Advance Journal of Food Science and Technology 5(4): 492-499, 2013
ISSN: 2042-4868; e-ISSN: 2042-4876

Submitted: December 31, 2012 Accepted: February 08, 2013 Published: April 15, 2013

Study on the Traceability System Establishment of Safety-Objective-Oriented Food Logistics Supply Chain

[1]Wei Liu, [1]Wen Cheng and [2]Jianmin Zhang
[1]College of Transport and Communications, Shanghai Maritime University, Shanghai, China
[2]World Maritime University, Malmö, Sweden

Abstract: Due to food safety issues, traceability is becoming a method of controlling food safety and connecting suppliers and consumers. The aim of this study is to build up a food logistics supply chain traceability system which can control food safety and connect suppliers and consumers. This paper discusses the establishment of traceability system based on the Structured Query Language (SQL) Server, uses the failure mode and effect analysis to assess key indicators of the system. The result shows, the largest Risk Priority Number (RPN) is the precision risk of information. Moreover, with fuzzy synthetic evaluation model and intensity weighted average method, this paper ranks the importance of the three factors of the food logistics supply chain traceability system and finds that the depth is the most important factor. Lastly, it uses a case of Green Pork Company to calculate economics effect to prove the feasibility of the system.

Keywords: Food logistics supply chain, fuzzy synthetic evaluation model, intensity weighted average method, SQL, traceability system establishment

INTRODUCTION

According to ISO, traceability means "the ability to trace history, application or location of an entity (Entity here is an activity or a process, a product, an organization or a person) by record". 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). EU General Food Regulations defines traceability as "the ability to trace and follow the food or feet production intended to be, or expected to be incorporated into food or feed, through all stages of production, processing and distribution" (EC, 2002).

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 and Wang, 2006). In recent years, lots of Chinese scientists have begun to do some research and try to establish a theoretical traceability system for China. Lin and Zhou (2005) give a theoretical construction of a food quality and safety traceability system in their research paper. They put forward some principals of establishing a traceability system. Yu *et al*. (2008) and his colleagues do some research on the food safety traceability system which is based on the Radio Frequency Identification (RFID) technology.

Every time a food safety incident happens, people just solve the particular problem at hand. This is not a sustainable way to control food safety. The food logistics supply chain traceability system is just an effective way to prevent the food incidents. For external environments, the food logistics 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 the fork. As so many food safety incidents occur in China, it is necessary to set up a food traceability system to give confidence to consumers. This is the objective of the study to build up a traceability system for food logistics supply chain which can control food safety and connect suppliers and consumers and discuss the effect of the system and to access key indicators of the system.

MATERIALS AND METHODS

Here the materials and methods for the establishment of traceability system for a food logistics supply chain are discussed.

The framework of a food logistics supply chain traceability system:

The structure of the traceability system: For the traceability system, the main task is to deliver and

Corresponding Author: Wei Liu, College of Transport and Communications, Shanghai Maritime University, Shanghai 201306, P.R. China

