Introduction of Information Collection Technology

A key requirement of the information collection of a traceability system is precision. Many technologies will be applied in this system. When we input information into the system, two different collection methods will be chosen. One is to use people to input the information which they get into the system. The other way is to use machines to get information, such as bar code readers. These machines can help people work faster and are more accurate.

3.3.2 Screening of Information Collection Technology

For screening information, the traceability system will do this automatically. When the system gets information from people or machines, it will allocate the information according to the system design. As I said above, this traceability system will provide a public service like checking safety issues for the products, so it will screen the information for the customer to give them what they want. For example, a customer from New York USA buys a piece of pork from a supermarket and now he wants to know where the piece of pork is from. So he can input bar codes into the platform and search the location, then he will get the answer: Auckland, New Zealand. The operation will be very simple and convenient for consumers. They needn't worry whether the food they will eat for dinner is from the unreliable black-market if we make the food supply chain traceability system for public.

3.4 Production Identification

Production identification is the basis for the whole food chain traceability system. In this system, production identification means tracking and tracing pallets, packages and batches of food. This will be similar to our ID card. On the ID card, we can get information like the ID number, age, gender and registration location. For food, the simplest information is location and production date which we can find from the labels or packages. If we have the traceability system, we can replace the paper record. So advanced identification technology will be used in the chain traceability system. Some typical technologies will be introduced.

3.4.1 Bar Codes

Bar codes are one of the most widely used technologies in our life. They have a good reputation for collecting information rapidly and accurately, so we can see them almost everywhere. Bar codes can provide a simple and inexpensive method of encoding text information which is easily read by some inexpensive machines. A bar code reader can decode a bar code by scanning when a light source goes across the bar code and light will be reflected back by the white spaces. It is shown in figure10.

Figure 10. Basic Structure of a Bar Code[6]
(Source: http://www.datacaptureinstitute.com/publications/book.htm)

In our daily life, UCC-EAN/13 bar code is the commonest bar code we get in touch with. The 13 in the name means it is a 13 digit code. Usually it is linked to the information of price for products. When we set up the bar code, we need to follow a format. As we see in the figure 11, the first 3 starting numbers are 692. That means this product is from China. Every country or area has its own starting numbers such as 690 to 695 for China, 300 to 379 for France.

Figure 11. UCC-EAN/13 Bar Code

The traditional bar code is limited by its storage space. This one dimensional bar code has a room only for about 30 bytes. When the food is transported from the farm to fork, lots of information will be recorded in the traceability system. Obviously, the one dimensional bar code is too limited, but the two dimensional bar code will meet the need. In this thesis, portable data file 417(PDF 417) bar code will be chosen for the chain track and trace. The PDF417 bar code consists of 3 to 90 rows, each of which is like a small linear bar code. The typical PDF417 bar code is shown in figure 12. This bar code can store up to about 1,800 printable ASCII characters or 1,100

[6] Quiet zone is the blank margin on either side of a bar code which can tell bar code reader should start or stop.

binary characters per symbol. PDF417 requires a 2-dimension scanner or laser scanner which is special decoding software. A wand scanner will not work. The normative standard for the PDF417 bar code is called ISO/IEC 15438:2001 from ISO International Standard.

Figure 12. PDF417 Bar Code
（Source: http://www.makebarcode.com/specs/pdf417.html）

3.4.2 Radio Frequency Identification (RFID)

Radio-frequency identification (RFID) is another technology to be used for identification (Freddy Brofman-Epelbaum, et al., 2007). It is similar to bar codes, but their principles are totally different from each other. As we discussed above, the bar code is based on optical theory. The RFID technology uses an object applied to or incorporated into a product, animal, or person for the purpose of identification and tracking using radio waves. All of these things are related to the RFID tag which can be read from several meters away and beyond the line of sight of the reader. Figure 13 shows a RFID tag.

Figure 13. RFID Ear Tag
(Source: http://img.alibaba.com/photo/214525481/RFID_Animal_Ear_Tag.jpg)

Each RFID tag has at least two parts: one is an integrated circuit for storing and processing information, modulating and demodulating a radio-frequency (RF) signal, and other specialized functions; the other is an antenna for receiving and transmitting the signal.

There are 2 different types of RFID tags. The first type is the active RFID tag. It contains a battery and can transmit signals autonomously. The Second type is the passive RFID tag. IT has no battery and requires an external source to activate signal transmission.

3.4.3 DNA Technology

With the development of biotechnology, DNA technology is also chosen for identification in the food supply chain traceability system. This technology is mainly applied in the meat supply chain. DNA identification uses an animal's DNA to identify itself from farm to fork in its products. This code is permanent and unique to each animal. It can be intact throughout the animal's whole life. This technology can help us to control safety issues when they affect to our food. When pigs or cows are shipped to the processing factory, they will be slaughtered and cut into many pieces. Sometimes pieces of different pigs from different farms will be mixed with each other, so at this time we need to keep samples which can help us to get its DNA. Then we just need to input the DNA information into computer and we can find out where it is from.

Figure 14 is a flow chart of DNA technology applied in pork supply chain traceability system in this dissertation. From the flow chart, we can see that we can get DNA from suppliers, processors to distributors. It is not necessary for customers to keep the pork sample for safety issues. So from distributors to customers, we can use UCC-EAN/13 and PDF417 bar codes to connect them together.

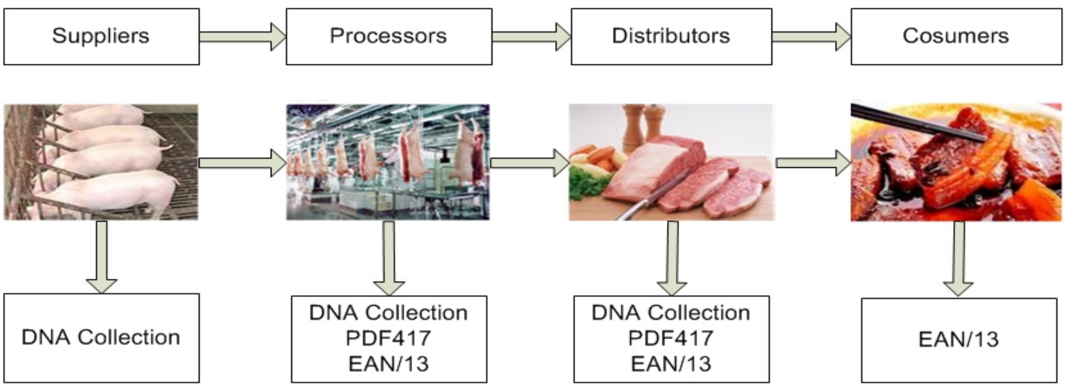

Figure 14. DNA Technology in Pork Supply Chain Traceability[7]

[7] This figure is designed by the author – ZHANG Jian-min.

3.5 Choice of Production Identification Technology

As we discussed, many technologies can be applied for production identification in the food supply chain traceability system. What kind of identification technology can we choose for production identification in this traceability? The answer is that different products will require different identification technologies. We will combine these technologies into this traceability system and let them work together.

3.6 The Whole Framework of a Food Supply Chain Traceability System

3.6.1 The Framework of the Traceability system

In figure 15, we can see that the whole traceability system is based on the SQL server 2008 platform which is the database center of the system. This database is not just for information storage, but it is also connected with a website which is the main communication path between the suppliers and the customers. One of the most important functions of the traceability system is to pass information. Here, from suppliers to consumers, all units on the food traceability chain are linked with each other by information. On the website, there are special portals which are open for access by the public. These portals are linked with the database center. In the food supply chain traceability system, technologies such as RFID, bar code, DNA, internet, etc. will be applied to the system. Depending on different needs, the traceability system will choose different technologies. The only point which we need to pay attention to, is to ensure that the technology for consumers to track and trace the food is the cheapest and simplest technology. Although we will use the RFID technology at the farm stage or processing stage, consumers will only use the UCC-EAN/13 bar code technology to trace the food through the website.

In this process, we will find out that the information passing between each unit on the supply chain and the database center is a two-way transfer. But the information between unit and unit, such as suppliers and processors is passed in single direction. The double-way transfer of information between units and database center can confirm the accuracy of information. Processors get information from suppliers and they can check the information with the database center to see if the information is right or wrong.

