Study on Traceability System Risk Management of the Food Supply Chain for Chinese Infant Accessory Food Industry

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（食品サプライチェーンのトレーサビリティシステムのリスク管理に関する考察--中国における乳幼児向け栄養補助食品産業）

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Abstract

The food traceability system is an important measure to ensure the safety of food supply. Due to the increasing size and complexity of food supply chains, the quality of food traceability activities is affected by various risks. The objective of this research is to identify and analyze the risk factors which affect traceability system in the food supply chain, focusing on the case of the Chinese infant accessory food industry in particular. The relevant literature in general and the food supply chain in particular were analysed and the fuzzy synthetic evaluation method was adopted. The traceability system risks are divided into four categories: management risks, equipment risks, technical risks and environmental risks. According to the assessment results, we can conclude that the overall risk of the supply chain is at a medium level. The degree of risk in the processing and storage phase is the highest, showing management risks are the main reason. The impact of management risk factors on the processing industry is presented as the most critical factor. The resolution of these challenges will be the key to the establishment and improvement of the traceability system in the Chinese infant accessory food industry.

A cross-industry benchmarking method has been applied to transfer successful strategies and critical success factors of automobile industry that attempt to deal with traceability system risks to the infant accessory food industry. After summarising the experiences and methods of the reference industry dealing with traceability system risks, this research defines three different scenarios: ① The government support scenario, ② The industry guild scenario, ③ The supply chain combination scenario. They all have the same goal to improve the response ability and accuracy of food traceability system. Its effect is measured by the level of user satisfaction. In order to compare the effects of these three scenarios, a normative stochastic model has been built. The parametric data for the model have been estimated, based on historical data, previous literature studies, field research, current policies and development plans of government. The outputs of simulations performed by the stochastic model show that the best approach to control and reduce the traceability system risk is: to use contracts and agreements to build a vertical joint-business network (scenario 3) as the core, and to appropriately combine it with multi-level government support (scenario 1).

Furthermore, this study proposes relevant recommendations concerning the different aspects of traceability system risk management. These include the implementation of an effective system of revenue distribution and enhancement of the internal stability of the supply chain. The establishment of a profit and risk sharing chain alliance which will strengthen the collaboration in the different links of the supply chain should be stimulated. Finally, the introduction of regulations and standards to achieve a unified management system covering all phases of food supply chain from production, processing to distribution all the way to consumption.

Keywords: Food Traceability System, Food Supply Chain, Risk Management, Infant Rice Cereal Products

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Ma He
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Abbreviations

AHP	Analytic Hierarchy Process
CAC	Codex Alimentarius Commission
CSF	Critical Success Factors
EAN	European Article Numbering
EANCOM	European Article Numbering Communication
ebXML	extensible Markup Language
EDI	Electronic Data Interchange
EPC	Electronic Product Code
FSC	Food Supply Chain
FSE	Fuzzy Synthetic Evaluation
GAP	Good Agriculture Practices
GIS	Geographic Information System
GLN	Global Location Number
GM	General Motors
GMP	Good Manufacturing Practice
GPS	Geographical Position System
GS1	Global Standard 1
GTIN	Global Trade Item Number
GVP	Good Veterinary Practices
HACCP	Hazards Analysis Critical Control Points
IAF	Infant Accessory Food
IRCP	Infant Rice Cereal Products
ISO	International Standards Organization
MRL	Maximum Residue Limit
RFID	Radio Frequency Identification
SCM	Supply Chain Management
SCOR	Supply Chain Operations Reference
SCRM	Supply Chain Risk Management
SSCC	Serial Shipping Container Code
TS	Traceability System
UCC	Uniform Code Council
WHO	World Health Organisation

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1. Introduction

1.1 Background

With scientific and technological improvements, and driven by a growing population and economic betterment worldwide, food production and distribution systems are becoming increasingly interdependent, integrated, and globalized. At the same time, escalating and heavily publicized outbreaks of foodborne diseases have raised awareness of the need to ensure food quality and safety (Hou 2011). For example, in recent years, many food safety incidents occurred all over the world, such as the mad cow disease outbreak in the UK, in 1986, and it subsequent spread to other European countries. As a result of this, beef products exports dropped drastically. This represented an annual loss of around five billion U.S. dollars, and the induced costs related to the loss of cows amounted to 30 billion U.S. dollars (Bao 2007). Another example, it is the carcinogenic dioxin contamination that affected poultry and cattle in Belgium in 1999. The losses amounted to more than 10 billion euros. Foot-and-mouth disease ravaged Britain in 2001, it led to seven million cattle being slaughtered and the losses of it represented a total loss of eight billion pounds for producers (Hu 2007). In 2003, the avian influenza outbreak in East Asia caused many Vietnamese deaths and about 150 million poultry died from the disease, the economic losses reached up to three billion U.S. dollars (Bao 2007). In 2005, Beijing detected many food products containing a carcinogenic component called Sudan number one. And Chinese dairy melamine pollution events were exposed in 2008, it caused 13000 infants suffer from kidney stones; expired meat products of fast food restaurant event in China 2014 etc. (Zhang 2012; Dong et al. 2011; He et al. 2016). These incidents prompted the international community and consumers to pay more attention to the food quality and safety issues. Moreover, these examples have highlighted the need to develop and invest in technological innovations that can help trace food consistently and efficiently from the point of origin to the point of consumption.

For a long time, the international general methods of food safety control have included HACCP, GMP, GVP, GAP and ISO9000. These technologies are mainly focused on controlling the production of food and processing environment with the aim to avoid food contamination through potential biological, chemical and physical factors in the whole food production process (Cheng 2012). However, these technologies cannot monitor problems that occur in the circulation process, and have yet to develop accurate and fast means to identify the roots causes of the problem. As a result of this, these processes take longer and are less efficient in reducing the greater damage that be caused to human health, and clear the responsibility of the relevant subjects. Therefore, tracking the entire food supply chain (FSC) from production to consumption is becoming very important. And the ensuring the traceability of products becomes the necessary means to monitor food safety and protect consumer’s health (Meng et al. 2009). It is also what consumer’s expect from their government and the food industry.

In order to ensure food safety and quality, and the effective monitoring of the factors of food supply chain that can lead to insecurity or low standards, the EU first proposed the concept of food traceability, a post-control technology. In 2002, based on the food safety green paper and the food safety white paper, the EU introduced *The Regulation (EC) No. 178/2002*. The regulation used in food, feed, livestock for food manufacturing and items related to food and feed manufacturing to enforce traceability system (TS) in various stages of production, processing and transportation (European Commission 2002). In the same year, the United States released *The Public Health Security and Bioterrorism Preparedness and Response Act*. This act requires the establishment of a record-keeping system in food production, processing, packaging, transportation, distribution and receiving aspect of the supply chain (Huang 2005). In April 2003, Japanese government has formulated and issued *The Food Traceability Guidelines*, to provide detailed guidance for agricultural enterprises build up traceability system in different stages of production, processing and distribution (Zhang 2014). Since 2005, Japanese National Federation of Agricultural Co-operative Associations (JA ZEN-NOH) implements traceability for all its sales agricultural products, such as meat and vegetables etc. (Tong et al, 2012)

Under the leadership of the Chinese central government, the research on food safety traceability system started from 2002. A series of pilot projects had been carried out, including food, vegetables, meat products and dairy products TS projects. But until 2015, Article 42 of the newly revised Food Safety Law of the People's Republic of China has explicitly stipulated that the country should build up food traceability system. During more than 10 years, the framework of China’s food safety TS is not clear. In a nation scale, food traceability systems are neither consistent nor continuous, still in the early stage (Chen et al, 2018).

Currently, articles about China food traceability systems mainly focus on construction of TS, willingness of each aspect of the supply chain to introduce the TS, analysis of government policies and regulations, as well as research on consumer behavior (Chen et al, 2018; Dong et al, 2016; Tang 2014; Yang et al, 2018; Yu 2017). The study on the risk management of the TS in infant accessory food (IAF) industry is still not available. However, food safety has already become a severe problem in the country. In particular, the incidents similar to illegal additives in milk powder bring harmful effects on infant health.

Thus, the analyse and understanding of various risk factors involved in the food supply chain and its associated impact on food traceability will improve the level of food safety and effectively reduce the losses. And also provide plenty of information for the consumers to enhance their confidence concerning the products (Van Rijswijk et al, 2012).

1.2 Problem Statement

The accuracy and efficiency of food traceability are of vital importance in ensuring food safety. But the quality of the food traceability is often affected by many uncertain factors in the complex FSC. How can one identify and control the factors of risks involved in food traceability, reduce and avoid the risk of adverse effects, and improve the efficiency and accuracy of food traceability? These are the issues at the core of this research.

The risk factors that affect food traceability can be divided into two main aspects, technical risk factors and managerial risk factors (Fotopoulos et al, 2009; Luning et al, 2007). The technical risk factors are the risk factors which occur in the application process of food traceability technology or in the attempt to innovate. For example, the use of Radio Frequency Identification Technology (RFID) does not only require tags but also software and hardware specification that allows the management of the information load through space and time (Costa et al. 2012). Risks using this technology are related to the fact that RFID technology is still recent and its applications to agriculture and food industry still rare, because of technical limitations (Costa et al. 2012). On the other hand, RFID offers quality food traceability in the supply chain management. For example, RFID reader micro-machined metal oxide gas sensors were used in fruit warehouses to monitor climacteric condition during transport and retail (Costa et al 2012). This allows users to monitor conservation stage of commonly traded fruit. The managerial risk factors are focused on the existing and potential risk factors, such as data loss or fraud, warehouse sanitation pollution, transport problems, different standards of food traceability, etc. All these factors can occur all throughout the process of food traceability. This research will mainly concentrate on analysing the managerial risk factors.

1.3 Research objective

The objective is to identify and analyse the risk factors which affect traceability system in the food supply chain. This research will help enterprises to ensure the accuracy and consistency of the food traceability, reduce the operating costs and provide theoretical reference for internationalization. The study consists of four parts:

- A review of the food supply chain, food traceability, risk management and food safety risks.
- The identification and analysis of the risk factors affecting food traceability in the specific food supply chain. For example, Chinese infant accessory foods supply chain.
- A cross-industry benchmarking study to list the critical success factors of traceability system of automobile industry to dig out what lessons can be learnt and which methods are suitable for Chinese infant accessory food enterprises.

- To apply the feasible reference industry practices into Chinese infant rice cereal product processing industry and analyze the effect of traceability system risk management instrument by a normative stochastic model.

1.4 The research framework

The research framework is presented in Figure 1. In part *A*, a review of the existing literature on food traceability in the food supply chain is laid out. This review is based on the existing theories concerning supply chain risk management and the related management disciplines. Following the literature study, in part *B,* a case study is analyzed and considers the risk factors involved in the IAF supply chain. Part C, will generate the assessment results according to the empirical data by fuzzy synthetic evaluation (FSE) model. Meanwhile, a critical success factors (CSF) analysis of successful experiences in the automobile industry will lead to useful lessons and methods in part *D*. Next, the results of the previous research will guide the scenario design. In the model simulation part *E*, will generate the results for the different scenarios. After elaborates on every simulation result, a conclusion will be drawn, and recommendations for risk factors of food traceability will be given in part *F*.

1.5 Methodology

There are three methodologies to be employed in this report.