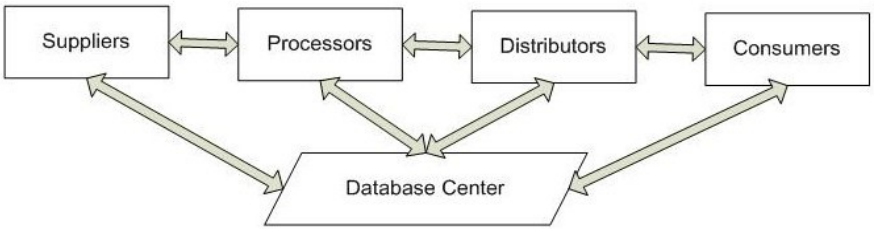

Fig. 1: Basic structure of the traceability system

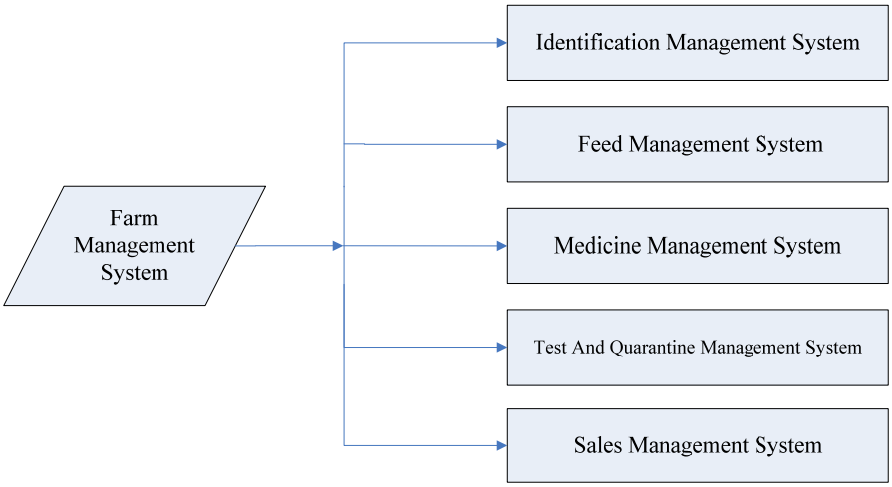

Fig. 2: Main supportive systems of a farm management system

record information during different stages of the whole food logistics supply chain. The key issue of the whole food logistics supply chain is to track and trace products and data. The basic units of a food logistics supply chain are pallets, packages and batches. Now we just name them as units of products (Bollen *et al*., 2007). 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.

The content of traceability system: Figure 1 is just the main structure of the whole traceability system. Each different part of the food logistics supply chain has many different contents supporting the chain (Zhang *et al*., 2008).

In Fig. 2, a farm management system is a collection of some management systems and it contains five main supportive systems: identification management system, feed management system, medicine management system, test and quarantine management system and sales management system. From the supplier stage, we need to assign an ID number to the ingredients. On this ID number, we input information into the management system. The information will be passed through the whole food logistics supply chain, even after the food is consumed and 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, such process as transportation, washing, slaughtering, packing, etc., will be processed (Shanahan *et al*., 2009). The supportive systems to the processing management system are as Fig. 3. The main supportive system is the child processing management system. 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 at a minimum level.

The design of database for the traceability system: According to Microsoft Company's introduction, Microsoft SQL Server 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