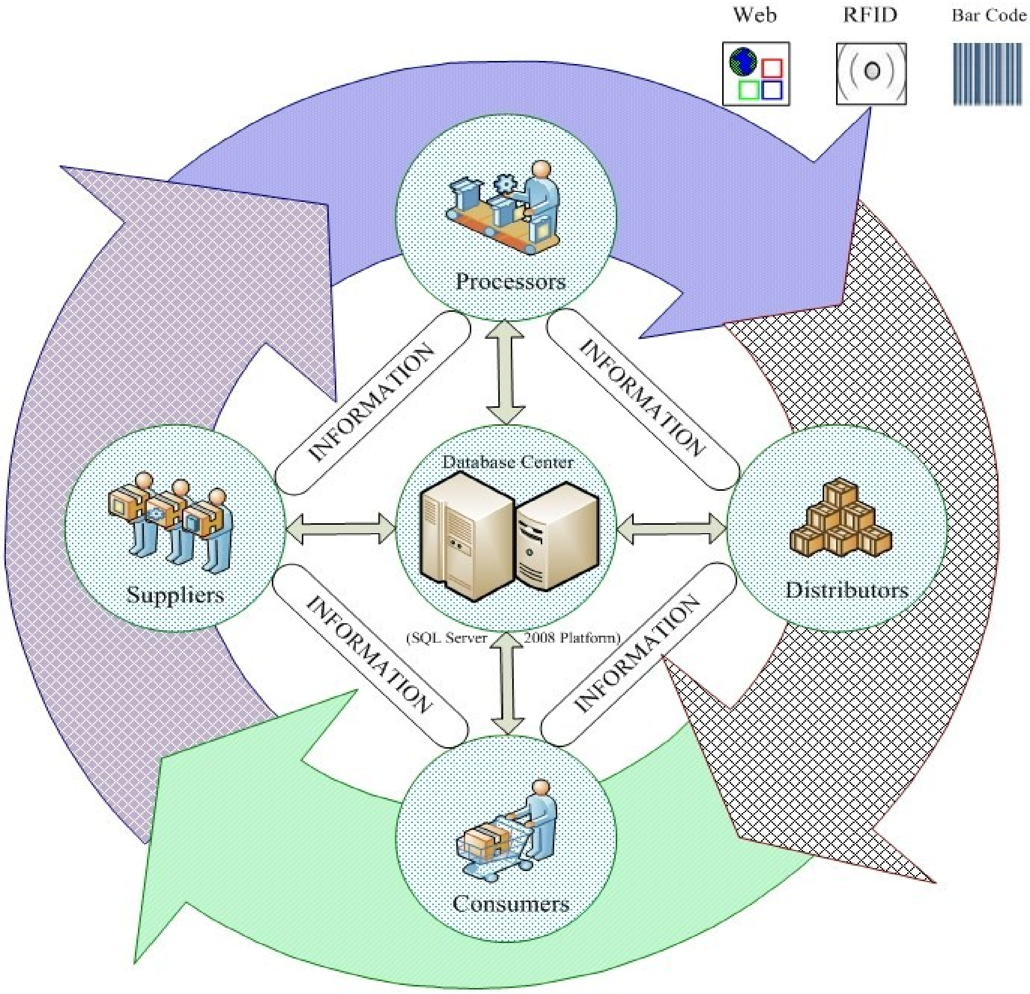

Figure 15. The Whole Process of the Food Supply Chain Traceability System[8]

3.6.2 Traceability Portals for Food

There are different portals according to different foods. The three main groups of food are the target groups that we want to track and trace in this system. So we will have three portals which are for: meat; fruits and vegetables; milk and eggs. They are presented in figure 16. We won't track and trace deep processed food, because deep processed food is packed very well and we can find the factory of origin from the package. If something wrong happens, we just need to go to the producing factory and check the goods record. But the factory should have the traceability system for their ingredients.

[8] This figure is designed by the author – ZHANG Jian-min.

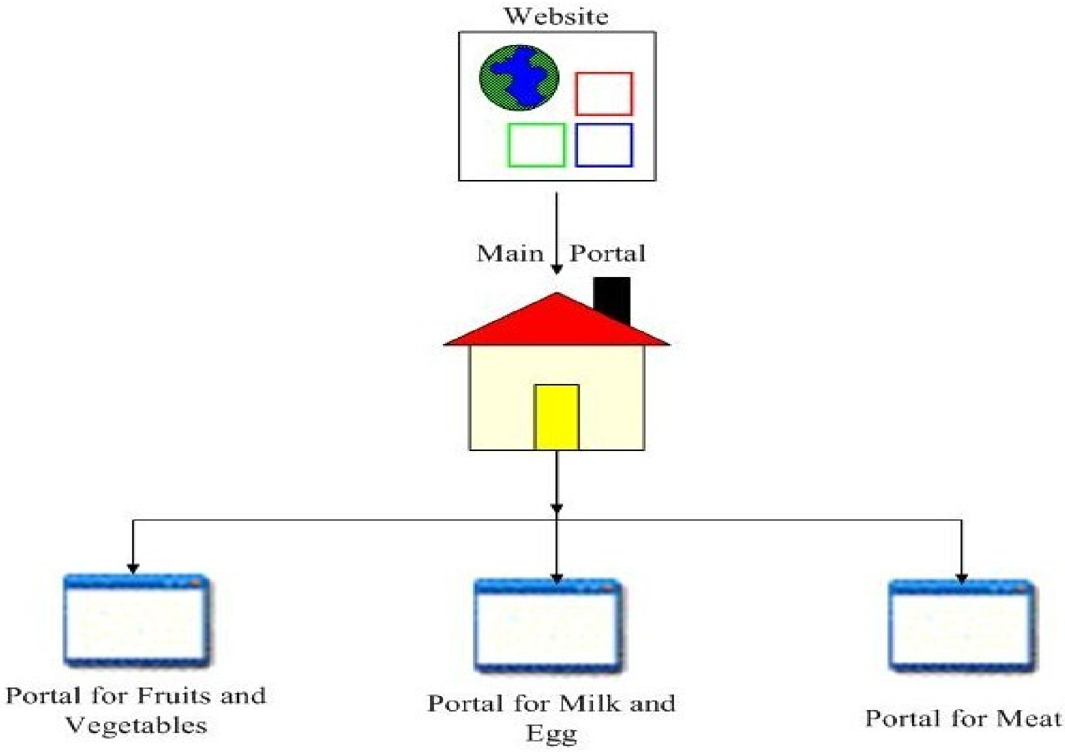

Figure 16. The Structure of Main Portals for the Service Website[9]

When people buy food in any of the three groups, they should keep the bar code number of the food. If they want information about the food, they just need to use the internet, go to the website, select the relevant portal and input the bar code number. If they don't have internet access, they can use the telephone. The service provider can apply for a special number for the service and write it on the label of the package. It can be free - such as numbers starting with 400 or 800 in China. This is convenient for people who are not familiar with the internet but also want to know about safety information of their foods.

3.6.3 The Main Functions of the Traceability

With the flow of information in the food supply chain traceability system, each unit of the value chain will begin to work. Now we need to focus on the database. This database can be used in many ways. The main functions are shown in the following figure 17.

We don't need to track and trace food everyday. But daily checking is important.

[9] This figure is designed by the author – ZHANG Jian-min.

Daily checking is to make sure of every part of the supply chain is working well. If something wrong happens to the food on the chain and some part of the chain is broken down, the damage to the integrity of the system is fatal. The traceability function and information service function are very basic requirements for this system (ZHANG Bing et al., 2007). If people who buy food from this value chain want to track and trace it, then the information service will come to meet his needs. Safety analysis and warning functions are close to each other. When workers do the daily checking, they should do some safety analysis[10]. If they find something is wrong according to safety analysis, they will pass the warning signals to each unit on the chain.

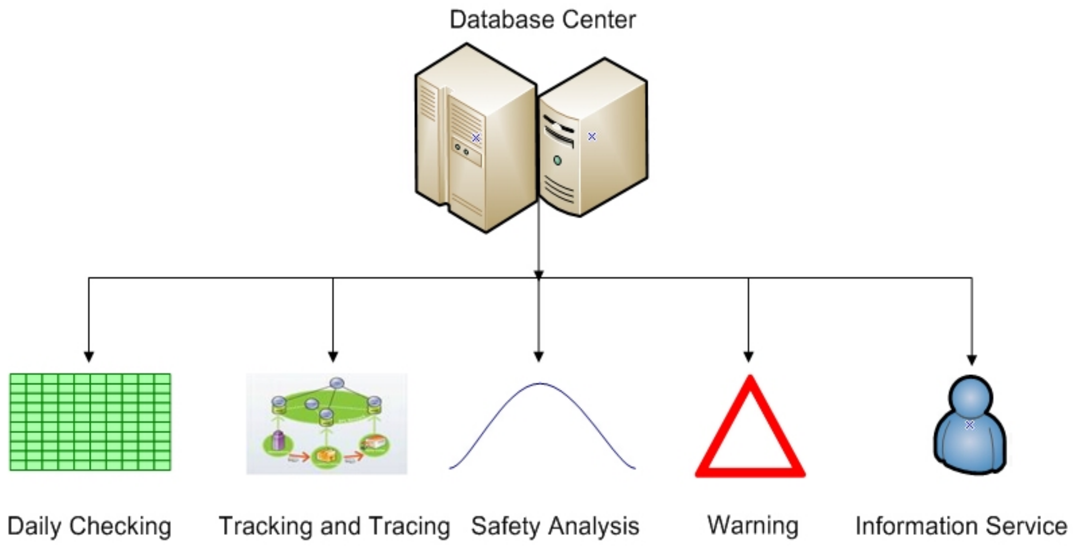

Figure 17. The Main Functions of Database Center[11]

[10] Safety analysis means analysis of potential food safety incidents according to the collected data.
[11] This figure is designed by the author – ZHANG Jian-min.