- Literature research is used to capture the theoretical information about all objectives. In order to deeply understand overall status of food traceability and food supply chains. The relevant literatures with respect to food traceability and FSC published in academic journals, thesis and books are essential. Different databases have been used to find appropriate literature, such as Google Scholar, CAB Abstracts, Scopus, Baidu scholar, CiNii and OvidSp. Moreover, the information related to general literature regarding supply chain management (SCM), food safety, food traceability and supply chain risk management (SCRM) are necessary complements.
- Assessment. Adopt the fuzzy synthetic evaluation method to set up a traceability risk assessment model, to evaluate the situation of traceability system risk of Chinese infant accessory food products supply chain. In order to analyze the impact of various risks, identify the major risk, and control the different risks of traceability system. The FSE method can combine quantitative and qualitative indexes effectively, also can be used to quantify the factors that are without clear boundary and difficult to quantify. In addition, a cross-industry benchmarking (Stewart 1997) method has been applied, to transfer critical success factors of automobile industry that attempt to deal with TS risks to the Chinese IAF industry. This method holds the potential to provide innovative and adoptable ideas from companies across industries.
- Simulation. Establish a normative stochastic model of IAF products supply chain, using empirical and assumed data to simulate whether the feasible other industry traceability system risk management can be effective for Chinese IAF companies.

This method can clearly represent the process of risk management to fulfill the requirement of objective four.

Research framework

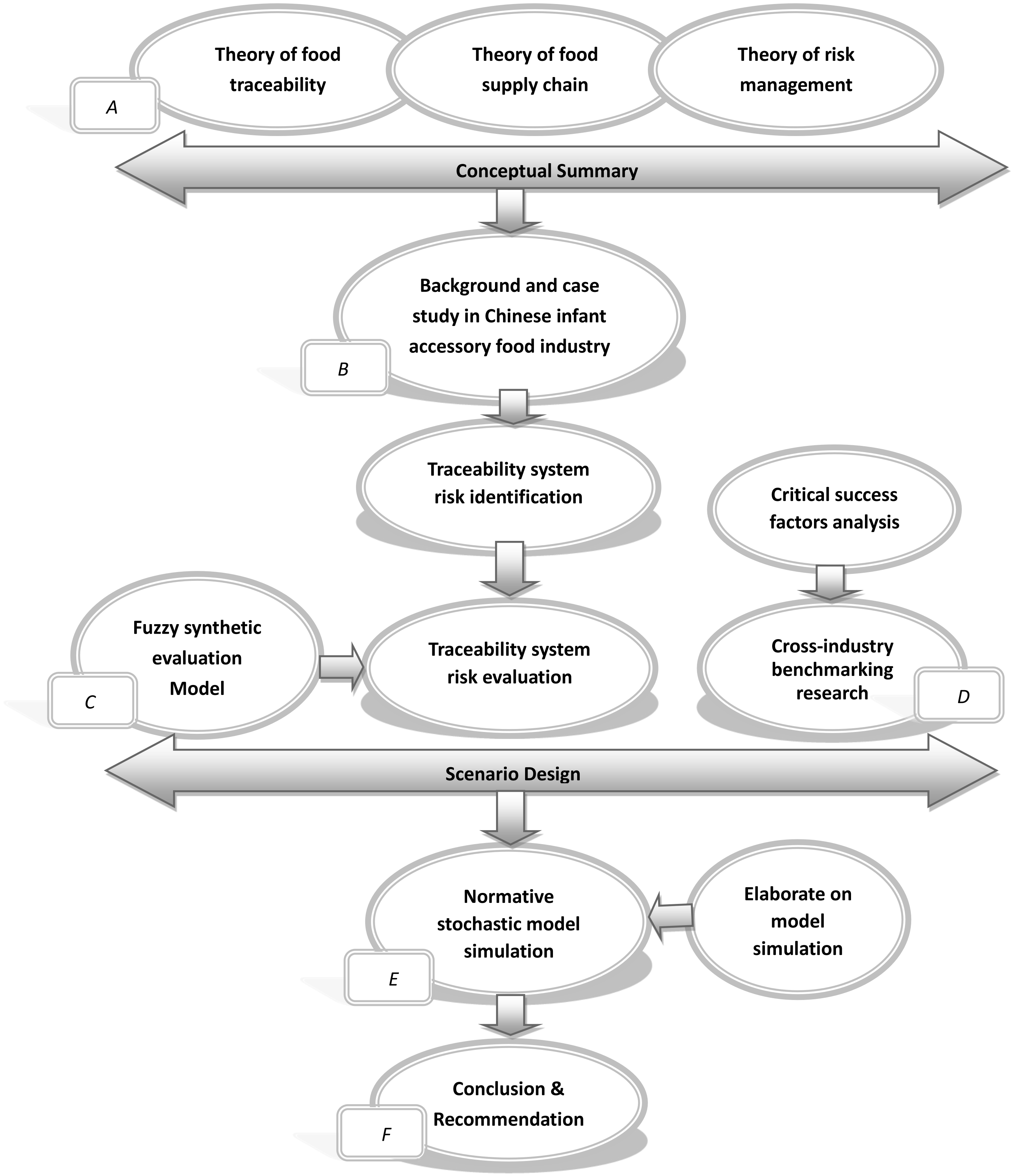

Figure 1 The research framework

1.6 The structure of research

This dissertation research consists of an introduction (Chapter 1), a theoretical framework (Chapters 2), the case studies and results of the analysis (Chapter 3, 4, 5), a discussion, conclusions and recommendations (Chapter 6), references and appendixes.

- Chapter 1 gives an introduction to the research. Also, the problem definition, the research objective and methodologies are outlined in this chapter.
- Chapter 2 is about the theoretical background. A general description of the food supply chain is done and the structure will be presented. In this chapter, the various theories and information about food traceability is also described. These studies will guide the analysis in the next phase. Risk management and supply chain risk management are used to analyse the risk factors and their impact on food safety.
- In Chapter 3, based on the literature research presented in the previous chapter, a specific case study will be analysed. Furthermore, it will help us draw conclusions and recommendations. The analysis of results of critical risk factors affecting traceability under the different phases of infant accessory food supply chain is shown and discussed in this section too.
- In chapter 4, The summaries of cross-industry benchmarking analysis are presented and discussed. At the same time, the rank of key CSF are listed and interpreted in this chapter. These studies will guide the analysis in the next phase.
- In chapter 5, the simulation model and three scenarios will be introduced. Meanwhile, results for the different scenarios are elaborated and compared.
- Chapter 6 gives a discussion, conclusions, and recommendations based on this research. Moreover, it will also give some suggestions for further study.

2. Literature study

2.1 Food supply chain

Christopher (1992) defined a supply chain as: "a network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate consumers". Food supply chain is proposed on the basis of the general supply chain. Den Ouden et al. (1996) believe that the FSC management is an integrated operation mode for the organizations of agricultural and food production and sales. In order to reduce the logistics costs of food and agricultural products, improve quality, and develop food safety and logistics service level. The food supply chain has for object, food and at its core concerns the food processes and operations involved from the production to the consumption of food. It coordinates the benefits among agricultural production materials suppliers, farmers, agricultural operators and consumers by controlling the logistics, information and capital flows. It is a series of processes from agricultural practices and side-line products procurement to food production, transport, purchase and distribution (Jin et al. 2008).

2.1.1 The characteristics of food supply chain

The food supply chain has different characteristics compared to the general supply chain, because it also concerns food safety.

The supply chain is long and complex

From the first stages of breeding and planting until the final step of consumption, the primary characteristic of the FSC is that it is a long and complex supply chain. It covers five aspects: breeding and planting, slaughtering and harvesting, production and circulation. For example, in the case of production and sale of soft drinks in the United States, the supply chain contains the spice extraction processing chain, corn sweeteners processing chain, beet and cane sugar processing chain, carbon dioxide gas processing, fruit cultivation and processing, compound preservatives production, purified water production, aluminium and steel cans processing, cartons processing, beverage production, transportation, storage, distribution, market research, sales, promotion and retail (Zheng 2008). This shows that the soft drink supply chain involves negotiation, implementation and dealing with a variety of supply chains and providing services all throughout the supply chain.

The enterprises situations are different in the chain

Food safety issues have actually arisen through the industrialization and mechanization of food production, which has been increasingly controlled by a few and dealing with enormous amount of production. For example, according to the records of the National Bureau of Statistics of China, the output value of the Chinese food industry reached 188.12 trillion JPY in 2017. While, 80 percent of the 60,000 food companies employ 10 or fewer people. The production scale is large while the degree of standardization and access conditions are low, which is the root causes of the past Chinese food safety incidents (Chen 2005).

The gap between developing and developed countries in regards to management standards is wide. Compared to European and American countries, the access conditions to running a food business in developing countries are very low. For example, only 55% of Chinese food products conform to international safety standards (Zheng 2008). In addition, the developing countries' traceability standards are still underdeveloped. In the meat industry, this means that livestock and later meat is hard to source. But it remains that the biggest food safety threat is the source pollution of the planting and breeding industry.

The proportion of logistics outsourcing is large and the consumption cycle is short in the FSC management

Because food and agricultural products involve a single-value cost, the price tends to be low, especially for those fast moving consumer goods. The producers in order to reduce the costs of logistics will outsource the related business (Bao 2007). The timely requirement of food and agricultural products (especially the fast moving consumer goods) is very high. In order to seize the market, they must ensure the products freshness. This is further complicated when from the production, processing, sales to the final step of consumption, FSC involve many stages. And at the same time food supply chain involve a multi-link operation. In a series of links, each phase must be careful and cautious in order to achieve the high quality of the final product. This requires the design and the operation management of the FSC must be efficient in order to guarantee the food quality and safety.

2.1.2 The structure of food supply chain

The food supply chain can be roughly divided into three stages. First is the planting/breeding chain, which includes laboratory research and development, from the raw material input to the output of primary products. Second is the processing chain, which includes the sourcing of raw materials (primary products) and the end products. Third is distribution chain, products through transport, storage and sales to finally reach the hands of consumers (Wang et al. 2006).

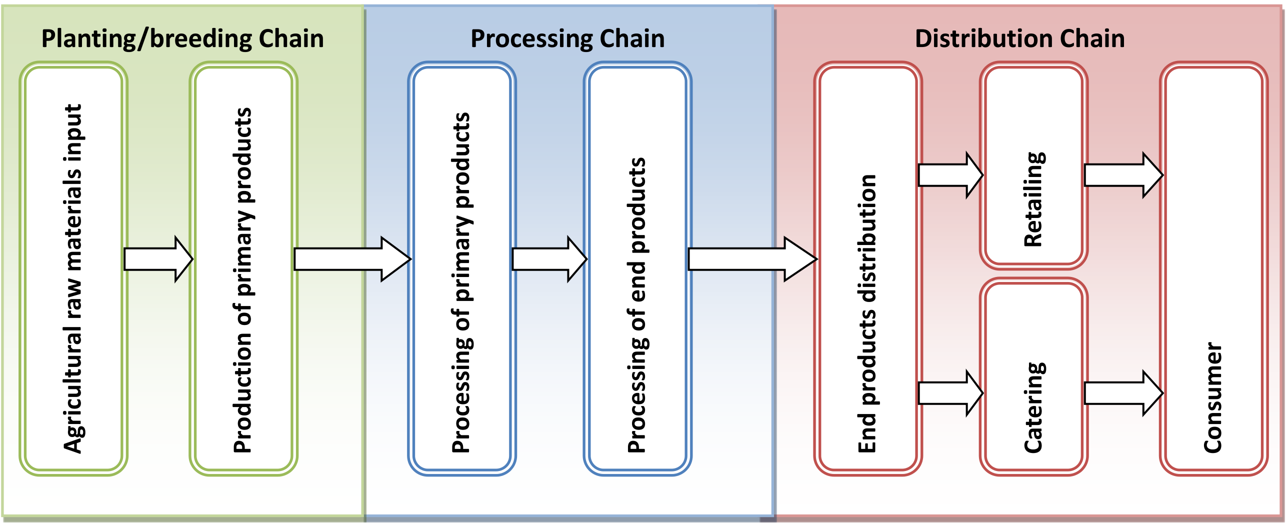

Figure 2 Food Supply Chain (Source：WHO 1996)

In Figure 2, the FSC involves three aspects from farm to fork: raw materials production, processing and distribution. The agricultural raw material inputs include fertilizers, pesticides, feed and other inputs. The processing chain mainly includes the processing of primary products, secondary products until the completion of the end products. In the distribution chain, the flow of domestic distribution and international markets is included. The end products mainly use the retailing and catering trade to reach consumers. This FSC structure has a clear relationship. No matter which phase is problematic, it can easily be traced to the root causes of the problem. It provides a good basis for all food traceability activities.