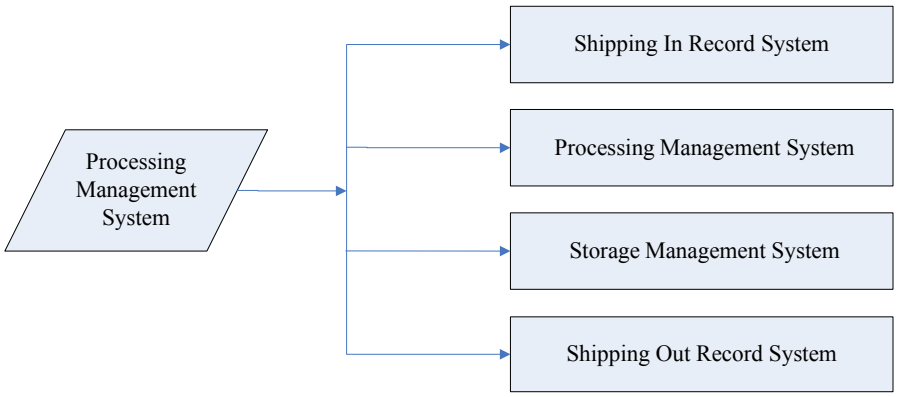

Fig. 3: Main supportive systems of a processing management system

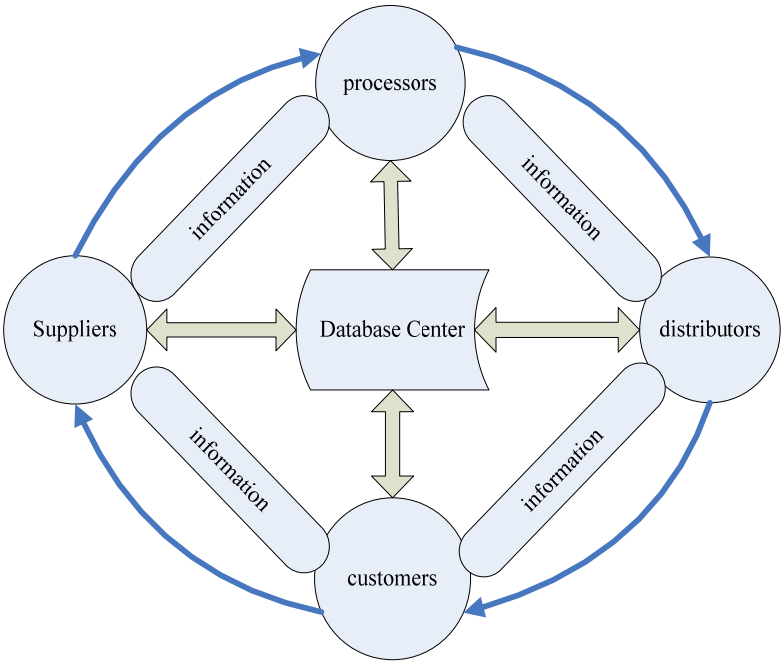

Fig. 4: The whole process of the food supply chain traceability system

life that this system can give reliable information for the public. The platform vision of the technology is flowing.

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. For food, the simplest information is location and production date which can be found from the labels or packages. The traceability system can replace the paper record. So advanced identification technology will be used in the traceability system. Some typical technologies will be introduced, such as bar code, Radio-Frequency Identification (RFID) and DNA technology.

The whole framework of a food logistics supply chain traceability system:

The framework of the traceability system: Figure 4 shows that the whole traceability system is based on the SQL server 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 accessible to the public by the public. This portal is linked with the database center. In the food logistics supply chain traceability system, technologies

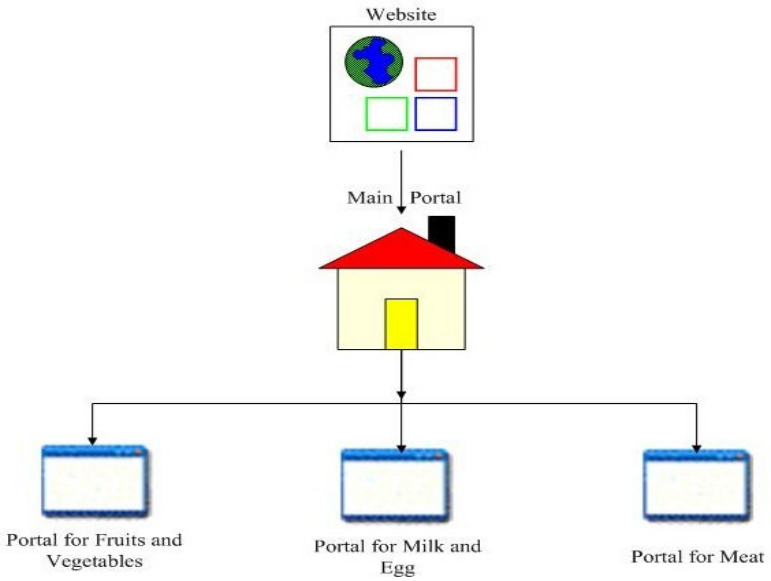

Fig. 5: The structure of main portal for the service website

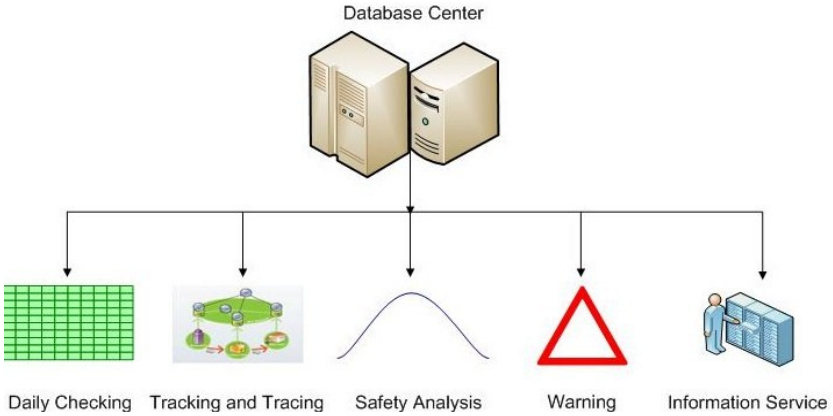

Fig. 6: The main functions of database center

such as RFID, bar code, DNA, internet, etc., will be applied in the system. 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, the information passing between each unit on the supply chain and the database center is 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.