CHAPTER 4

Assessment of the Traceability System

4.1 Introduction of Requirements for Assessment of the Traceability System

How can we judge whether a traceability system is good or not? It must have a high information service level and guarantee a low occurrence of food safety incidents. According to Elise Golan, et al., (2004), three elements are very important to the food supply chain traceability system. They are breadth, depth and precision.

4.1.1 Breadth of the Traceability System

Breadth in the food supply chain traceability system means the amount of information which can be recorded and stored in the system. Moreover, breadth means how much information we will collect about each item. Taking pigs as an example, from birth to fork, a large amount of information will be kept in the system for tracking and tracing. Location of birth, name of farm, quarantine and test data, sales location, etc, almost everything about the pigs will be recorded.

4.1.2 Depth of the Traceability System

Depth is the second requirement for the traceability system. How far back or forward the system can track is the meaning of depth in this system. We know that some traceability systems only can tell you who are your suppliers or who are your buyers. However a food supply chain traceability system should be able to give a certain track and trace service to all the people who are involved in this value chain. The depth of this traceability system is to monitor food safety issues from farm to fork.

4.1.3 Precision of the Traceability System

Precision is another requirement for the supply chain system. When we provide an information service for the public, we must be sure all of information we give to them is correct and timely. If mad cow disease appears in a country, the government of that country wants to know where these sick cows are from and wants the supply chain traceability system to provide detailed information. If this system indentifies the wrong farm - which is in a province adjacent to the real sick cow farm - we can imagine what kind of a disaster it could create. False information is not just harmful to the system itself, but also wastes the public resource thus wastes money. More seriously, it will lead to the death o innocent people directly or indirectly. So for the traceability system, the precision is one kind of abilities to detect the problem and its cause and features accurately.

4.2 Assessment of the Traceability System

We know the three key requirements of the food supply chain traceability system now, and so we need to assess the three elements. Through the three elements, we will know whether the system is good enough or not, for food traceability. A new method-failure mode and effect analysis model (FMEA) will be used for the assessment. Then we will use fuzzy synthetic evaluation model and intensity weighted average method to check which requirement is the most important of the three.

4.2.1 Introduction of Failure Mode and Effects Analysis (FMEA) Model

Failure modes and effects analysis (FMEA) is a method for identifying all potential failures in a design, a manufacturing or assembly process, or a product or service (LI Lu-wen, et al., 2004; Julie Greenall, et al., 2007; P.-X. Thivel, et al., 2008). FMEA can integrate with design for manufacturing & assembly technologies, improve the quality, reliability, etc.

“Failure modes” means the method, or way malfunction may come about. Failures can be any errors or mistakes. The function of the part number is to allow for identification of exactly where or how a breakdown may have occurred. Usually, every component part number of a system is analyzed to determine its possible failure mode. Each part has many potential failure modes.

The other part -“Effects analysis” relates to the consequences of these failures. It analyzes the effects of the failures to the process, or a product or service.

On the basis of the principle of the FMEA, the failures will be judged by how serious these failures are, how frequently these failures occur and how easily these failures can be found. It is used to prevent problems from occurring and to take actions to reduce these failures.

4.2.2 Structure of Failure Mode and Effects Analysis (FMEA) Model

For Failure mode and effects analysis model, there are three basic concepts: severity rating, occurrence rating and detection rating. Severity of FMEA model means how serious it is if something is wrong in the system. We need to have a criterion to judge the seriousness for us. It is shown in table 1.

This severity rating is based on the assessment of the food supply chain traceability system. According to different levels, we will give different judgments to the system in traceability.

Table 1. Severity Rating Scale

Rating	Description	Definition
10	Dangerously high	The system is not reliable in traceability, and failure could injure customers without warning.
9	Extremely high	The system is not reliable in traceability, and failure is dangerous to customers with warning.
8	Very high	Loss of the main functions of systems in traceability.
7	High	The main functions of systems in traceability have some performance loss.
6	Moderate	Loss of the minor functions of systems in traceability.
5	Low	The minor functions of systems in traceability have some performance loss.
4	Very low	Failure can be overcome with modifications to the traceability system.
3	Minor	Failure has some effects to the system in traceability.
2	Very minor	Failure almost has no effects to the system in traceability.
1	None	No effects.

(Source: Adapted from: The Basics of FMEA, Productivity, Inc. Copyright 1996 Resource Engineering, Inc.)

Occurrence of FMEA Model refers to how frequently the failure will happen to the system. They also have the criteria for judgments for occurrence rating. As shown in table 2, the higher the rating is, the more easily the failure happens. Taking 10 rating as an example, it means failure is almost unavoidable. It could happen more than once per day or more than 3 occurrences in 10 events.

Table 2. Occurrence Rating Scale

Rating	Description	Definition
10	Very High：Failure is almost inevitable	More than one occurrence per day or a probability of more than three occurrences in 10 events.
9	High: Failures occur	One occurrence every three to four days or a probability of three occurrences in 10 events.
8	High: Repeated failures	One occurrence per week or a probability of 5 occurrences in 100 events.
7	High: Failures occur often	One occurrence every month or one occurrence in 100 events.
6	Moderately High: Frequent failures	One occurrence every three months or three occurrences in 1,000 events
5	Moderate: Occasional failures	One occurrence every six months to one year or five occurrences in 10,000 events
4	Moderately Low: Infrequent failures	One occurrence per year or six occurrences in 100,000 events
3	Low: Relatively few failures	One occurrence every one to three years or six occurrences in ten million events
2	Low: Failures are few	One occurrence every three to five years or 2 occurrences in one billion events
1	Remote: Failure is unlikely	One occurrence in greater than five years or less than two occurrences in one billion events

(Source: Adapted from: The Basics of FMEA, Productivity, Inc. Copyright 1996 Resource Engineering, Inc.)

Detection of FMEA Model measures how easy is it to detect a cause by failure. The higher rating is, the lower chance they will get to detect the cause which created a failure in the food supply chain traceability system. These ratings are listed in table 3. Using rating 4 and rating 5 as examples, if rating 4 just has 60% probability chance of discovering the cause, ratings 5 just has 50% probability chance of finding the cause.

Table 3. Detection Rating Scale

Rating	Description	Definition
10	Absolute Uncertainty	Can't detect a potential cause by failure
9	Very Remote	Very remote chance to detect a potential cause by failure
8	Remote	Remote chance to detect a potential cause by failure
7	Very Low	Very low chance to detect a potential cause by failure
6	Low	Low chance to detect a potential cause by failure
5	Moderate	Moderate chance to detect a potential cause by failure
4	Moderately High	Moderately high chance to detect a potential cause by failure
3	High	High chance to detect a potential cause by failure
2	Very High	Very High chance to detect a potential cause by failure
1	Almost Certain	Almost certainly detect a potential cause by failure

(Source: Adapted from: The Basics of FMEA, Productivity, Inc. Copyright 1996 Resource Engineering, Inc.)

4.2.3 Steps of Failure Mode and Effects Analysis (FMEA) Model

When we use the failure mode and effects analysis model to assess our system, process or design, we need to follow the steps of this model to control the quality of our products. Figure 15 shows us the whole process of this quality control and assessment model in use.

From figure 18, we can see that step 1 is to detect a failure mode and determine the failure modes which are based on the requirements and effects. In our supply chain traceability system, we have four main different parts: suppliers, processors, distributors and consumers. Now we name them successively as failure mode 1, failure mode 2, failure mode 3, failure mode 4. For an effect, we call it effect 1. Effect 1 could be caused by failure model 1, failure model 2, or combined with failure model 1 and failure model 2. Of course it also could be caused by model 3 or model 4. We just give an example here to see how the effect is caused.