2.2 Food traceability

Codex alimentarius commission (CAC) and International standards organization (ISO) defined traceability as the ability to tracking history and use (or position) of commodities or behaviours, based on the registered identification code. Traceability is the ability of using the registered marks (this mark is unique to each batch of product. It means the mark and the tracing object have one-to-one relationship. At the same time, these marks are saved as a record) to trace products history (including the background of raw materials, parts and components of the product), status of use, location, similar products and activities (Mo et al. 2010). These quality assurance systems provide traceability of raw materials to suppliers at the generic level but traceability from farm to fork often requires additional measures (Van der Vorst 2006). In practice, "traceability" is the information and documentation record system for food composition and flows in the FSC. Food traceability is a two-fold framework which offers practical guidance for the food industry to make their food traceable all throughout the supply chain and exchange information between different actors in the FSC. Food traceability is also beneficial for consumers as it provides them with information, so they can make well-informed choices and also ensure food quality.

Food traceability systems include two levels of meaning (Mo et al. 2010): at the macro level, lies the national food traceability system for food production and regulatory authorities to recall the unsafe food and trace the origin of the food, and communicate with enterprises and consumers. At the micro level, the management system of food safety and quality control for food companies can trace and track the raw materials and the end products.

The establishment of a food traceability system includes food traceability technology system, standard system, information platform, and the promotion and implementation among the food enterprises (Ye 2011). It should cover all aspects of the food chain from primary production to the end consumer. Every type of food can be traced through shared information platforms, forecasting, analyzing and estimating by governments, enterprises and consumers.

2.2.1 General information of food traceability

There are two parts to the process of food traceability:

Tracking
Tracking refers to the ability of tracking a specific unit or a group of products through the different steps and between the links, and from the upstream to downstream of the supply chain. In detail, it means that products can be traced from the production base to the processing enterprises to the distribution companies to the retail enterprises to final consumers. This method is mainly used to understand the flow of the product, to determine the final form of the product, and the distribution of the consumer groups.

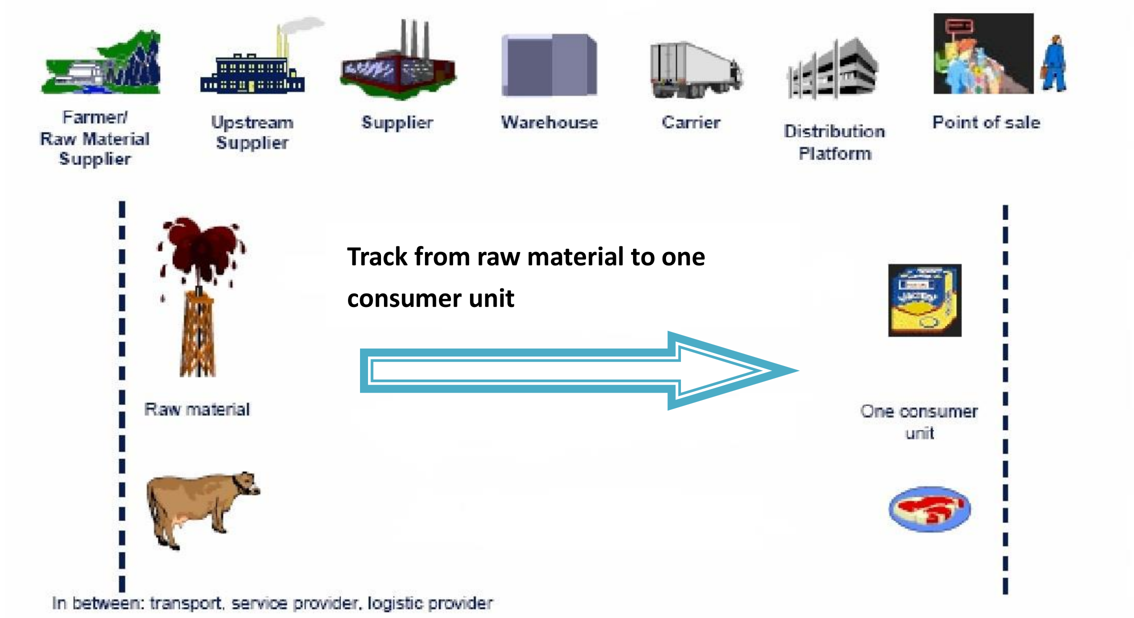

Figure 3 The tracking schematic diagram (Source：Zhang 2012)

Tracing

Tracing refers to the ability of tracing a specific unit or a group of products going through the different steps or the links, and from the downstream to upstream of the supply chain. It is the ability of tracing the origins, purpose and location of an object based on the way of record identification. From the bottom to the top, it means if consumer discovered any quality or safety issue concerning an item of food, they can trace it back to the supply chain and determine the origin of the problem. This method is mainly used to the product recall, to find the reason that caused quality problems, and to determine the origin and characteristics of the products.

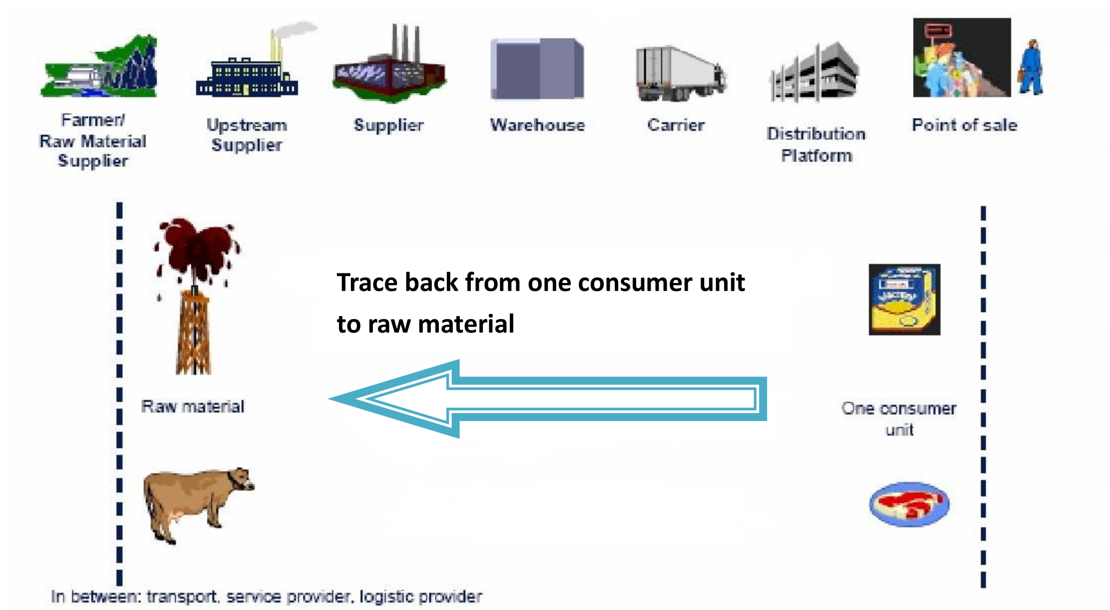

Figure 4 The tracing schematic diagram (Source：Zhang 2012)

The UK Food Agency pointed out that traceability in the FSC has the following functions: emergency treatment for food safety accident, control the food residues, assess the risk of food safety, and manage the trademark system, fraud, food waste and hygiene of meat products (Zhang 2012). In the different aspect of food production and distribution, the function of food TS is different. Based on the different subjects, the function of food traceability includes:

1. Agricultural raw material producer

For the agricultural raw material producers, according to the traceability information according to which their product was recorded, food traceability system can help them reduce the costs involved in the distribution system, to decrease the expense of the product recall, and improve the management of the supply (Elise et al. 2004).

2. Consumers

Food traceability system is closely related to benefiting the consumers. In case of emergency, it can protect food safety by effective product recall. This method can easily avoid the discomfort caused by certain food and ingredients, whether due to allergies, food intolerances, or habits and customs. In addition, it allows consumers to freely choose their food, which is produced in different ways (McKean 2001).

3. Government

There are several roles the government plays in ensuring the value of food traceability system. Mainly the government influences food quality through rules and procedures and also via inspection (Luning et al. 2007). The government can revoke the food being sold to protect public health. The government is responsible of the implementation of traceability systems and in charge of providing guarantees associated with traceability (Rijswick et al. 2012). Moreover, the government through the detection and analysis can regulate unreliable commercial fraud, such as counterfeit organic food. It can control the human and animal infectious diseases, such as tuberculosis, salmonella, and mad cow disease.

In case of an emergency, it can effectively control the problems that affect human and animal health, such as contamination of land or raw materials. By rapidly identifying the source of disease and the risk of exposure the government can control in a more effective way the epizootics and local epizootic. Through the establishment of a set of rules livestock owners need to comply with by law, the government can more effectively prevent, monitor and control livestock numbers and animal diseases. This means faster intervention responses to outbreak diseases, identification of unknown diseases, and monitoring of trends and development (Tompkin 2001). This has major impact on the main duty of the government in ensuring public health and safety. For example, in the USA, foodborne disease led to more than 1,500 outbreaks and 23 deaths, according to the US Centers for Disease Control and Prevention (CDC). Hence food traceability could avoid compromising the health – and even lives of millions of people worldwide.

4. Food producer

For the food producer, food TS is part of a complete industrial production system. The establishment of a food traceability system can propel the entire production process to obey the relevant laws and regulations. The use of traceability technologies, such as barcode technology, RFID and etc. In order to protect the company's trademark and reputation, in the event of an unsafe or irregular product, rapid action is required to remove it from the sales. That is a stopgap when dealing with the product's quality or food safety incident. It can minimize the scale of food recall, and reduce the cost of repaired or adjusted products return to the market at the same time.

Food traceability systems can also help find out the underlying problems between production and its relevant obligations. Food traceability systems can protect the "identity", or standards of certain products, such as non-genetically modified soybeans and other ingredients. It can minimize the scale of infectious diseases in livestock, and effectively prevent the FSC from the contamination of animal disease. It can ensure the quality of meat products, livestock, and consumer's confidence.

Based on the mode of production, food producers will sell different products on different market mainly because food traceability. For example, raises consumer's awareness and ability to trace back the origin and quality of their food and are more likely to hold companies accountable for any defect in the product quality (Linus 2003). Furthermore, it can help diagnose problems linked to the production and determine who is liable for this problem. This can help facilitate recall for manufacturers of final products, because while they are still responsible for the recall, with food traceability, and the availability of complete record of ingredients, they might be able to ask for indemnification from responsible third parties (Linus 2003).

An example of the ways in which food traceability systems can help government in ensuring quality food, avoiding disease outbreaks, addressing the risks to and protecting public health. At the end of December 2010, in the North Rhine-Westphalia region of Germany, a chicken farmer found out that the animal feed was contaminated by dioxins. Then the contaminated feed was discovered in other states soon after that. In order to prevent these harmful products to enter the consumers market, the German Ministry of Agriculture announced they were temporarily shutting down more than 4,700 farms, which accounted for about one percent of the total number of farms. More than 8,000 chickens were forced to be slaughtered, and they prohibited those contaminated farms to sale their poultry and egg products. In early January 2011, the perpetrators' company was formally charged. Other damaged farms proposed a civil compensation, which amounted to about 40 million to 60 million euros a week (Ye 2011).