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 there are three portals which are for: meat; fruits and vegetables; milk and eggs. They are presented in Fig. 5. Deep processed food is not tracked and traced, because it is packed very well and it is easy to find the original factory from the package. If something wrong happens, people can go to the producing factory and check the goods record. But the factory should have the traceability system for their ingredients.

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 and just likes 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.

The main functions of the traceability: The main functions are shown in the following Fig. 6. Tracking and tracing food everyday is not needed. But daily checking is important, which is to make sure that 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 *et al*., 2007). If people who buy food from this value chain want to track and trace it, 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. If they find something is wrong according to safety analysis, they will pass the warning signals to each unit on the chain.

RESULTS AND DISCUSSION

Here the results of establishment of traceability system for a food logistics supply chain are assessed and discussed.

Introduction of requirements for assessment of the traceability system: A traceability system must have a high information service level and guarantee a low occurrence of food safety incidents. According to Elise *et al*. (2003), the important elements to the food logistics supply chain traceability system are breadth, depth and precision.

Breadth in the food logistics 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. Depth is to design a traceability system to monitor food safety issues from farm to fork. Precision is that all of information we give to them is correct and timely.

Assessment of the traceability system:

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. Occurrence refers to how frequently the failure will happen to the system. Detection measures how easy it is to detect a cause by failure.

According to the criterions (The Basics of FMEA, Productivity, Inc. Copyright 1996 Resource Engineering, Inc.), 20 people have done the questionnaire[1] to get the ratings for the traceability system. The results are showed in Table 1. Then calculate the average ratings for these risks. With severity rating, occurrence rating and detection rating, the Risk Priority Number (RPN) was calculated as followed:

Table 1: 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

$$\mathrm{RPN} = \mathrm{SR} \times \mathrm{OR} \times \mathrm{DR} \tag{1}$$

RPN = Risk Priority Number
SR = Severity Rating
OR = Occurrence Rating
DR = Detection Rating

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 gets the most important position than other risks. So the RPN value of each risk must be paid attention. When the risk gets the priority rating, it means something is needed to do to prevent the risk failure to the traceability system.

Assessment of the three factors by fuzzy synthetic evaluation model:

Establishment of the fuzzy synthetic evaluation model: As shown in the Fig. 7, there are three factors for the traceability system and for each factor there are three elements: severity, occurrence and detection

Calculation of the fuzzy synthetic evaluation model: According to the questionnaire results, calculate Bi with the establish of the Evaluation Set (V), a Factor Set (U) for the Traceability System, an Element Weighting Set (W) and the Fuzzy Relationship Matrix ®:

B1 = [0.280 0.167 0.167]
B2 = [0.100 0.250 0.267]
B3 = [0.270 0.033 0.033]

Ranking the three factors: Then 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[2]:

$$\mathrm{Aj} = \frac{\sum_{j=1}^{m} b_j^{\,k} * j}{\sum_{j=1}^{m} b_j^{\,k}} \qquad m = 1, 2, 3 \qquad k = 2 \tag{2}$$