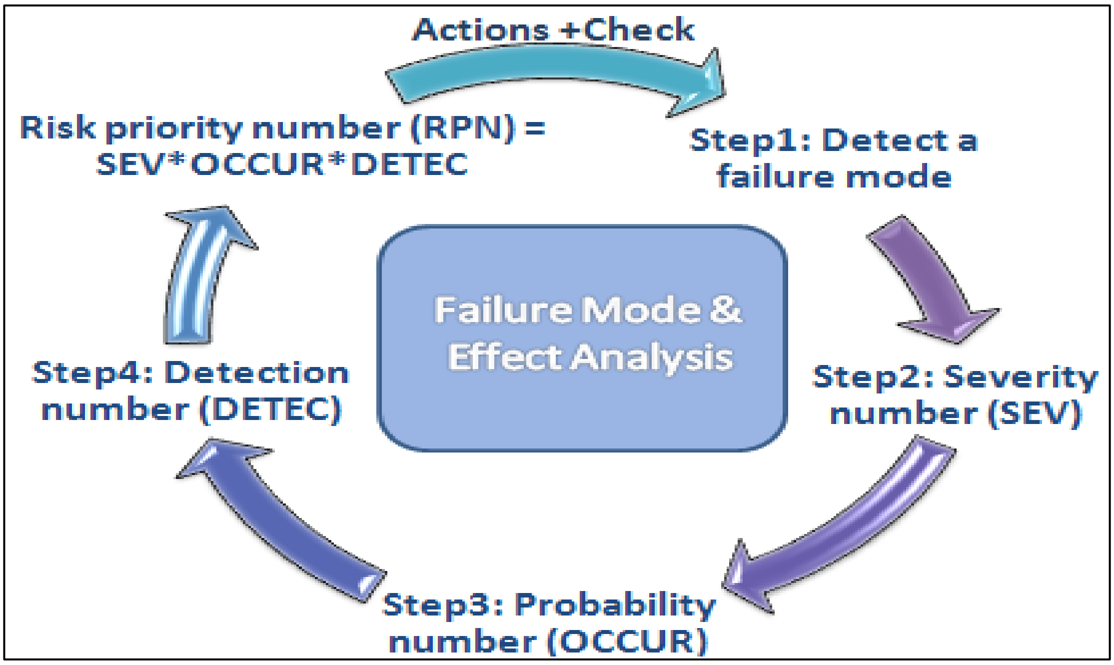

Figure 18. Steps of Failure Modes and Effects Analysis (FMEA) Model
(Source: http://en.wikipedia.org/wiki/Failure_mode_and_effects_analysis)

We introduced 3 key criteria for a food supply chain traceability system. Now we take the 3 key criteria as 3 different risks for the traceability system: breadth risk, depth risk and precision risk[12] (Table 4).

Table 4. Risk of the Traceability System

Number	Name of Risk	Description
1	Breadth Risk	Can't get enough information for the traceability system
2	Depth Risk	Can't provide the track and trace service from farm to forks
3	Precision Risk	Can't provide exact information of the traceability service

[12] When I use FMEA model to analyze breadth, depth and precision of the traceability system, they are called as risks. Then When I use the Fuzzy synthetic evaluation model, the three requirements will be called as factors.

Table 5. Assessment of Each Risk

Name	Severity Rating	Occurrence Rating	Detection Rating
Breadth Risk			
Depth Risk			
Precision Risk			

From step 2 to step 4, we need give the ratings to each risk according to table 1, table 2 and table 3. Most of the companies will choose the people who are related to the project which will be assessed by FMEA model, to give the ratings to each risk factor, but we will use a questionnaire to get the ratings for the traceability system. Usually this type of project will have 6 people working on it. But we chose 20 people to do the questionnaire[13]. We explained the whole supply chain traceability system, FMEA model to them, and then asked them to complete table 5. At the same time, we also provided table 1, table 2, table 3 and table 4 to them.

When we got the ratings for each risk from the 20 people, we calculated the average ratings for these risks. After that, according to picture 6, we need use severity rating, occurrence rating and detection rating to calculate the Risk Priority Number (RPN).

$$\text{RPN} = \text{Severity Rating} \times \text{Occurrence Rating} \times \text{Detection Rating}$$

We have got the formula of Risk Priority Number (RPN), but we need to explain what the RPN is and what we can do with the RPN.

RPN has no value or meaning in itself. It is the product of severity rating, occurrence rating and detection rating. The larger the RPN is, the higher priority the risk will get. But the largest RPN of the risk doesn't mean it has a more important position than other risks. So we have the RPN value of each risk, we must pay attention to them. When the risk gets the priority rating, we need to take action to reduce the risks of the chain traceability system. Taking action here means we need to do something to

[13] The reason we choose 20 people as a team to judge is that it will reduce the individual effects by using a wider sample and get more accurate information which will be used for the calculation in the FMEA model and Fuzzy synthetic evaluation model.

prevent the risk failure to the traceability system. It is not just based on the value of RPN, but also has to think about the severity, occurrence and detection. Sometimes we will the get same RPN from different severity, occurrence and detection values, and we will evaluate the whole risk and decide to take action or not.

4.3 Application of Failure Mode and Effects Analysis (FMEA) Model

Now we need to calculate the average ratings for each risk first and then get the outcome of a Risk Priority Number (RPN). When we finish those things above, we need to do something to reduce the risks of failures from the three indicators.

4.3.1 Calculation of Average Rating

Table 6. The Statistics of Risk of Breadth, Depth, Precision

Breadth Risk	Severity	Occurrence	Detection
1	1	5	1
2	3	6	1
3	5	7	2
4	1	8	3
5	2	9	1
6	3	7	1
7	4	9	3
8	1	9	1
9	2	7	2
10	1	8	1
11	6	6	3
12	5	5	1
13	1	7	2
14	1	8	1
15	2	8	2
16	1	7	3
17	2	3	1
18	3	6	2
19	1	9	3
20	2	4	3
Depth Risk	Severity	Occurrence	Detection
1	5	1	5
2	3	2	2
3	7	1	5

(Continued on next page)

(Continued from previous page)

4	4	3	1
5	3	3	1
6	3	3	2
7	5	3	4
8	6	2	4
9	4	5	3
10	3	2	2
11	2	2	5
12	4	2	7
13	3	2	1
14	6	3	4
15	5	1	2
16	3	2	4
17	2	3	4
18	5	2	3
19	7	3	4
20	5	2	3
Precision Risk	Severity	Occurrence	Detection
1	7	1	10
2	5	1	10
3	8	2	10
4	4	1	6
5	6	2	7
6	9	1	9
7	10	1	9
8	8	1	8
9	4	1	8
10	3	1	10
11	8	1	5
12	9	3	6
13	10	4	7
14	7	1	7
15	6	1	7
16	4	1	10
17	10	1	5
18	10	1	9
19	9	1	8
20	8	1	8

Taking the answers from the questionnaire we then get the average results as follows. All of numbers in the table are rounded. For example, 1.5 equals 2 and 1.4 equals 1. From table 6, we get the average rating of each risk (Table 7).

Table 7. Average Rating of Each Risk

Name	Severity Rating	Occurrence Rating	Detection Rating
Breadth Risk	2	7	2
Depth Risk	4	2	3
Precision Risk	7	1	8

4.3.2 Calculation of Risk Priority Number (RPN)

We use the formula to calculate the value of RPN in table 7 and figure 19. The RPN number is also rounded.

Table 8. Risk Priority Number (RPN) of Each Risk

Name	Severity	Occurrence	Detection	RPN
Breadth Risk	2	7	2	28
Depth Risk	4	2	3	24
Precision Risk	7	1	8	56

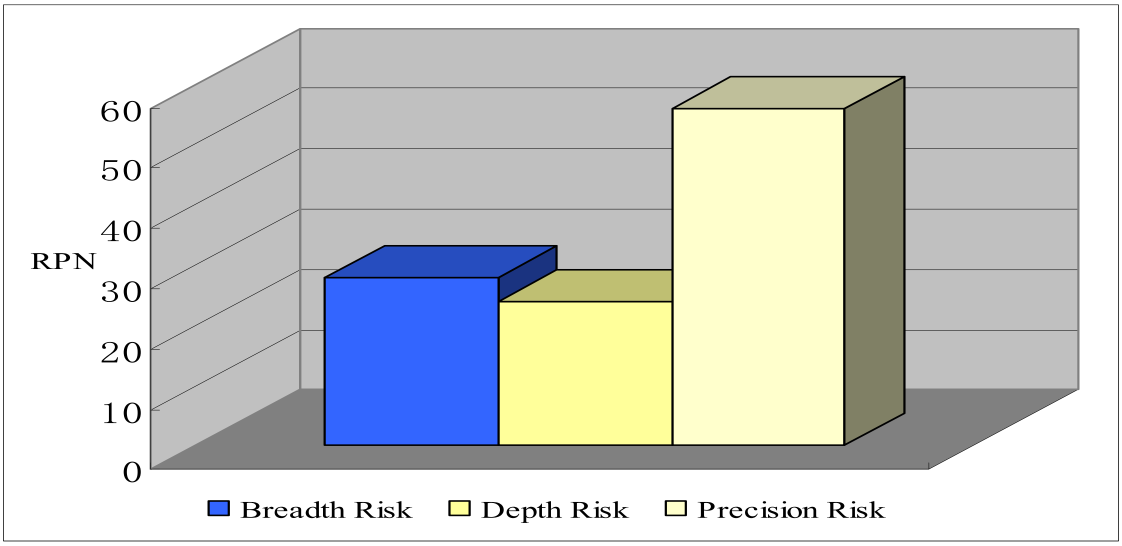

Figure 19. The Risk Priority Number (RPN) of Each Risk

4.3.3 Action Taking

According to table 7, we need to take action to prevent failures of breadth risk, depth risk and precision risk of the food supply chain traceability system. From table 8 and figure 19, we can see that the RPN of precision risk is the highest one. Breadth risk and depth risk take up the second and third position.