Based on the effective traceability information of the products, the company, which were guilty were soon identified after the incident, and cleared the flow of contaminated food. The food traceability system informed in a timely manner the national management department to trace back in the consumers market the contaminated products. In this case, German identified the contamination source, and food traceability was used as a tool by the government to clearly understand the flow of contaminated products, which tool less than a month. However, a similar incident occurred in Belgium, in 1999, and because they were lacking useful traceability information and technology, the investigation took more than four months and caused huge economic losses. This shows that food traceability has a significant impact for food safety in economic terms and to ensure public health.

2.2.2 The types and trends of food traceability

According to the degree to which products are linked to the supply chain, the food traceability can be divided into: national sources traceability, retailer traceability, processor traceability, farm traceability and complete traceability (See Table 1).

Table 1 The types of traceability system

Type	Description
Complete traceability	From the retail to the farm stage, including the genes of livestock, feeding products and production system etc.
Farm traceability	Can identify the original farm or source of a single product, but cannot help trace back to the original production component.
Processor traceability	Can identify the origin processor of a single product, but cannot trace back to the original producer.
Retailer traceability	Can identify the origin retailer of a single product, but cannot trace back to the original processor.
National sources traceability	Can identify the origin country of a single product, but cannot trace back to the original retailer or processor.

Source: Liddell et al. 2001

This classification can provide the appropriate depth of traceability system for different food safety issues. For example, the prevention of mad cow disease need to be traced back to the animal feeds, only complete TS can meet the requirements. As the animal tuberculosis prevention only needs to be traced back to the farm operation, the farm TS is able to meet the requirements; in this case there is no need for complete traceability system. It can reduce the costs of traceability. The ideal system in this classification is complete traceability. It is a thorough tracing for the end product from the farm to the retail stage. But this system requires a large capital investment and data devices, so the cost is high. The batch traceability system currently is the most popular in the United States and Europe. The TS includes two parts. In the first part, the raw materials can be traced from the processing company to the farm. In the second part, the products can be traced from the retail to the processing company. The tracing for the second part can be achieved by setting up a batch number of the daily output, thus to tracing a smaller batch can be achieved by subdividing the production line. The advantage of it is the optimal batch size is determined by the market. If the batch size is too large and caused the high cost of the recall, the manufacturer will automatically reduce the batch scale (Dong et al. 2011).

The traceability system was first used in 1997 in the European beef industry. Now, after years of development, the following trends can be highlighted (Dong et al. 2011):

- Traceability covers a wide range of products. Food traceability systems appeared in the beef industry after the mad cow crisis, and then gradually extended to other meat sectors, dairy products, aquatic products, vegetables, and other industries. Nowadays, all the food and agricultural products that are sold on the EU market must be traceable.

- The degree and accuracy of food traceability are higher and higher. Some EU countries are actively promoting the complete traceability system, such as Denmark, as one of the world's major pork exporters is promote the complete traceability system in the whole country.

- The traceability technology is improving. World’s traceability technology is developing from the ear tag methods to the bio-molecular techniques and the electronic and information technology. Canadian cattle industry installed radio frequency identification (RFID) reader before the end of 2011 in all the country's 250 auction market to track the arrival and departure of the cattle. In addition, a high accuracy rate technology of iris recognition is planned to be used in the near future. The technology development will improve the implementation and extension of food traceability system.

- The TS will become the new standard for the international trade. As more and more countries integrate traceability system into the policy of food safety, it may become the new trade barriers or standards in the international market. For example, *The Global Traceability Standard*, include the most versatile traceability standards in the global business currently, with the most comprehensive technology, detailed content and full intellectual properties.

2.2.3 The technology and management of food traceability

The traceability system is the information and documentation record system for food composition and flows in the FSC (Meng et al. 2009). Therefore, the traceability system is essentially a set of information management system to track food, feed, food producing animals or substance that will be used for consumption through all stages of production, distribution and consumption. To achieve the information integration and sharing processes, food traceability includes information identification, collection, transfer and associated management in all stages of the food supply chain. The general food traceability technologies include instruments to help collect, record and exchange information, and also includes logistic tracking technology. To help identify batches or units of ingredients and products, identification technologies are used, which comprises machine readable labels, which can be scanned, identified and recorded automatically in the information system. These in turn help to identify objects that move, like pallets, packages and units of products. To provide links to history of the products and its origins, linkages to all data collected is integrated as part of the system (Zhao et al. 2007). For example, once a unit or batch is labelled, the information is recorded and it can therefore be used to provide the information on the links between the products and the origins of its ingredients. This information is related to the path it has followed through the chain, from production to manufacturing, distribution and retail.

The information identification technology

The premise of information management uses widely accepted standards to identify information, and then collect and transfer this information. With globalization and its implication (increased links and interrelations between international actors) food traceability must be taken into account in the global flow of information, and must adopt a global standard system for information management (Li 2005). Currently the common identification system for product information identification, collection and transfer in the world is the EAN • UCC (European Article Numbering • Uniform Code Council) system, which has been developed by the Global Standard 1 (GS1). The EAN • UCC system is an opening standard system based on the item's trading code, logistic units, location, assets and service relationships. It correlated with the technologies of automated data collection, electronic data interchange, global product classification, global data synchronization, and electronic product code (EPC) and etc. (such as bar code, RFID) to serve the supply chain. More than 100 countries and a million enterprises have adopted this system in the world (Yu 2010). Therefore, the system has become a practical international standard.

The coding system provides the basis to establish a traceability system and is a standard information identification technology. The coding system includes coding for the participants, trade items, logistic units, location, assets and service relationships in the supply chain. Its coding structure provides a unique, globally recognised identification code in the related field, and guarantees that the identification code is unique in the supply chain. For example, in the process of tracking beef products, it gives a unique slaughter origin code for the beef carcass, which links it to the slaughterhouse and enables to identify the carcass. Furthermore, the product's coding provides the relevant information with the slaughter origin code, such as slaughter batch, date and carcass weight. The computer system is used to transfer the related information from the production stage to the packaging of the end product. At the end of the process, the unique barcode is displayed on the package of the end product. It means the food produced in the same day and same batch may contain a different barcode (Regattieri et al. 2007).

The information collection technology

Currently, the most commonly used information collection technology is the barcode technology. The barcode technology uses barcode symbols, which can be read by a photoelectric scanning device and allows the automatic identification, fast and accurate input of the information onto the computer. This technology allows data processing in order to achieve the purpose of automated management (Vitiello et al. 2001). The barcode technology combines computer and information technology, set coding, printing, identification, data collection and processing in one piece. The coding system can play an important role for governments in ensuring public health and safety. A concrete example of its possible application and use is the case of the contaminated milk in the Netherlands, which occurred in 2004. National authorities found a high level of dioxin in milk, and using the bar code system was able to trace back the origin of the contamination trough the chain. The source of contamination was rapidly identified to be the clay that was used in food processing to separate high quality potatoes from lower quality ones. With the food traceability process and coding it was soon found out that the contaminated clay had also been supplied to several food processing companies in Europe, notably in France, Germany and Belgium. The products were identified and never reached consumers (European Commission 2007). This shows that the food traceability system can help decision makers and local authorities to take timely and efficiency measures in avoid contamination in the food chain before it reaches consumers.

The advantages of this technology include: sample, the barcode symbols are easy to produce and the scanning operation is simple. The speed of information gathering is fast. Using the barcode scanning method to input information is 20 times faster than if using a keyboard. The amount of information collected is important. Using barcode scanning can help collect dozens of character information, and choosing different type of barcode symbol can increase the character density. The amount of information collected will increase several times. The reliability is high. The error rate of barcode scanning is only one time out of a million and the first reading rate accuracy is over 98%. It is flexible and practical, barcode symbols as a means of identification can be used alone or together with related equipment to achieve the automatic identification. This technology can also be combined with other control devices to achieve the automated management of the whole system. Meanwhile, it is also possible to use keyboard input when lacking automatic recognition device. Free to use, scanning device and barcode symbol can be used in a vast array of situation, greater with the use of the OCR (Optical Character Recognition). The device structure of barcode symbol identification is simple and easy to operate and the costs of promoting of the use of barcode technology are low (Hu 2007).

RFID is a non-contact automatic identification technology. It automatically identifies the target by the radio frequency and access to relevant data. RFID allows the identification work without human intervention, and it can work in a variety of bad environments. RFID technology can identify fast moving objects and can also identify multiple tags, the distance of identification from tens of centimetres to several meters. According to the way of reading and writing, it can input thousands bytes of information, and also has a very high level of confidentiality (Zhang et al. 2009). The basic RFID system consists of tags, readers and antennas.

In the applications of food traceability, RFID tags are more convenient, safer, and offer more transparency. For example, the producer added RFID tags on food products and raw materials, and input the basic information such as place of origin, production date, storage methods, and method of eating. In the next step, the products from the place of origin to the food processing company, those companies will input the processing information on the tags. Then the department of quarantine will input the quarantine information onto the tags. In the warehouse the storage information will be writing on the tags. All throughout the different steps of the process (from the warehouse up onto the market) information is inputted. Finally, when the food reaches the consumers' table each link in the FSC can be traced (Conill et al. 2002). However, RFID technology has not a mature and uniform standard throughout the world, and its cost is still high, so this technology is still not widely used for these reasons.

EPC is a new traceability technology, which aims at improving the level of logistics and supply chain management, and reducing the costs. It can give all objects (including retail goods, logistics unit, container, freight packaging and etc.) a unique mark. The EPC system is an advanced, comprehensive and complex system. The main purpose of it is to establish a global and open standard for every single product. There are three parts to the EPC system; the radio frequency identification system and information network system.

EPC system in the traceability of food safety has a great application value. In the production stage, a unique EPC tag is given to the food, product then a scanner will read it, and the product is ready to be taken from the warehouse to the distribution centre. In the distribution centre, reader record all the information from every single product and tray, also realized the commodities inventory management. When food shipped from the distribution centre to retailer, whether in the store or in the warehouse, the reader will record the information again from the commodities. In the last stage of retail, all product information will be read and written down, and then the whole process of traceability is done. The efficiency of this technology is very high. Currently, about 90 end users and 75 system integrators in the world are testing the EPC system.

The information exchange technology

In order to achieve fast, accurate, low-cost, high-efficiency exchange of electronic data information between the trading partners, GS1 developed EDI (Electronic Data Interchange) global standards. It consists of the EANCOM (European Article Numbering Communication) and ebXML (extensible Markup Language) two pats (GS1 China 2011； Yu 2010).

EANCOM is based on the coding system of EAN • UCC system (Global Trade Item Number, Serial Shipping Container Code, Global Location Number, etc.). It is the application guide of EDIFACT (Electronic Data Interchange For Administration Commerce Transport) standard of the United Nations, and it was introduced after simplified by GS1. The EANCOM provides clear definitions and descriptions, which makes the application of EDI more simple and convenient. EANCOM has a broad impact on the global retail industry and has been extended to the field of finance and transport.

ebXML provides a standard for the exchange of businesses information via the internet. The ebXML message standards developed by ISO all use the standard code, such as GTIN, GLN. No matter the differences about the type of software and hard ware of the trading members, the data still can be integrated in a timely manner, efficiently and accurately and then exchanged on the internet.

The logistic tracking technology

The Geographic Information System (GIS) and the Geographical Position System (GPS) systems provide an accurate tracking record of the logistics and process of transportation (Wang 2005). GIS is based on the geospatial data, using the geographic model analysis method, to timely provide a variety of space and dynamic geographic information. It is a geographic research and geographic decision-making services computer technology system. GPS is an advanced navigation technology, which consists of three subsystems space satellite system, ground surveillance system and user reception system.