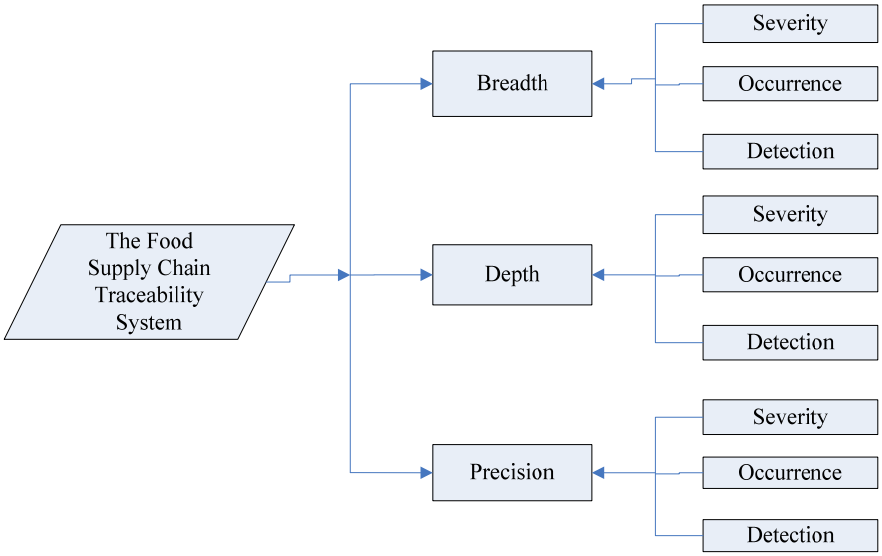

Fig. 7: Index system for evaluation of the traceability system

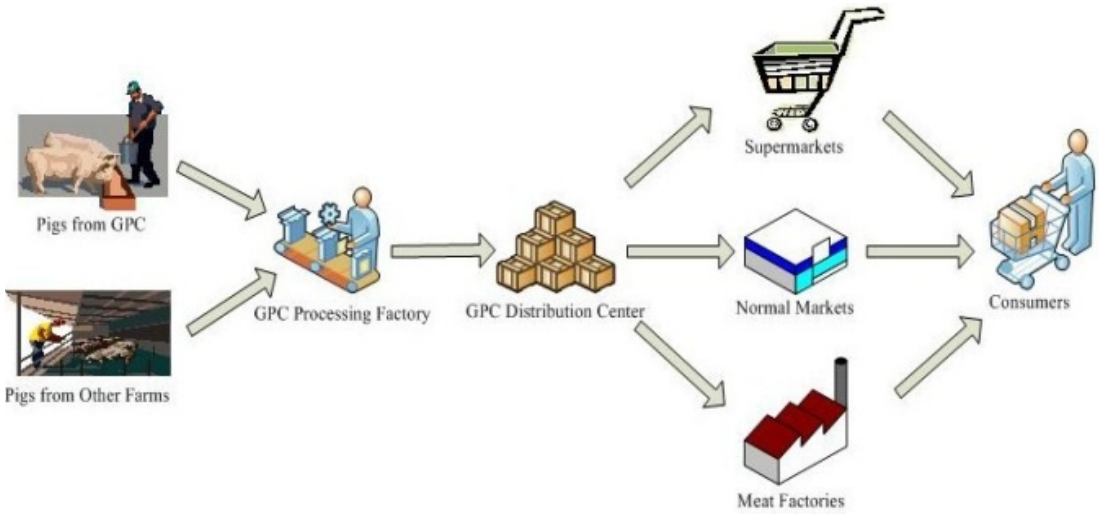

Fig. 8: Whole pork supply chain of Green Pork Company (GPC)

So: A1 = 1.6236 A2 = 2.4262 A3 = 1.0435

For the factors, A1 = Depth (2.4262) >A2 = Breadth (1.6236) >A3 = Precision (1.04435). It shows that the depth is the most important indicator to the food logistics supply chain traceability system.

CASE ANALYSIS

A case of a meat supply factory is analyzed here.

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 150 kg. As Green Pork has a distribution center, they can ship the pork from the processing factory to supermarkets, normal markets and some other deep processing meat factories by themselves.

Table 2: Technology choice of the traceability system in green pork company

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

Table 3: The cost of the traceability system for green pork (RMB 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	1 Yuan/one
Administrative fee	Variable	None	None	200,000 Yuan	For one year
Additional funds	Variable	None	None	300,000 Yuan	For one year

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

Establishment of a traceability system for green pork company:

The pork supply chain of GPC: For Green pork, the processed pigs are from two places: one is their own farm; the other is other farms. The distribution paths of Green Pork have three destinations: supermarkets, normal markets and deep processing meat factories. As discussed above, the whole process of pork supply chain includes four parts: farm, processing factory, distribution center and consumers. So the whole pork supply chain flow chart is as follows (Fig. 8).