Precision Risk Analysis

Now let's deal with the precision risk first. In table 7, the three indicators are 7, 1 and 8. That means the failure of precision doesn't happen often. But if it happens to the system, the severity level is 7. Using table 1 as the standard, we know that if it happens, that means the main functions of the supply traceability don't perform well. And if it happens, from the scale of detection, we have a remote chance to detect a potential cause by failure. Although we needn't to take action because it seldom happens, we should take care when inputting data as accurate information is critical to the integrity of the system.

Breadth Risk Analysis

The RPN of breadth level risk is 28, but the each indicator has a big difference in performance. Both of the severity and detection scale are 2. The figure points out that when a failure of breadth happens to the system, the severity level is easily detected by the traceability system. But the rating of occurrence happens in every month. All of indicators tell us that the breadth of information is limited. We can't give the people all the information that they want. What can we do now? The only solution is to improve the process to collect as much information as we can, as wide as we can.

Depth Risk Analysis

The smallest RPN is depth risk. From its three ratings, we see that the failure of depth doesn't occur frequently. If a failure happens, it is also easily found. The severity to the system is quite small. So we needn't to take action to the depth risk. So from the analysis of the three RPNs, in order to prevent the failures of the three risks, we must pay attention to the precision and the breadth of information. But among the three risks, which one is most important one? Now we will use fuzzy synthetic evaluation model and intensity weighted average method to get the answer.

4.4 Assessment of the Three Factors by Fuzzy Synthetic Evaluation Model

Although we have used the FMEA model to assess the risks of breadth, depth, and precision, we still need to know which requirement or factor is the most important one to the traceability system. If we know the most important one, we will pay attention to the indicator when we establish the traceability system. Another new model-fuzzy synthetic evaluation model will be applied in the assessment. We will still use the data from the table 6.

4.4.1 The Brief Introduction of Fuzzy Synthetic Evaluation Model

Fuzzy synthetic evaluation theory is used for making decisions in complex systems when some problem is not clear (Min HUANG et al., 2008). The concept of fuzzy sets is introduced by Zadeh to describe something imprecise or vague[14]. Fuzzy set theory is regarded as one kind of classical set theories. The food supply chain traceability system is very complex, and we just choose three indicators to judge whether the system is good not. Actually a traceability system has many requirements, so it is fuzzy for the system when we just choose breadth, depth and precision. As shown in the figure 20, there are three factors for the traceability system and for each factor there are three elements-severity, occurrence and detection.

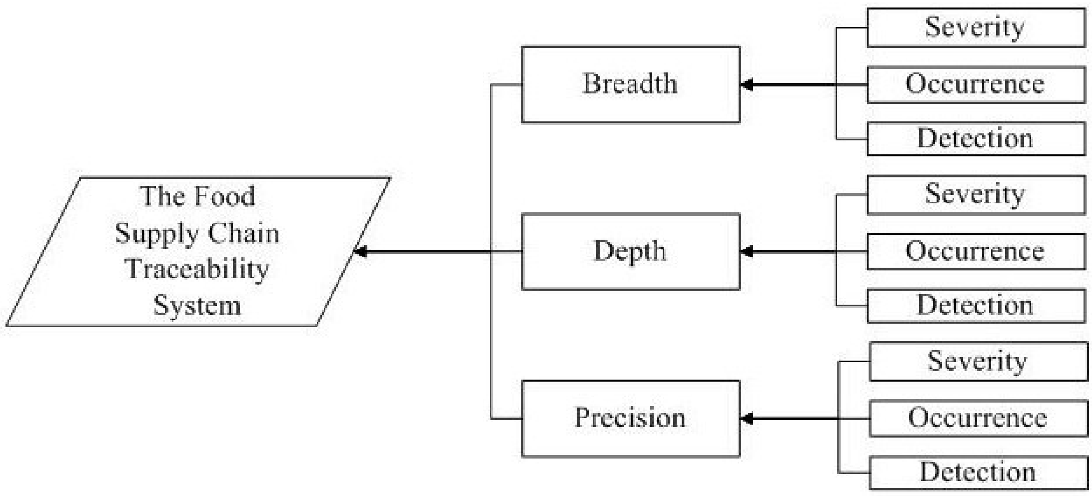

Figure 20. Index System for Evaluation of the Traceability System

[14] http://www.eecs.berkeley.edu/~zadeh/

4.4.2 Establish the Evaluation Set (V)

The aim of choosing the fuzzy synthetic evaluation model to judge the requirements of the traceability is that we want to know which indicators for customers are the most important, so we will not give any level scale such as good or not good for the evaluators' comments, but we will judge the elements by 10 levels which are from tables of rating scale of severity, occurrence and detection. Then we will use weighted average method to rank the three factors.

4.4.3 Establish the Factor Set (U)

In the assessment of the food traceability system, the factor set will be the three indicators, so the U set is as follows.

$$U = \{\text{Breadth, Depth, Precision}\}$$
$$u_i, i = 1,2,3$$

4.4.4 Establish the Element Weighting Set (W)

According to the figure 20, we have three elements for each factor. The three elements are from FMEA model, and they are very important to judge the three factors. So here we give them the same weight.

$$W = (w_1, w_2, w_3)$$
$$w_i, i = 1, 2, 3$$
$$\sum_{i=1}^{n} w_i = 1, n = 3$$
$$W = (0.3333, 0.3333, 0.3333)$$

4.4.5 Establish the Fuzzy Relationship Matrix (R)

The main use of the fuzzy synthetic evaluation model is to evaluate each factor in the factor set. The elements are used for judging the factors. We have 20 answers for each element of each factor. All of these answers belong to 10 level scales. Taking breadth as an example, for the element of severity, we have 8 people choose level 1, 5 people choose level 2, 3 people choose level 3, 1 person choose level 4, 2 people choose level 5 and 1 person choose level 6.[15] So we will get a fuzzy relationship matrix which is R_{ij}. .

[15] The aim to do the statistical work is for the normalization processing which can simplify the question and calculation.

$$R_i = (r_{ij})$$
$$i = 1, 2, 3$$
$$j = 1, 2, 3 \dots 9, 10$$

So we can get a matrix from the table as follows.

For Breadth: $R_1 = \begin{bmatrix} 8 & 5 & 3 & 1 & 2 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 2 & 3 & 5 & 4 & 4 & 0 \\ 9 & 5 & 6 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$

For Depth: $R_2 = \begin{bmatrix} 0 & 2 & 6 & 3 & 5 & 2 & 2 & 0 & 0 & 0 \\ 3 & 9 & 7 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 3 & 4 & 3 & 6 & 3 & 1 & 0 & 0 & 0 & 0 \end{bmatrix}$

For Precision: $R_3 = \begin{bmatrix} 0 & 0 & 1 & 3 & 1 & 2 & 2 & 4 & 3 & 4 \\ 16 & 2 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 2 & 2 & 4 & 4 & 3 & 5 \end{bmatrix}$

After normalization processing:

$$R_1 = \begin{bmatrix} 0.4 & 0.25 & 0.15 & 0.05 & 0.1 & 0.05 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0.05 & 0.05 & 0.1 & 0.15 & 0.25 & 0.2 & 0.2 & 0 \\ 0.45 & 0.25 & 0.3 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$R_2 = \begin{bmatrix} 0 & 0.1 & 0.3 & 0.15 & 0.25 & 0.1 & 0.1 & 0 & 0 & 0 \\ 0.15 & 0.45 & 0.35 & 0 & 0.05 & 0 & 0 & 0 & 0 & 0 \\ 0.15 & 0.2 & 0.15 & 0.3 & 0.15 & 0.05 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$R_3 = \begin{bmatrix} 0 & 0 & 0.05 & 0.15 & 0.05 & 0.1 & 0.1 & 0.2 & 0.15 & 0.2 \\ 0.8 & 0.1 & 0.05 & 0.05 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0.1 & 0.1 & 0.2 & 0.2 & 0.15 & 0.25 \end{bmatrix}$$

4.4.6 Calculation of the Matrix of Elements

First of all, we need to calculate for the matrix of elements (B_i,i=1,2,3), but we should remember the weight of elements set(W). So when we calculate Bi, we need to use the next formula.

$$B_i = W \times R_i$$
$$i = 1, 2, 3$$

So we can get:

$B_1 = W * R_1$

$B_1 = [0.280 \quad 0.167 \quad 0.167]$

So we can use the same way to B_2 and B_3.

$B_2 = [0.100 \quad 0.250 \quad 0.267]$

$B_3 = [0.270 \quad 0.033 \quad 0.033]$

4.4.7 Ranking the Three Factors

We have got the result of the evaluation of elements. Now we will use the intensity weighted average method to calculate the value of the three factors and rank them according to the result.