GPS is mainly used for real-time acquisition, positioning the geographical coordinates of the target point. GIS can store, analyze, process and output the spatial geographic information by the support of computer technology. GIS can be used to manage and apply the coordinate location data obtained from GPS system. GPS can quickly and accurately collect data from GIS and also provide real-time object monitoring for GIS. In the process of logistics and transport, GIS / GPS technology not only can give a real-time tracking and monitoring to the transport vehicle, but can also monitor and adjust the temperature of the vehicle. This technology is based on the status of real-time tracking and calculates the optimal logistic route, navigate the transport equipment, reduce the run time, and decrease the operating costs (Zhou et al. 2010). Therefore, GIS / GPS technology can track and record the entire logistic process. It is the information infrastructure of food TS.

Implement the food traceability system also requires the participation and cooperation of all supply chain, along with the relevant technical side. It will not be able to implement the tracking and tracing of activities when missing any link. This requires effective management for production, processing, transportation, distribution, sales and other aspects of the supply chain, to ensure that the information in every links is standard and accurate. Safe and fast transfer of the information from one link to the next link can realize the tracking for product and also establish the good foundation for further tracing. The characteristics of good food traceability systems also include (Meng et al. 2009):

A complete regulations and laws, and normative enforcement

A sound legal system is the basic of food safety and the guarantee of the safe operation of the supply chain. A legal framework, which covers all food categories and food supply chain can provide a reliable basis for the formulation of the regulatory policies, testing standards and quality certification. For example, the EU's general Food Law, which was applied in 2002, makes traceability compulsory for all food and feed businesses. All food and feed businesses are required to identify where their products have come from where they are going (the "one step forward, one step back" principle). Producers are also strongly encouraged to keep track of the volume or quantity of a product, the batch number and a more detailed of the production (e.g. whether it is raw or not) (European Commission 2002).

Science-based traceability system

"Science-based" traceability is one of the basic principles of food safety management.

Every development of laws, regulations and standards about food safety must be maximized based on scientific theories. In some aspects it is difficult to determine food safety because of the restrictions at the level of scientific development. Hence it is necessary to ask for the opinion of experts to increase the scientific value for decision-making. In this respect, substantial investment and sufficient financial resources in food safety research are needed to guarantee the development of the food research institutions and further scientific knowledge about food safety.

Integrated management and monitoring for the entire process

The integrated function and management is a significant feature of the quality food supply chain management. In developed countries, the food safety regulatory system gradually tends to adopt the mode of integrated management, coordination and operation. Many countries have centralized food safety management into one or several departments and by doing so have increased the interdepartmental coordination efforts in order to improve the efficiency of the food safety management (Hou 2011). Monitoring for the entire process is an important principle of the quality food safety management. Each link of food production, from processing to distribution, sales and consumption imply potential safety issues. Only by supervising the entire process, "from farm to fork", can ensure public health safety in terms of food. Before the production, it needs a strict control the inputs of production and processing, especially the agricultural production inputs, such as pesticides, feed additives and animal vaccines. During the production, develop HACCP or other methods of production regulations to guide the food production, in order to minimize the harmful substances of food. After the production, it is necessary to emphasize the education about the knowledge of food safety and hygiene to consumers, and enhance public awareness about this subject. Meanwhile, an advanced foodborne disease monitoring system can play an important role in food safety management.

This integrated food traceability system is used in tracking animals crossing borders for example in the EU. In April 2004, the EU introduced the TRAde Control and Expert System (TRACES), which provides a database with information on animals crossing borders within Europe and third countries. This shows that in the event of a disease outbreak all potentially affected animals can be quickly identified and authorities will have the tools to take appropriate measures (Huang 2005). Existing traceability systems differ in scope, depth and precision, and according to the size and interests of the invested business. Therefore, there is an urgent need to look at ways for the public and private sectors to cooperate in order to strengthen and clarify traceability standards and management of these systems. Furthermore, cooperation or alliances between the private and public sector would serve consumers in helping to verify that all food products comply with policies and regulations as determined by governmental agencies.

Complete standards and efficient measures

Compared with the laws and regulations, food safety standards are more directly needed to ensure food quality and safety. Develop strict standards in all aspects of food production, distribution and consumption is imperative. Equally important are restrictions and sanctions for the sale of substandard food products. In the early 1980s, Britain, France, Germany among other countries adopted international standards concerning food products are more than 80%, some standards for specific food even higher the level of CAC standards (Ye 2011). Apply standard management is one of the most effective means to regulate the production behaviour, improve product quality and ensure food safety. The primary function of the government in food safety management is developing food safety standards and enforcement of these standards. These standards include the general prohibition on adulterated food and the specifically limitation about the amount of chemical residues in food. It also includes the standard requirements of product and the procedures of processing.

Open information and public participation

In the process of food supply chain risk management, the exchange and dissemination of risk information is very important. The government must pay attention to the public's right to know, to strengthen the openness and transparency of the food safety system construction and food safety management, and establish an effective FSC safety information system. Governments regularly release useful information, such as the testing result of food market, the recall information about substandard food, and the motions of management department, to enable consumers to understand the real situation of food safety, and enhance their ability for self-protection.

2.3 Risk management

Sitkin and Pablo (1992) define risk as being “the extent to which there is uncertainty about whether potentially significant and/or disappointing outcomes of decisions will be realized.” There are many different definitions of risk, but risk is mostly contextualized within the area of decision making (individual or organizational), (un) predictability and potential loss. Risk management covers many areas, including policy risk, market development risk, production risk, financial risk, operation management risk and investment risk.

The process of risk management has two parts: before the occurrence of the loss and the management of after the occurrence of the loss (Ma et al. 2005). The objective of the risk management process before the occurrence of the loss is to avoid or reduce potential accidents, and also includes saving on operation costs and decreasing anxiety Levels. The objective after the occurrence of the loss is to try to restore the loss to the state, which includes the maintenance of the survival of the enterprise, continuing production and provision of services, ensuring stability of income, and the continued growth of the production and a certain level of social responsibility. The effective combination of both parts constitutes a complete risk management objective.

How to deal with the risks is at the core of risk management. A basic principle of risk management is getting the maximum protection at a minimum cost. There are four methods to deal with the risks (Hu et al. 2005):

Risk avoiding

Risk avoiding includes a complete risk-averse approach, which is to cut off the sources of risks. It means abandoning or terminating the collaboration of the supply chain, or change the environment of cooperation, to avoid the impact of external accident on the enterprise. Although this method can fundamentally eliminate potential risks, it obviously includes a lot of limitations as well. Because not every risk is able or should be avoided, sometimes it means the loss of potential profit making opportunities.

Risk prevention

This method is based on risk identification and assessment, and takes preventive and control activities to the related risk, to reduce the opportunity and damage of the loss. Risk prevention involves a comparison between current costs and potential loss. If the potential loss is much greater than the current costs, it should take into account this method to prevent the risk, such as building water conservancy projects and construction of shelterbelts.

Risk transfer

Risk transfer is a method, which implies the transfer of all or part of possible risks. This method is the most effective risk management tools with the widest range of applications. There are two types of risk transfer: insurance transfer and non-insurance transfer. The first one refers to buying insurance from the insurance company and transferring part of the risk of loss to the insurance company. The second implies the transfer of risk to the outside enterprise of supply chain; this means that the risk is shared by the entire supply chain enterprises.

Risk absorption

This method implies that all potential risks are taken care of by the company. They may know the existing risks, but are willing to stand the chance for huge economic benefits in return. Another reason that is they cannot avoid it due to the fact that it is a system risk of the supply chain. The only way to solve this is to absorb the risk by all enterprise in the supply chain, and it is cheaper than buying insurance. Risk absorption is normally used to deal with the risk of small occurrence probability and which imply low level of losses.

In the supply chain, the risk often transfers from one enterprise to another enterprise, and this has a magnifying effect. Thus, the collaboration in the supply chain for risk management is absolutely essential (Hallikas et al. 2004). Some risks can only be mitigated and not eliminated, such as climatic disaster. Therefore, the endurance in the supply chain is necessary. The method chosen of risk management is a scientific based decision. It should be based on the full understanding of the internal situation and external environment of the supply chain, but also pay attention to the applicability of the method and effect. Generally, the choice of a risk management method is not isolate, and it is the combination of several methods.

2.3.1 Supply chain risk management

Supply chain risk management combines risk management into SCM. According to Brindley (2004) “Supply chain risk management is at the intersection of supply chain management and risk management and has for objective to help organizations handle the uncertainties and risks involved in the supply chain”. Especially in the food chain, the quality control and the ability to track and trace are critical (Fearne et al. 2001).

SCRM is becoming a critical SCM discipline, especially considering that supply chain offers greater exposure to new risks caused by changes of outsourcing, lean manufacturing and Just-In-Time inventory. Focusing on the supply chain, SCRM cover all aspects of risk management in the supply chain. Waters (2007) believes that “the overall aim of supply chain risk management is to ensure that supply chains continue to work as planned, with smooth and uninterrupted flows of all materials from initial suppliers all the way through to final customers”. This definition does not purely focus on risk prevention but also on the supply chain working as planned, in fact, which is the key target of SCM.

SCRM connected strongly and closely not only with SCM but also risk management. Both SCRM and risk management have the same goal, that is, to help organizations understand, evaluate and take actions on the different risks, in order to reduce failure and sustain successful business. The difference is that SCRM focuses on the risks in the supply chain and the failure and success of the whole supply chain while risk management stresses the risks of one individual organization, as is the case in general risk management.

2.3.2 Categories of supply chain risk

In or between the different links of the supply chain, risks can be detected and bring a huge influence on the different members of the supply chain. It is therefore very critical to know where in the supply chain the risks exist and what their causes are.

Different ways to categorize risks are described in the risk management section (Brindley 2004; Christopher et al. 2004; ISO International Standard 2007). One of the common characteristics of the various categorizations is the distinction between external and internal risks. The risk categorization of Christopher et al. (2004) is the most widely used and accepted in SCRM. See Figure 5.

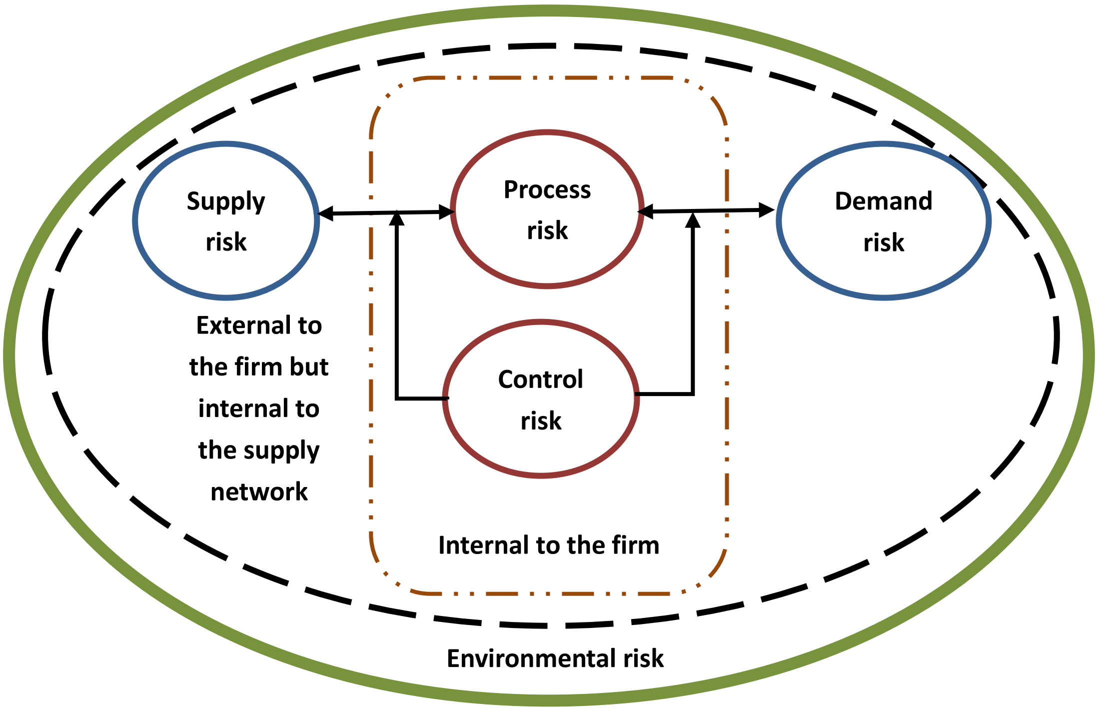

Figure 5 Sources of risk in the supply chain (Source: Christopher et al. 2004)

Internal risks

Further breakdown of the internal risks exposes two internal risks, including risks that are internal to the firm and risks that are internal to the supply network. Supply chain risks that occur internally in the firm can be much diversified. Christopher et al. (2004) split internal risks into control and process risks. This internal element can also be compared with the "make" element of the supply chain operation reference (SCOR) model (Christopher et al. 2004). Supply chain internal risks are risks that occur between the walls of the firm under the influence of more than one supply chain member.