Establishment of a traceability system: In Table 2, 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 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 the 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.

Economic effect of establishing a food traceability system:

The cost of a traceability system: In this case, the main costs of the traceability system are the cost of database center which includes machines and software. Variable costs are 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 3. Then the fixed costs and variable costs in one year for GPC can be calculated

The economic effect of a traceability system: To get the economic effect of a traceability system, the annual turnover of GPC and the total costs of a traceability system need to be calculated. At present the price of pork is about 18 Yuan/kg in Shanghai, China[3]. By calculating based on Table 3, it shows that they will spend more 10.48 Yuan on 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.

The calculation of the costs on each pig shows that the price of pork will increase when the traceability is set up. But it just increases by only 0.07 Yuan/kg. 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/kg. 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 really a good way to increase their market shares. It is a "win-win" situation for the company and their customers.

CONCLUSION

Many countries, have established a food logistics supply chain traceability system to guarantee the food safety. In this dissertation, we choose the SQL Server 2008 as the basis of traceability platform. Suppliers, processors, distributors and consumers-each part on the value chain-can communicate with each other through this platform. 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 and the fuzzy synthetic evaluation model and intensity weighted average method to analysis. It is imperative to have a traceability system for food safety. I hope my dissertation can inspire someone who can design a more effective food logistics supply chain traceability system and put it into practice.

ACKNOWLEDGMENT

The authors are thankful to the National Natural Science Foundation and the Ministry of Education of China, Shanghai Municipal Education Commission and Science and Technology Commission and Shanghai Maritime University for providing support for this research (Grant number: 71272219; 11YJA630067;

S30601; 11510501800; 20110020; YC2012011, respectively). The authors would also like to express their gratitude to those who have helped them with encouragement, advice, information and materials, especially Prof. Tony Hu and Zhijun Gao who have contributed to the research.

REFERENCES

Bollen, A.F., C.P. Riden and N.R. Cox, 2007. Agricultural supply system traceability, Part I: Role of packing procedures and effects of fruit mixing. Biosyst. Eng., 98: 391-400.

EC, 2002. Regulation (EC) No. 178/2002 of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in maters of food safety. Official J. Eur. Comm., L 31, 1-24.

Elise, G., K. Barry, K. Fred, N. Ken, P. Greg and C. Linda, 2003. Traceability in the US Food Supply: Dead End or Superhighway? Choices American Agricultural Economics Association. Retrieved from: www.farmdoc.illinois.edu/policy/choices/20032/2003-2-04.pdf.

ISO, 2007. Traceability in Feed and Food Chain: General Principles and Basic Requirements for System Design and Implementation. ISO22005, International Standards Organization, Geneva.

Lin, L. and D.Y. Zhou, 2005. On the construction of food quality and safety traceability system. Comm. Res., 2005(21).

Ma, H.W. and S.X. Wang, 2006. Traceability system for meat products under food safety circumstance. China Safety Sci. J., 16(11).

Shanahan, C., B. Kernan, G. Ayalew, K. McDonnell, F. Butler and S. Ward, 2009. A framework for beef traceability from farm to slaughter using global standards: An Irish perspective. Comput. Electr. Agric., 66(1): 62-69.

Yu, P.X., Y.M. Wu, Y.M. Hu, L. Chen and L. Wang, 2008. Optimal policy for read rate in RFID food safety traceability system. Trans. CSAE, 24(7).

Zhang, J., L.X. Liu, X.S. Zhang and Z.T. Fu, 2008. Optimization analysis of process flow in meat food traceability system. Food Sci., 29(2).

Zhang, B., Z.Y. Huang, C.L. Ye, R. Wang, S.H. Gu, B.H. Liu, M.T. Huang, H.C. Lin and S.Z. Yu, 2007. Design and implement of vegetable quality and safety traceability system. Food Sci., 28(8): 573-577.

End note:

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

2: k in the formula is a indeterminate coefficient which can reduce the effects of individual to the result.

3: The price of pork is from Shanghai Price Information Service Network (http://www. shdrc. gov.cn/) in December, 2012.