The formula of intensity weighted average method is as follows[16].

$$A_j = \frac{\sum_{j=1}^{m} b_j^{k} * j}{\sum_{j=1}^{m} b_j^{k}}$$

$$m = 1, 2, 3$$

$$k = 2$$

So for B_1:

$$A_1 = \frac{1*0.28^2 + 2*0.167^2 + 3*0.167^2}{0.28^2 + 0.167^2 + 0.167^2}$$

$= 1.6236$

We use the same way to calculate the B_2 and B_3 to get A_2 and A_3.

$A_2 = 2.4262$

$A_3 = 1.0435$

For the factors, we can get: A_1=Depth (2.4262)> A_2=Breadth (1.6236)> A_3=Precision (1.04435). From the ranking of the three factors, we can that the depth is the most important indicator for the food supply chain traceability system.

4.5 Conclusions

We use the failure mode and effects analysis (FMEA) model to judge this food supply chain system. We use breadth, depth and precision as the risks for the system in the FMEA model. From the result of the questionnaire, the design of the traceability system is as we expect, so we needn't to worry about it. It can give a quality safety tracking and tracing checking system for the public. What we need to

[16] k in the formula is a indeterminate coefficient which can reduce the effects of individual to the result.

do is to ensure the information which we input into the system is correct and collect as much information as we can, as wide as we can. At the same time, we use the fuzzy synthetic evaluation model and intensity weighted average method to know the depth factor is the most important factor of the three for the food supply chain traceability system. Actually, the depth is the commonest disadvantage for the food traceability system. Now we must take care of the depth of the traceability system. We should try our best to provide the best service for the consumers to trace the food from fork to farm to ensure the food safety.

CHAPTER 5 Case Study
Application of Food Supply Chain Traceability Systems in a Meat Supply Factory

5.1 Introduction of the Pork Supply Factory

We name the pork supply factory as Green Pork Company (GPC). Green Pork Company is a big pork supply factory which has a farm, a processing factory and a distribution center. On the farm, there will be 60,000 pigs a year going to the processing factory. In addition, 60,000 pigs from other farms not operated by GPC will come to the GPC processing factory. The average weight for each pig is about 150kg. Green Pork has a distribution center and their own logistics service to ship the pork from the processing factory to supermarkets, other markets and some other deep processing meat factories. Nowadays, the food safety issue has become more and more important than before, so people can be induced to buy the pork which is from companies with a good reputation. For example, People like to choose pork from Light Pork factory that has a meat supply chain traceability system. Customers can check the source of the pork they buy by using the internet. Although the price of pork from Light Pork is more expensive than Green Pork's, the market share in Shanghai China is about 25%. The market share of Green Pork is about 12%.

Now Green Pork also wants to have their own traceability system and hope it can help them to control the quality of their products. At the same time, they want to increase the reputation of their company and the confidence of customers' by using the traceability system. They also hope the total cost of this traceability system will be reasonable.

5.2 Establishment of a Traceability System for Green Pork Company

According to the methodology, we need to analyze the pork supply chain of the company first. Then we need to design a supply chain traceability system for this company. Meanwhile, we should choose the proper identification technology for different stages on the value chain.

5.2.1 The Pork Supply Chain of GPC

For Green pork, the processed pigs are from 2 places: one is their own farm; the other is other farms. The distribution paths of Green Pork are three destinations: supermarkets, other markets and deep processing meat factories. As discussed above, the whole process of pork supply chain includes 4 parts: farm, processing factory, distribution center and consumers. So the whole pork supply chain flow chart is as follows (Figure 21).

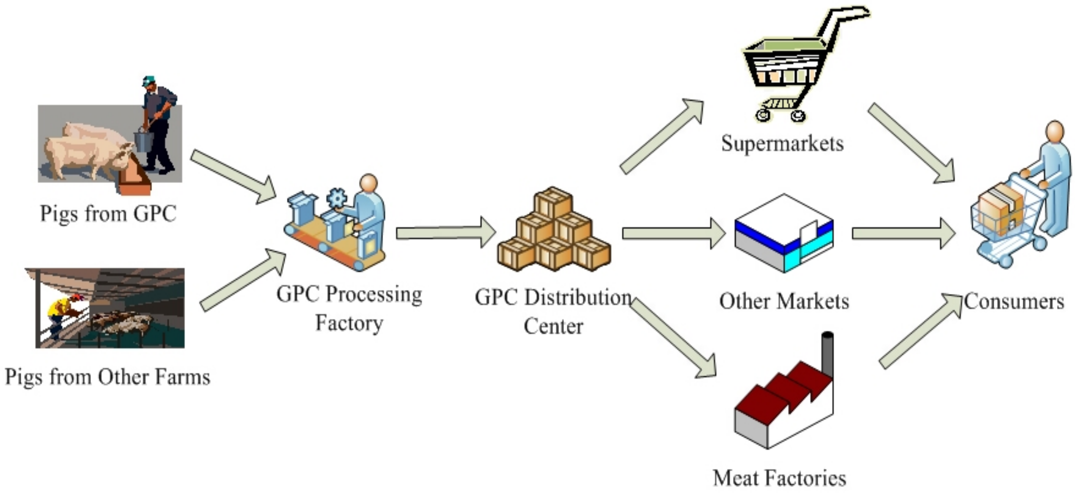

Figure 21. Whole Pork Supply Chain of Green Pork Company (GPC)[17]

5.2.2 Establishment of a Traceability System

For the traceability system, the most important thing is the data flow. In order to make sure that the information will be passed exactly from the last step, the information identification technology must be chosen properly.

From table 9, there are four stages on the value chain. In the different stages, different technologies will be chosen for tracking and tracing the pork. The database center we choose is the SQL Server 2008 Platform to do the information integration work. This system can support mobile facilities. At the same time, we need to design a website which can provide an information service for the public. Customers just need to input the bar code of the package into the portal of website to get the information that they want to know.

[17] This figure is designed by the author – ZHANG Jian-min.

Table 9. Technology Choice of the Traceability System in Green Pork Company

Stage	Technology Choice			
	RFID	EAN/13	PDF417	Internet
Farm Stage	√		√	√
Processing Stage	√	√	√	√
Market Stage	√	√	√	√
Consumer Stage		√		√

Farm Stage

As mentioned above, Green Pork source their pigs from two places: their own farm and other farms. The pigs from their own farm will be given an ear tag which has RFID chip inside. This ear tag can record the information of the pig from birth to the stage before being shipped to the markets. For the next steps, bar coding is required. So we need to put a bar code which is using the PDF 417 technology on the out side of the ear tag. When this pig is going to the processing factory, they still can use this bar code.

The pigs from other farms also can use the same technology. But the information recorded in the database will differentiate from pigs on their own farm.

Slaughtering and Transport Stage

When these pigs are shipped to the processing factory, the first thing is a check of information of these pigs which will be processed in the factory. The information is stored in ear tag and PDF bar code, so we just need to verify everything is the same as recorded in the database center. Then these pigs will be slaughtered and cut into several pieces. Now each piece needs to bar coded. But the bar code is different. For each piece, we will keep the PDF bar code which is the original one from the pig for each piece of this pig and use new code-EAN/13 bar code to give this piece a 2^{nd} label. On the delivering bill, we just use the EAN/13. The reason to keep the PDF bar code is for the intermediate businessmen such as supermarkets and deep processing factories to deeply track and trace the pork from GPC.

Distribution Stage

When the three main markets get the pork from Green Pork Processing Factory, they will use a portable bar code reader to get information from the PDF417 bar code and verify with data from database center. If everything is all right, they will get rid of these PDF bar codes from these pieces. They will not dump them until 3 months to 6 months later. This depends on the different companies. For example, for supermarkets and other markets, they will keep these things for 3 months. But for the deep processing factory, maybe they will keep them for 6 months or longer time. Then they will do some necessary processes like labeling and pricing. But these EAN/13 bar codes will be as same as the last stage.

Consumption Stage

When the customers buy the pork from these markets, they will see the bar code from the package of the pork. They just need to input the bar code into the selected portal of the website and they will get the necessary consumer information.

That's the whole track and trace system for the Green Pork Company. Now, Green Pork Company wants to know the cost of establishment for the track and trace system.

5.3 Economic Effect of Establishing a Food Traceability System

The establishment cost is very important to the traceability system (Alessandro Banterle, Stefanella Stranieri, 2008; Moises, 2006)). If the cost is too high, nobody wants to set up a traceability system for themselves, because companies don't want to spend too much on the system which will increase costs for them. Now let's study the economic effects of establishing a food traceability system.

5.3.1 The Cost of a Traceability System

For cost, we need have very clear mind about fixed cost and variable cost. In economics, fixed costs are business expenses that do not vary depending on the activities of the business. The biggest characteristic of fixed costs is that they tend to be time-related. In this case, the main costs of the traceability system are the cost of database center which includes machines and software. Variable costs are expenses that change in proportion to the activity of a business. They are costs that can be varied flexibly as conditions change. In other words, variable cost is the sum of marginal costs. They can also be considered normal running costs. The variable costs of the traceability system are these printed bar codes, ear tags and administrative overheads. The total costs for the traceability system are in table 10. In this table, we can calculate the fixed costs and variable costs over one year for GPC.