Risks that are external to the firm, but internal to the supply network are the risks occur in upstream or downstream of the chain. Christopher et al. (2004) call these risks the supply and demand risks. These risk areas can be compared to the "source" and "deliver" elements of the SCOR model.

External risks

External risks are defined as the risks that are outside of the whole supply chain network. Since these risks are not easy to predict and avoid, risks in the external environment are not included in the development of the SCRM method. External risks are important risks that exert an influence on the supply or demand side of the supply chain or on the internal operation of the focal firm.

2.3.3 The risk factors impact on food safety

According to the WHO (1996) definition: food safety is a guarantee that the intended way to produce and use food will not cause damage to consumers. According to the popular explanation the food safety encompasses two aspects. On the one hand it concerns the nutritional value of food, and the aspect of quality. People care more about the quality aspect in their daily lives, such as food spoilage, the nutritional value of food, etc. On the other hand, it is the problem of the natural and pure attribute of food that has been changed by human in the process of production, processing, transportation, storage and sales (Wang et al. 2004). These problems are concerned by the activities of food traceability.

The following information concerns the food safety risks that have been identified in the literature:

Classification by the different segments of the food chain
The risk factors can be defined as (Xie et al. 2009): hazards in the food ingredients (such as natural toxic substances, pesticide residue, veterinary drug residues, harmful metals, environmental persistent organic pollutants, and biological contaminants), food processing hazards (such as hazards generated by heat processing, safety issues of new technology, safety issues of new resources, the side effects of food additives, processing environment and etc.), contamination of food containers and packaging materials (such as plastic hygiene problems, hygiene problems of rubber products, paint hygiene problems, hygiene problems of other materials), hazards in the food storage and transportation process (such as chemicals contamination, hygiene problems caused by improper temperature, personnel hygiene pollution and etc.).

Classification by the hazardous substances
The risk factors can be defined as (Wu 2003; Jin et al. 2008): microbial contamination hazards (such as bacterial contamination, food-borne parasitic diseases, fungi and their toxins, food spoilage, etc.), chemical pollution hazards (such as veterinary drug residues, pesticide residues, heavy metals and other trace elements, nitrate, nitrite and N-nitrate compounds, polycyclic aromatic hydrocarbon compounds, heterocyclic amines compounds, dioxins, radioactive material, etc.), the dangers of food additives (such as preservatives, bleaches, antioxidants, flavor agents, flavoring agents, emulsifiers, etc.), new technologies, as well as the safety of the food processing.

Classification by the pollutants
The risk factors can be defined as (Xu et al. 2008b): biological pollution (such as bacterial contamination, mold and mycotoxin contamination), chemical contamination (such as pesticide pollution, metal toxic pollution, pollution of N-nitroso compounds, polycyclic aromatic hydrocarbons, etc.), physical pollution (such as exogenous foreign body, radioactive contamination, etc.).

The above classification methods are basically from the point of view of natural science to classify the toxic and harmful factors that may occur in the food. They constitute the entire content of the food safety risk. In these risks, the main problems affecting the food safety are as following:

1. The problem of food additives

The excessive use of food additives is one of the important factors that lead to food safety issues (Yu 2004). Food additive are necessary basic ingredients in the food production and processing, to ensure longer shelf-time and conservation of the products and are the most important products used for safety. The production of food additives needs a rigorous assessment and toxicological tests, and the value evaluation of ADI (Acceptable Daily Intake). It is safe to use the food additives under the health standard. Correct and rational use of food additives will not contaminate the products, but can also in the contrary safeguard the safety of the food. There is a problem in the use of unqualified food additives in the food additive management. The unclear and substandard label made by food additives producer, and the misuse of industrially produced, chemical products in food production will cause serious impact on food safety.

2. The problem of non-food materials

Most of the non-food raw materials used in food production are industrial additives, non-food chemical materials and industrial chemical products. Those materials can cause harm to human health, such as in the case of "alkaline green" in seaweed products, "Sudan red" in chili products, melamine, "malachite green", sodium formaldehyde sulfoxylate in milk powder products.

3. The food safety regulations and standards problem

The biggest issue related to regulation and standards of food safety is the incomplete food technology regulations and standards, especially the safety and testing standards. The food safety standard system is confusing because of the development and management of standards, which are based on various departments. Testing standards and food quality control system are two processes that have yet to be standardized. The safety production technology standards and operation standards in food chains make a big difference in comparison with food standards, pollutant limitation standards, and the analysis and testing standards. It is difficult to ensure efficient control of the entire food chain.

4. The problem of primary products and agricultural inputs

This is a main problem concerning food safety issues. Food raw materials come from primary agricultural products, and the key problem of it is the misuse of agricultural inputs. For examples, the illegal use pesticides and veterinary drugs will easily cause drug contamination of food (McEvoy 2002). The agricultural chemical residues on food can cause the resistance of the pathogens (Butaye et al. 2001; Barbosa et al. 2005). The biological, chemical and environmental pollutants in the primary agricultural products are serious problem (Xu et al 2008a). The EU made a clear and detailed provision for MRL (maximum residue limit) and the use of drugs in food of animal origin (European Commission 1990; Van Petehem et al. 2004).

It is important to base safety measures on risk monitoring, analysis and assessment technology, which can further strengthen the study of primary agricultural products, agricultural inputs, safety infrastructure and application, and food safety management. This is essential in order to discover fast and efficient testing methods and technologies for the research of pathogens, pesticides, veterinary drugs, chemical pollutants in food (Li et al. 2009). For example, the use of biosensors technology can help detect the drug residues in food of animal origin (Franek et al. 2005), then use the evaluation of the data analysis to determine the MRL standards, so that the quality of primary agricultural products in the food chain can be guaranteed.

5. The problem of processing, storing, transporting and environment pollution

The scale, technology, hygiene conditions, transportation and storage capacity, and management of food processing enterprises will have an important impact on food safety. In the food raw material production, processing, storage, transportation, and sales sectors, due to the problems of production and storage technology, it could easily lead to food secondary contamination. This is the potential risk factor of food safety issues (Chen et al. 2008).

6. The problem of application and safety testing system

Enterprise must continue to improve the safety testing and evaluation system for new products, technologies, processes, accessories and raw materials, such as food additives, genetically modified foods, enzyme preparation, food packaging materials and food containers (Song et al. 2009). For example, there are many difficulties that arise from the use of the traditional toxicology test method and risk assessment procedures to evaluate the safety of genetically modified foods. Losey et al. (1999) published an article in *Nature* magazine about the safety problem of genetically modified crops. They argue that the biological food safety issue has become the focus of attention of the international community. Most of the new technology of the food industry use chemical and biological technology. Those food products need a verification and assessment process, and the continuous development of new technologies also brings new issues for the food safety. Those problems need to set up a complete scientific and systemic safety testing and evaluation system (Tang et al 2005).

7. The problem of food safety analysis, assessment, and early warning system

Food safety analysis, assessment, and early warning require setting up a complete system. In order to ensure the system running in an effective way there is also the need to establish a set of technical and procedural rules and regulations, and the good cooperation and communication among every department. In the end, a complete and effective risk analysis and assessment system will be developed.

3. The critical risk factors impact on food traceability

Food traceability is necessary in order to monitor and track various risk factors, which affect food safety. Based on relevant food traceability technologies, food traceability systems can collect large numbers of data for risk analysis and risk management. It provides timely, continuous and accurate records and information tracking for the food chain. It can predict the reasons of hazards and degree of risk, and also provide a flow and range of polluted products. Food traceability provides the possibility to proceed to food recall. It is an important tool for enterprises to enhance food safety and quality control. In order to ensure the accuracy and consistency of food traceability, it is necessary to study the risk factors that affect the quality of food traceability. A concrete example of the application of food traceability and its benefits is illustrated by the use of the Rapid Alert System for Food and Feed (RASFF). There are 27 member states part of this warning system which allows the traceability and rapid exchange of information in the event of a potential threat to food quality, or feed safety. In the event of such contamination issue, member states need to notify the European commission, which will immediately take appropriate measures to correct the situation (European Commission 2007).

The risk factors that affect food traceability can be divided into two main categories, technical risk factors and managerial risk factors (Fotopoulos et al, 2009; Luning et al, 2007). The technical risk factors are the factors which occur during the application and innovation concerning food traceability technology. Such as the information identification technology, the information collection technology, the information exchange technology, the logistic tracking technology. The application of any new technology requires a testing period. During this period, the authenticity of the food traceability activities is easily influenced, distorted or un-collectable. This will decrease the quality of the results of traceability and increase the risk.

The managerial risk factors are focused on the existing and potential human-centered risk factors. During the process of food traceability, they are locating in the various parts of the FSC. For instance, misuse low quality raw materials, data loss or fraud, warehouse pollution, transport problems, vicious competition, food traceability standards differences, safety awareness, etc. In comparison with the technical risk factors, managerial risk factors are much more complex and more difficult to control. It has higher concealment and subjective, food traceability can be affected in every link of the food supply chain. If a problem occurs, it will result in a great deal of damage for the quality of food traceability (Chen 2005; Zhao et al. 2007). Therefore, this research is based on Figure 2 in the division of the food supply chain, take infant rice cereal products (IRCP) supply chain as the example, and mainly pay attention to analyzing the managerial risk factors.

The planting/breeding Chain

This section, concerns the provision and quality of agricultural raw materials input and production of primary products two parts. As the first stage in the food supply chain, it is the source of food biological pollution. The development of modern industry caused a lot of damage to the environment, and the pollution of this damage began to slowly spread to the countryside. The planting and breeding environment in rural areas is continually polluted by chemical hazards and pathogenic bacterium. The pollution of land, rain, and atmosphere will directly contaminate agricultural production, and the influence of pesticides, antibiotics, growth substance, etc. It shows the biological contamination existed in agricultural production stage (You et al. 2009). Due to differences in the quality of farmers, the degree of attention for contamination of crops, the disease of poultry and livestock are different too. This brings a lot of obstacles to food traceability. For example, when poultry or livestock deaths in the farm, some of them may casually abandoned those corpses at fields or rivers, and do not take any methods of isolation and destruction. It is easy to cause a wide range of cross-infection, and this infection is difficult to be traced back to the source.

The processing Chain

The processing part is an important link for food traceability. The raw materials of food processing enterprises usually come from the separate production organization. From the processing of primary products to the end product, various primary products and auxiliary materials are used in the process and changed the traits. This can lead to cross-contamination of agricultural products, and makes the process of traceability more complex. The way to use food additives, the difference of production processes, and the regulatory hygiene standards will further increase the difficulties of the food traceability activities (Meng et al. 2009). In addition, the collaboration among different enterprises in the FSC and the transparency of the production and operation processes are poor. Those man-made factors directly affect the efficiency and authenticity of traceability. For example, because of vicious competition, some processing sectors in order to reduce the costs to use inferior raw materials and tampering the traceability information. This approach reduces the quality of the final product, but it is hard to be traced back to the origin.