Table 10. The Costs of the Traceability System for Green Pork (Unit: Yuan)

Name	Type	Number	Brand	Value	Remarks
Database Center Software	Fixed	1	Microsoft	2,500,000 Yuan	SQL Server 2008
Computers and Peripherals	Fixed	5	Lenovo	50,000 Yuan	Computers, Cables, etc.
Bar Coder Reader (Portable)	Fixed	10	Gyong	4,000 Yuan	400 Yuan/One
RFID System	Fixed	2	Siemens	20,000 Yuan	10,000 Yuan/One
RFID Reader (Portable)	Fixed	10	Hongyu	5,000 Yuan	500 Yuan/One
PDF Bar Code Reader (Portable)	Fixed	5	Honeywell	5,000 Yuan	1000 Yuan/One
Bar Code Print Machine	Fixed	2	Shengde	3,600 Yuan	Also can print PDF Bar Code, 1,800 Yuan/One
Employee Salaries	Variable	2	None	10,000 Yuan/Month	
Ear Tag (RFID Chip)	Variable	10,000/ Month	Putexin	10,000Yuan/Month	1Yuan/One
Administrative Fee	Variable	None	None	200,000 Yuan	For one year
Additional Funds	Variable	None	None	300,000 Yuan	For One year

Note: 1. Additional funds are used to pay miscellaneous expenses.

2.The two employees are the software engineers for the maintenance and development of software.

5.3.2 The Economic Effect of a Traceability System

If we want to know the economic effect of a traceability system, we need to calculate the annual turnover of GPC and the total costs of a traceability system. At present the price of pork is about 14 Yuan/kg in Shanghai, China[18].

Annual Turnover of GPC

$$\begin{aligned}\text{Annual Turnover} &= \text{Numbers of Pigs} \times \text{Weight per pig} \times \text{price}\\ &= 120000 \times 150 \times 14\\ &= 252{,}000{,}000 \text{ Yuan/ Year}\end{aligned}$$

Total Costs of a Traceability System

$$\text{Total Costs} = \text{Total Fixed Costs} + \text{Total Variable Costs}$$

Annual Total Fixed Costs

From the table 10, we just need to add all fixed costs to get the total fixed costs of a traceability system.

$$\begin{aligned}\text{Total Fixed Costs} &= 2{,}500{,}000 + 50{,}000 + 4{,}000 + 20{,}000 + 5{,}000 + 5{,}000 + 3{,}600\\ &= 2{,}587{,}600 \text{ Yuan}\end{aligned}$$

But the total fixed costs will not be taken into account just in one year. These facilities will be depreciated. So we take 5 years as a period for the depreciation. So the total fixed cost for each year is just one fifth of the initial outlay.

$$\begin{aligned}\text{Annual Total Fixed Costs} &= \text{Total Fixed Costs}/5\\ &= 2{,}587{,}600/5\\ &= 517{,}520 \text{ Yuan/Year}\end{aligned}$$

Annual Total Variable Costs

From the table10, annual total variable costs are the sum of the each variable cost in the table.

$$\begin{aligned}\text{Annual Total Variable Costs} &= 10{,}000 \times 12 + 10{,}000 \times 12 + 200{,}000 + 300{,}000\\ &= 740{,}000 \text{ Yuan}\end{aligned}$$

$$\begin{aligned}\text{Annual Total Costs} &= \text{Annual Total Fixed Costs} + \text{Annual Total Variable Costs}\\ &= 517{,}520 + 740{,}000\\ &= 1{,}257{,}520 \text{ Yuan/ Year}\end{aligned}$$

But if we say annual total fixed costs, it will confuse someone. So from here we just

[18] The price of pork is from Shanghai Price Information Service Network (http://www.wj.sh.cn) in April, 2009.

say total fixed costs and total variable costs instead of the annual total fixed costs and the annual total variable costs. Figure 22 is the percentage of total fixed costs and total variable costs of total costs. The percentage of total fixed costs is about 41% which is smaller than the total variable costs (59%).

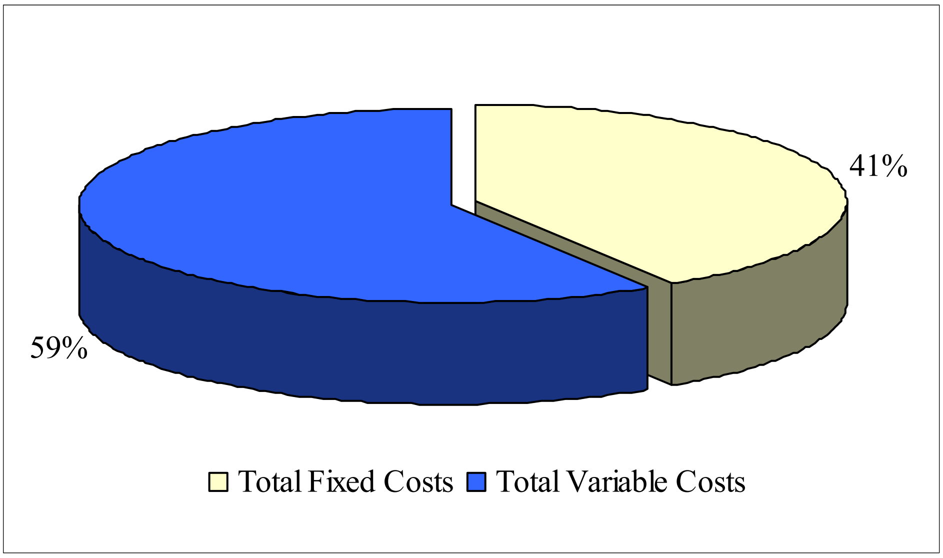

Figure 22. Percentage of Total Fixed Costs and Total Variable Costs

Compared with annual turnover of Green Pork Company, the total costs take up 0.50%.

$$\text{Total Costs/ Annual Turnover} = 1{,}257{,}520/252{,}000{,}000$$
$$= 0.50\%$$

But how much money do we need to spend more on each pig and how should we price the pork?

$$\text{Total Costs/ Number of Pig per Year} = 1{,}257{,}520\ /120{,}000$$
$$= 10.48\ \text{Yuan/Pig}$$

$$\text{Total Costs/ (Number of Pig per Year} \times \text{Average Weight of Each Pig)}$$
$$= 1{,}161{,}520\ /(120{,}000 \times 150)$$
$$= 0.07\ \text{Yuan/Kg}$$

That means they will spend more 10.48 Yuan on the each pig in order to establish the pork supply chain traceability system. Thus, they need to increase the price of pork by 0.07 Yuan to earn the cost back.

5.4 Conclusions

From the calculation of the costs on the each pig, we know that when we set up traceability the price of pork will increase. But it just increases by only 0.07 Yuan per kilogram. Although this figure is an estimate, it is still less than 0.1 Yuan/kg. If the customers know the pork has a safety guarantee, they will be willing to pay this 0.07 Yuan - even 0.1 Yuan extra per kilogram. Green Pork Company can use this traceability system as their advertisement for their products. This system will attract more people to buy their products. This is very good way to increase their market share. It is a “win-win” situation for the company and their customers.

CHAPTER 6 Conclusions and Suggestions

Many countries, have established a food supply chain traceability system to guarantee the food safety issue. Taking New Zealand for example, they have a National Livestock Identification System (NLIS) to track and trace the livestock from birth to slaughter. But with technology development, more and more new technologies will be applied to the traceability system. In this dissertation, we choose the SQL Server 2008 as the basis of traceability platform. PDF417 bar code technology and RFID identification are also used. In addition, suppliers, processors, distributors and consumers - each part on the value chain - can communicate with each other through this platform.

In order to make sure this system can work well, we use the failure mode and effect analysis model to test three basic and vital requirements of a traceability system. They are the breadth of information, the depth of tracking and tracing ability, the precision of information. From the result of FMEA model, we have enough confidence with the establishment of the traceability system. We needn't worry about the three risks too much. What we should do is to pay close attention to the information we input into the system. We must check and double check the information that we get from each unit to assure customers of information's authenticity. At the same time, we should collect as much as information as we can, as wide as we can, then we can provide better service for the public.

Moreover, we use the fuzzy synthetic evaluation model and intensity weighted average method for analysis, and we find that the depth factor is the most important factors of the three for the food supply chain traceability system. For almost every traceability system, the depth factor is always a big disadvantage. It is really very difficult for suppliers to track the food from farm to fork and for consumers to trace the food from fork back to farm. What we can do is to take care of depth of the traceability system and try our best to provide better service for consumers. Additionally, we also need to pay attention to the other two factors when we set up our food supply chain traceability to ensure the food safety.