The distribution Chain

The food distribution is the last part of the food supply chain and direct link with consumers, and likely to cause the secondary pollution. It is the initial stages of the food traceability. The quality of food depends, partially on transportation and therefore the correct and effective storage equipment and ways of transportation. The development of the food industry leads to the distance between the production process of food and consumers at the end of the chain. Foods often need to go through the long-distance transport, a wide range of sales, as well as multi-channel and multi-link circulation (Bao 2007). This trend has increased the difficulty of food traceability processes. The shelf life of the food is short. Transportation needs to be achieved in a timely manner, and there are some necessary measures to ensure the produce quality. The end products are delivered to the retail industry and catering trade, and finally reach the consumer's table. At this stage, the quality of enterprise management, the level of storage and transportation equipment, the supervision of the marketing place will all impact the accuracy and efficiency of food traceability. Regarding the consumer links to the food traceability, the consumer limited awareness and understanding of food safety can hinder the extension and implementation of food traceability to a certain degree.

3.1 The risk factors affecting food traceability in Chinese infant accessory food industry

3.1.1 Basic information and characteristics of Chinese infant rice cereal industry

This research refers to IAF industry as the example. The industry has a long industrial chain and various links. Its vertical extension involves the primary industry (agriculture), secondary industry (food processing industry) and tertiary industry (distribution, logistics, etc.). The IAF industry has a lot of potential risks in and between the links. According to the "Rules for examination of production licenses for infant accessory foods 2017" issued by the State Administration for Market Regulation, IAF products can be divided into three categories: (1) Satiety complementary foods based on rice cereals and noodles; (2) Non-staple food supplements based on biscuits; (3) Complementary food based on fruit and vegetable puree.

Meanwhile, infant rice cereal products are the second major category in infant food (Wu et al, 2014). But compared to the milk powder products, Chinese society and consumers have insufficient awareness and attention to the safety of the product. Due to the adverse effects of previous milk powder incident, China's infant food industry is constantly developing new products and markets for its survival. However, with the growing market for IRCP, many IAF companies have experienced various safety issues. IRCP are the main IAF product and occupies about half of the market. It involves more links and risk factors in the FSC. Research on this industry is indispensable for the development of the IAF industry, so this paper chose IRCP industry as the research object.

Usually, infant rice cereal is made of rice which is key raw material and other auxiliary materials including vegetables, fruits, eggs, beans, meat, etc. as well as other nutritional fortification parts such as mineral and vitamins. All of these are mixed together to process out infant supplementary food (Geng et al, 2016). According to statistics from the State Food and Drug Administration in 2016, there are 103 dairies and IAF products manufacturers nationwide. The sales of Chinese infant food (dairy & IAF products) reached 2269.33 billion JPY by 2015, growing at annual rate of 16.1%. Domestic market is expected to break through the 3400 billion JPY, registering a remarkable expansion in 2018.

According to industry statistics, the market size of IRCP in China approached 142 billion JPY in 2017. Compared with developed countries, China is still in preliminary phase of IRCP development and research. Most of Chinese IAF companies were established around 1990. Currently, the brand concentration of this market is relatively high. The top 3 companies (Heinz, Beingmate, Nestle) accounted for 65% of the entire IRCP markets in China (See figure 6). The market share of the three major brands is mainly focused in about 30 large cities in China, and the market share of each region is different. Small and mid-sized enterprises, such as Synutra, Yashily, Eastwes, Gerber, Wondersun etc. are basically only sold in the local market of the province or region, and have absolute price advantages (Jie et al, 2017). Due to the vast territory of China, although the brand concentration in this industry is relatively high, it has not formed a market oligopoly. Their market developments are characterized as early-stage business activities.

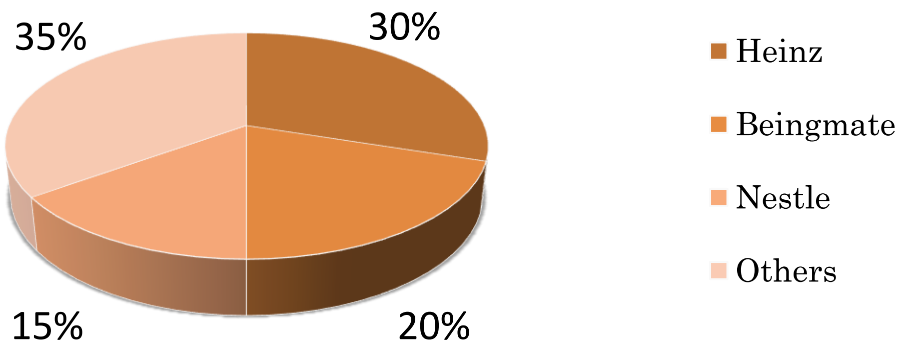

Figure 6: The market shares of Chinese infant rice cereal products in 2016 (Source: Jie et al, 2017)

On the other hand, governments pointed out that current market is limited, management is not efficient, types of products and numbers of production enterprises are high, and also, the quality is poor. The sampling carried out by the State Food and Drug Administration discovered that 21.6% of products were unqualified (Jie et al, 2017; Huang et al, 2011). The major reasons include: The microbial and microbial toxin levels exceeded the standard, such as E. coli, yeast and mold; No nutritional supplements were added or insufficient; Heavy metal content exceeds the standard and so on (China Food and Drug Administration 2017).

The frequently happened food safety accidents were mainly caused by:
(1) Processing technology. Small or mid-sized enterprises are accustomed to adopting traditional production technologies, which resulted in the water-soluble rate of product is slow, poor taste and not easy to prepare.

(2) Nutrition fortification. Processing of rice cereal may cause nutrition loss. To cut down costs, manufacturers do not add or put few nutrition enhancers specified in product standards, leading to the low nutrition content.

(3) Sanitary. Obsolete equipment, poor production management and unsatisfied sanitary condition of production environment cause serious sanitary issues. Secondary pollution of raw materials occurs frequently in many processing enterprises.

(4) Market management. The managerial problems include, reasonable long-term supervision and management mechanism is not well established. The implementation of the market access system is not enough. Laws and regulations are not sound (Wu et al, 2014).

Due to the late establishment of China's infant food industry, related laws and regulations have not formed a complete system. Compared with developed countries, there are many deficiencies in content and quantity (Geng et al, 2016). The management system of this industry is segmented control and independently supervised by a number of different departments. There are various problems such as poor coordination among departments, decentralized functions, blurred function definitions, the formulation of new laws and regulations that cannot keep up with the needs of social development, and the lack of junction and coherence between laws and regulations etc. This situation is common in various industries of edible agricultural products in China.

Facing with the new conditions in living style transformation and increased demand from market, both safety issues and quality challenges of IRCP will hinder the continuous progress of the industry. Any quality problems on the link of rice cereal supply chain will affect the quality and safety of the entire supply chain, and finally impact the consumer’s living quality. Therefore, it is very important and necessary for IAF industry to set up and optimize product safety traceability system.

3.1.2 The identification and analysis of the risk factors

According to the IRCP supply chain structure, the identification and analysis of the risk factors play a role in determining the quality of traceability of the product at each stage of the chain. Based on the different subjects of the IRCP supply chain, it is divided into four interconnected phases. Meanwhile, each phase can be divided into four categories based on the analysis of its current status of safety risks and starting from its influencing factors. The traceability system risks are management risks, equipment risks, technical risks, and environmental risks. Through the research in Chapter 2, the risk factors of each category are summarized as follows:

1) Risk assessment indicators of grain (raw materials) production phase

a. Management risks

- Seeds quality: The quality of the seed will determine the characteristics of the grain products. High-quality seeds are the guarantee for the benefit of the end product.
- Pesticides and fertilizer safety: The choice of pesticides and fertilizers is directly related to the safety of grain products and the impact on the human body and the

environment.

- The quality of employees: The staff's management concept, management level and safety awareness are the keys to ensuring food production.
- Information acquisition: The ability of grain producers to acquire market and technical information. It will affect the management level of production. Insufficient ability will result in reduced competitiveness and increased management risk.
- Data record of the Planting process: Data recording is helpful for work supervision, retrospective verification, statistical summary and management level improvement. Incorrect or incomplete records will lead to the failure of traceability activities.

b. Equipment risks

- Irrigation: The safety risks of irrigation equipment in the working process. Such as the management of water quality.
- Farming: The equipment used in the cultivation and harvesting process poses a safety risk to grain products.
- Storage: The safety risk of grain storage equipment, whether there is a risk of secondary pollution in warehouse facilities.
- Sterilizing: Whether the disinfection equipment meets the safety standards, if there is a problem, it will affect the safety of food products.

c. Technical risks

- Fertilizer application: The choice of fertilizer is the key to grain growth, and there are many risk factors in it.
- Prevention and treatment of disease: The level of disease control will directly affect the quality of grain products. Misuse of pesticides creates a risk of pollution.
- The quality of technical staff: The professional level, safety awareness, and risk awareness of technical staff are important factors affecting food security.
- The ability of new technology application: The application of new technologies is an important factor in improving the safety of food products and increasing competitiveness.

d. Environmental risks

- Natural disaster: Natural disasters such as floods, droughts, and earthquakes can cause devastating blows to grain products.
- Policies and regulations: Whether the current policies and regulations can effectively manage and supervise various risk factors.
- Consumer awareness: the level of awareness about grain production and food safety will improve producers' emphasis on quality and safety.

2) Risk assessment indicators of grain (raw materials) transportation phase

a. Management risks

- Grain shipment inspection system: Grain passes through different areas in the transportation process. If there is no strict inspection system, many potential dangers of insecurity will arise.
- Vehicle disinfection plan execution: Disinfection and cleaning of transportation

vehicles help prevent various pollution and diseases.

- Contract’s execution quality: The contract signed by the transportation company and the client is an important part of the traceability information.
- The quality of employees: The management concept, management level and safety awareness of freight employees are important guarantees for transportation safety.
- Information acquisition: The ability of transportation companies to obtain supply and demand information and technical information is an important factor in controlling risks and ensuring safety.
- Data record of the transportation process: The record of cargo information during transportation facilitates traceability verification and supervision and management. Incorrect or incomplete records will lead to the failure of traceability activities.

b. Equipment risks

- Vehicle failure: The failure of the transportation vehicle will affect the execution of the transportation plan and increase the risk of insecurity.
- Container equipment issue: The quality and safety of the container can reduce losses during transportation.
- Disinfection equipment issue: Disinfection equipment can reduce the risk of pollution and ensure the implementation of the transportation plan.

c. Technical risks

- Loading technical problem: The rationality of the grain product loading plan can improve transportation safety and reduce losses.
- The quality of operator: Operators' experience level, safety awareness, and risk awareness are important factors affecting transportation safety.
- Abnormal situation processing technology: The abnormal situation during transportation is composed of many factors, and advanced equipment and methods can improve the safety of transportation.

d. Environmental risks

- Traffic accident: If a traffic accident occurs during transportation, it will cause serious losses to the safety of food products.
- Natural disaster: If floods, earthquakes, typhoons and other disasters occur during transportation, it will cause vehicle damage or plan delays, increasing the probability of traceability risks.
- Policies and regulations: The policies, standards, and operating specifications of the transportation industry will affect the service level of transportation companies.
- Consumer awareness: Consumers' understanding of the transportation process and requirements for grain product safety will promote the safety management capabilities of transportation companies.
- Government supervision: The government's supervision of the transportation industry will affect the safety and quality of food transportation.