Although we just studied one case of Green Pork Company, we can see that the total cost to establish a whole process traceability system is reasonable. It only increases the price of pork by 0.07Yuan/kg which is less than 0.1Yuan/Kg. This is negligible for customers. But this is just tracking and tracing in pork industry. We anticipate this system can be used for three different group foods: fruits and vegetables, milk and egg, meat. The basic structure of the traceability system for each group food is the same. So we just need to design different portals on the website for different group food. Although we don't use DNA identification technology in the traceability system of Green Pork Company, if we track the food such as egg and milk, we can apply the DNA technology in the traceability system.

Then we just design a system specific to a company. The best way is that government can design and provide the traceability service for the public. We need the food traceability system to control quality and safety of food (Norbert Hirschauer, Oliver Musshoff, 2007; Gregory Scott Bennet, 2008). It benefits her national citizens. The breadth of information, the depth of tracking and tracing ability and the precision of information will be more reliable for the consumers.

In the final analysis, it is imperative to have a traceability system for food safety. Every year on the earth, because of food safety issues, we lose lots of lives and millions of dollars. My dissertation selected a simple case study of the Green Pork Company, as a government study is beyond the scope of this research. However, I hope my paper can inspire someone who can design an effective food nation-wide supply chain traceability system and put it into practice.

REFERENCES

A.Bechini, M.G.C.A. Cimino, B. Lazzerini, F. Marcelloni, & A. Tomasi. (2005). A general Framework for food Traceability. *Proceedings of the 2005 Symposium on Applications and the Internet Workshops* (pp.366-369). Washington, DC: IEEE Computer Society.

A.F.Bollen, C.P.Riden, N.R.COX. (2007). Agricultural supply system traceability, Part I: Role of packing procedures and effects of fruit mixing. *Biosystems Engineering, 98*, 391-400.

Alessandro Arienzo, Christian Coff, & David Barling. (2008). The European Union and the Regulation of Food Traceability: From Risk Management to Informed Choice? *Ethical Traceability and Communicating Food* (pp.23-42). Dordrecht, Netherlands: Springer Netherlands Press.

Alessandro Banterle, Stefanella Stranieri. (2008). The consequences of voluntary traceability system for supply chain relationship. An application of transaction cost economics. *Food Policy, 33*, 560-569.

Arni Petersen. (2004). *Status of Food traceability in the European Union (EU) and United States of America (US), with Special Emphasis on Seafood and Fishery Products.* Published master's thesis, Danish technical University (DTU), Lyngby, Denmark.

C.Shanahan, B.Kernan, G.Ayalew, K.Mcdonnell, F.Butler, & S.Ward. (2009). A framework for beef traceability from farm to slaughter using global standards: An Irish Perspective. *Computer and Electronics in Agriculture, 66*, 62-69.

David Barling. (2008). Governing and Governance in the Agri-Food Sector and Traceability. *Ethical Traceability and Communicating Food* (pp.43-62). Dordrecht, Netherlands: Springer Netherlands Press.

David M. McEvoy, & Diogo M. Souza-Monteiro. (2008). Can an Industry Voluntary Agreement on Food Traceability Minimize the Cost of Food Safety Incidents? *The Organized Session on the "Economics of Traceability" at the XIIth Congress of the European Association of Agricultural Economics Association*, Gent: European Association of Agricultural Economics Association.

Dickinson, David L., & Bailey, Deevon. (2002). Meat Traceability: are U.S. consumers willing to pay for it? *Journal of Agricultural and Resource Economics, 27* (2), 348-364.

Diogo M. Souza Monteiro, & Julie A. Caswell. (2009). Traceability adoption at the farm level: An Empirical Analysis of the Portuguese per industry. *Food Policy, 34*, 94-101.

DU Wei. (2007). Application of RFID in Food Safety Traceability System. *Food Science and Technology, 2*, 25-28.

Elise Golan, Barry Krissoff, Fred Kuchler, Ken Nelson, Greg Price, & Linda Calvin. (2003). Traceability in the US Food Supply: Dead End or Superhighway? *CHOICES, 18*, 17-20.

Elise Golan, Barry Krissoff, Fred Kuchler, Linda Calvin, Ken Nelson, & Greg Price. (2004). *Traceability in the USA Food Supply.* Retrieved April 5, 2009 from the World Wide Web: http://www.ers.usda.gov/publications/aer830/aer830.pdf.

Freddy Brofman-Epelbaum, & Luis Kluwe Aguiar. (2007). Tracking and Tracing Food Products with RFID Technology: an application for agricultural commodities? *17th Annual Forum and Symposium IAMA Conference*. Parma, Italy: International Food and Agribusiness Management Association.

GUAN En-ping, & ZHANG Yi-bing. (2006). Studies on Implementation of Food Traceability Management. *Chinese Journal of Food Hygiene, 18*(5), 449-452.

Gregory Scott Bennet. (2008). *Identity preservation & traceability: the sate of art-from a grain perspective (status of agricultural quality systems/ traceability/ certification systems).* Published Doctor's dissertation, Iowa State University, Ames, Iowa, USA.

ISO. Traceability in feed and food chain – General principles and basic requirements for system design and implementation, ISO22005, ISO. (2007).

Julie Greenall, Donna Walsh, & Kristina Wichman. (2007). Failure mode and effects analysis: a tool for identifying risk in community pharmacies. *CPJ/RPC, 140*(3), 191-193.

Katsuaki Sugiura, & Takashi Onodera. (2008). Cattle traceability system in Japan for Bovine Spongiform Encephalopathy. *Veterinaria Italiana, 44*(3), 519-526.

LIN Ling, & ZHOU De-yi. (2005). On the Construction of Food Quality and Safety Traceability System. *Commercial Research, 21*, 41-44.

Liddell, S., & Bailey, D. (2001). Market opportunities and threats to the US pork industry posed by traceability systems. *International Food and Agribusiness Management Review, 4* (3), 287-302.

LI Lu-wen, ZHANG Jie, & GUI Hai-yan. (2004). An Analysis of Potential Risks in Purchasing in Lower Cost Region with FMEA. *Industrial Engineering and Management, Supplement*, 186-192.

LIU Ying, & CHEN Li-cheng. (2003). Brief Introduction of beef traceability production system in European Union and USA. *Food Science, 24* (8), 182-185.

MA Han-wu, & WANG Shan-xia. (2006). Traceability System for Meat Products under Food safety Circumstance. *China Safety Science Journal, 16* (11), 4-9.

Maria L. Loureiro, & Wendy J. Umberger. (2007). A choice experiment model for beef: What US consumer responses tell us about relative preferences for food safety, country –of –origin labeling and traceability. *Food Policy, 32* (4), 496-514.

Min HUANG, W.H.Ip, Hongmei YANG, Xingwei WANG, & Henry C.W.Lau. (2008). A Fuzzy synthetic evaluation embedded tabu search for risk programming of virtual enterprises. *Int.J. Production Economics,* 116, 104-114.

Moises de Andrade Resende Filho. (2006). *Essays on Economics of Cattle and Beef traceability. Published doctor's dissertation*, University of Minnesota, Minnesota, USA.

Norbert Hirschauer, & Oliver Musshoff. (2007). A game-theoretic approach to behavioral food risks: The case of grain producers. *Food Policy, 32*, 246-265.

P. Cheek. (2006). Factors impacting the acceptance of traceability in the food supply chain in the United States of America. *Rev Sci Tech Off Int Epiz, 25*(1), 313-319.

P.-X. Thivel, Y. Bultel, & F. Delpech. (2008). Risk analysis of a biomass combustion process using MOSAR and FMEA methods. *Journal of Hazardous Materials, 151*, 221-231.

Roxanne Clemens. (2003, November). Meat Traceability in Japan. *Iowa Agricultural Review, 9*(4), 4-5.

SHI Xi-ju, MA Gui-ping, LIU Quan-guo, LI Bin-ling, LIU Xu-hui, & LI Yan-xin. (2006). Food Traceability Systems in European Union. *Progress in Veterinary Medicine, 27* (12), 109-112.

WANG Bo, WANG Shun-xi, LI Jun-guo, & XIE Jing. (2007). Current Research Situation of Traceability System in the Field of Agricultural Products and Food. *China Safety Science Journal, 17* (10), 108-114.

YU Ping-xiang, WU Yuan-mei, & HU Yue-ming. (2008, July). Optimal policy for read rate in RFID food safety traceability system. *Transactions of the CSAE, 24* (7), 132-136.

YANG Tian-he, & CHU Bao-jin. (2005). Study on Control System of Food Safety From Farm to Table. *Food Science, 26* (3), 264-268.

ZHANG Bing, HUANG Zhao-yu, YE Chun-ling, WANG Rui, GU Song-hao, LIU Ben-hua, HUANG Min-Tong, LIN Hui-chun, & YU Shao-zhou. (2007). Design and Implement of Vegetable Quality and Safety traceability System. *Food Science, 28* (8), 573-577.

ZHANG Jian, LIU Li-xin, ZHANG Xiao-shuan, & FU Ze-tian. (2008).Optimization Analysis of Process Flow in Meat Food Traceability System. *Food Science, 29* (2), 451-455.