3) Risk assessment indicators of processing and storage phase

a. Management risks

- Raw materials and additives detection: The testing of raw materials and additives in food processing is the most important part of food safety, and the lack of strict testing will cause serious safety hazards.
- End products quality inspection: A large amount of traceability information is mixed in the end product, which is a key part of the traceability system and must be strictly managed.
- Packaging material safety: Food packaging plays a decisive role in food safety. It is the key to protecting food safety and recording traceability information.
- The quality of employees: The level of food processing safety control and risk handling capabilities depends to a large extent on the quality of management employees.
- Disinfection plan execution: In the complex processing process, the probability of food contamination increases, and careful implementation of the disinfection plan is the guarantee to reduce the risk.
- Information acquisition: Processing companies need to have a comprehensive grasp of raw material supply information, market information, and competitor information. So that companies can take corresponding measures to deal with risks and improve management.
- Data record of the processing and storage process: There are many links in the processing process, and more information needs to be recorded. At the same time, product storage information needs to be carefully recorded. Incomplete or wrong information will lead to the failure of traceability activities.

b. Equipment risks

- Workshop hygiene design: The design of the workshop must comply with relevant government regulations to control pollution problems during processing.
- Processing equipment issue: Failure of processing equipment will increase the risk of food contamination.
- Packaging Equipment issue: The quality of packaging equipment will directly affect the safety of end products.
- Warehousing and handling equipment issue: The warehouse facilities and the quality of the building will influence the risk of product storage. The failure of handling equipment is also the key to secondary pollution.
- Disinfection equipment issue: The failure of disinfection equipment will affect the disinfection effect of the environment and facilities, fail to achieve the purpose of controlling microbial pollution, and increase potential safety hazards.
- Detection and monitoring equipment issue: The quality of detection equipment will affect the authenticity of testing results, which is a key step in food traceability.

c. Technical risks

- Hygiene control of processing operations: Whether the hygiene control measures for processing operations are reasonable or not is an important factor affecting product quality and safety.
- Inspection and detection technology: Advanced detection and inspection technology is the guarantee of efficient and accurate control of product safety.

- Cryogenic storage technology: Temperature control is the core content of food preservation. If the technology is unqualified, it will have an adverse effect on the product.
- The quality of operator: The operator's inspection level, safety awareness, and risk awareness are important factors affecting processing safety.

d. Environmental risks

- Natural disaster: Disasters such as floods and earthquakes in the location of factories or warehouses can cause fatal damage to products and enterprises.
- Air and water pollution: Pollution of air and water sources during processing will seriously undermine the safety of food products.
- Policies and regulations: The rationality of policies, regulations and standards will affect the safety management behavior of processing enterprises. It is an important guarantee for traceability activities.
- Consumer awareness: Consumers' understanding and attention to processing and storage processes are an important driving force for companies to improve risk management and traceability.
- Government supervision: The intensity and quality of government supervision are important factors that affect the processing and storage phase. It can improve the standardization of the industry and reduce the impact of risk factors.

4) Risk assessment indicators of end products distribution phase

a. Management risks

- Procurement quality assurance: The sellers ask for quality-related certification from the supplier to ensure the quality and safety of the product.
- Products quality inspection: In order to ensure safety, random inspections of purchased products are required.
- Shelf life management: Sellers must formulate strict shelf life management to prevent the sale of expired products.
- Contract's execution quality: The contract signed by distributors and retailers is an important part of traceability information. Ensure the integrity of traceability activities.
- The quality of employees: The staff's management concept, hygiene awareness and safety awareness will affect the safety risk control level of the entire distribution chain.
- Abnormal situation processing: If there is an abnormality in equipment or products in the distribution process, it needs to be properly handled in time to reduce the impact on product safety risks.
- Information acquisition: The distribution phase has high requirements for the ability to obtain information. The demand information of the entrusting party, the information of the target customer, the safety information of the product, the information of the transportation, etc. need to be effectively obtained, otherwise it will affect the safety of the product.
- Data record of the sales process: The record of the sales process is an important part of traceability activities, and perfect and timely records are an essential

element of risk control.

b. Equipment risks

- Storage facility hygiene: If the storage location lacks sanitation control facilities, it will inevitably affect the quality of the product and increase the risk of adverse.
- Disinfection equipment issue: The failure of disinfection equipment in warehouses and vehicles will affect the normal operation of the disinfection process and bring safety risks.
- Handling equipment issue: If the handling equipment cannot be cleaned up in time, it is easy to cause cross-infection and bring obstacles to traceability activities.
- Detection equipment issue: The failure of the detection equipment will affect the authenticity of the detection results and cause the distortion of product monitoring information.

c. Technical risks

- Delivery time control: The accuracy of delivery time is an important factor in reducing food safety risks.
- Rationality of disinfection measures: The correctness of the disinfection method is an important condition that determines the disinfection effect. If the hygiene requirements are not up to standard, it will cause more pollution.
- Rationality of detection technology: The use of reasonable and efficient detection methods will help improve management quality. Testing methods that comply with government regulations are also an important basis for traceability activities.
- Rationality of inventory control: Reasonable control of inventory and speeding up turnover are effective ways to reduce safety risks.

d. Environmental risks

- Natural disaster: Natural disasters in the distribution phase will destroy the traceability information of the product and cause unnecessary losses to the enterprise.
- Policies and regulations: Food-related delivery and distribution laws are necessary to ensure food safety and restrict personnel operations.
- Consumer awareness: Consumers' understanding of the distribution process and requirements for food product safety will directly affect distributors' behavior and attitudes regarding safety risks.
- Government supervision: The level of government supervision is the guarantee that retailers can perform sanitary operations in accordance with standardized procedures. It is also the reliance of consumers for traceability activities.

3.2 The Chinese infant rice cereal products supply chain risk assessment model

Due to the globalization of economy and the expansion of international food trade, the scale and complexity of the FSC are also increased (Kher et al, 2010). In order to ensure the accuracy and consistency of the food traceability, every part of the FSC needs to be monitored (Houghton et al, 2008). All the different parts of the supply chain involve different risk factors. These risk factors will cause the deviation of the results, affecting the quality of the food traceability, and at the same time resulting in adverse impact for consumers and weaken customers' trust on the products (Van der Vorst, 2006; Golan et al, 2002; Van Rijswijk et al, 2012).

The fuzzy synthetic evaluation method was adopted to set up a critical risk factors assessment model. Questionnaire data were dealt to evaluate the risk situation of Chinese IRCP supply chain. All of these were considered to guarantee the efficient identification of the key risk of TS and profound analysis of the impact from various sources of risk were addressed. The FSE method is used to combine quantitative and qualitative indexes effectively, and also quantify the factors that have an unclear boundary and are difficult to quantify. It has strengths of practicality, systematicity and simplicity (Chung et al, 2005; Xu 1998).

3.2.1 The mathematic model for the synthetic evaluation

In this model, (U and V are 2 finite sets: U; V) **U** = {$\mathbf{u_1, u_2,\ldots,u_m}$} is a set of elements composed of a variety of factors that influence the evaluation object. The $\mathbf{u_i}$ represents the $\mathbf{i_{th}}$ factor that affects the evaluation object. **V** = {$\mathbf{v_1, v_2,\ldots,v_m}$ } is a set of comments that the evaluator may make on the evaluation object. The $\mathbf{v_j}$ represents the $\mathbf{j_{th}}$ evaluation comment. If the membership of the $\mathbf{i_{th}}$ element in the set **U** to the first element in the set **V** is the $\mathbf{r_{i1}}$, the result of the single factor evaluation of the $\mathbf{i_{th}}$ element is represented by a fuzzy set as: $\mathbf{R_i}$ = ($\mathbf{r_{i1}, r_{i2},\ldots,r_{im}}$) . Using n single factor evaluation sets ($\mathbf{R_1, R_2,\ldots,R_n}$) as the row to composite matrix $\mathbf{R_{n*m}}$. Then we got **R**, fuzzy relation, which is an overall evaluation matrix. $\mathbf{r_{ij}}$ denotes the degree of affiliation of $\mathbf{u_i}$ with $\mathbf{v_j}$. (**U**, **V**, **R**) constitutes a FSE model.

$$\mathbf{R} = \begin{bmatrix} r_{11}, & r_{12}, & \cdots\ r_{1m} \\ r_{21}, & r_{22}, & \cdots\ r_{2m} \\ r_{n1}, & r_{n2}, & \cdots\ r_{nm} \end{bmatrix}$$

Due to the significance of each factor is different, in order to reflect the importance level, each factor $\mathbf{u_i}$ should be given the corresponding weight $\mathbf{a_i}$. **A** = {$\mathbf{a_1, a_2,\ldots,a_n}$ } is used to represent the weight of each factor, and $\sum_{i=1}^{n} a_i = 1$

When the weight vector **A** and the evaluation matrix **R** are known, a fuzzy transformation can be performed for comprehensive evaluation. The membership vector B' of the set **U** for the set **V** is obtained. The mathematic model is B' = A • R, then normalization of B' = **B**. According to the principle of maximum membership, the $\mathbf{v_j}$ corresponding to the largest $\mathbf{b_j}$ in FSE set **B** is selected as the synthetic evaluation result, which means the risk level of each phase.

$$B' = \mathbf{A} \bullet \mathbf{R} = \{\mathbf{b'_1, b'_2,\ldots,b'_m}\} \quad (1)$$

$$\mathbf{B} = \{ \mathbf{b_1, b_2,\ldots,b_m} \} \quad (2)$$

3.2.2 Establish a multi-level evaluation model and compare judgment matrix

The multi-level evaluation model is based on analytic hierarchy process (AHP) method. AHP is a multi-level weight analysis decision-making method created by Saaty (1994). It can divide various factors of a complex problem into an interconnected orderly level, making the complex problem more organized. Furthermore, the method can combine data, expert opinion and analyst judgment directly and effectively. After the multi-level evaluation model being well established, the subordination relationship of the factors between the upper and lower levels can be determined. Compare factors of one level to those of the upper level, and give a judgment on the relative importance for each factor in each level (Li et al, 2006). A relative comparison between the two factors is performed by using a method of 1 to 9 ratios (See table 2). The judgment matrix is as follows:

Table 2 The scale and meaning of the judgment matrix

Intensity of importance of an absolute scale	Definition	Description
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance of one over another	Experience and judgment strongly favor one activity over another
5	Essential or strong importance	Experience and judgment strongly favor one activity over another
7	Very strong importance	An activity is strongly favored and its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent judgments	When compromise is needed
Reciprocals	If activity *i* has one of the above numbers assigned to it when compared with activity *j*. then *j* has the reciprocal value when compared with *i*.	
Rational	Ratios arising from the scale	If consistency were to be forced by obtaining *n* numerical value to span the matrix

Source: Saaty (1994)

B_k - C	C_1	C_2	$\cdots$	C_m
C_1	C_{11}	C_{12}	$\cdots$	C_{1m}
C_2	C_{21}	C_{22}	$\cdots$	C_{2m}
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$
C_m	C_{m1}	C_{m2}	$\cdots$	C_{mm}

The judgment matrix B_k – C = (c_{ij}) m*m has the following properties:

(1) $c_{ij} > 0$; (2) $c_{ij} = 1 / c_{ji}$; (3) $c_{ii} = 1$.

Where c_{ij} represents the relative upper factor B_k, which is the scale of the importance of factor c_i and factor c_j. After that, the power method is used to calculate the maximum eigenvalue λ_{max} and the corresponding weight vector **A** (Chen et al, 2007). The calculation method is as follows:
(1) The factors of Bk – C are multiplied by rows;
(2) The obtained product is opened n_{th} power;
(3) The root vector is normalized to obtain the sorting weight vector **A**.

$$\lambda_{max} = \sum_{i=1}^{n} \frac{(B_k - C \cdot A)_i}{n \cdot A_i} \quad (3)$$

In order to maintain the consistency of judgment thinking, the consistency test is carried out after λ_{max} has been obtained. The inspection process is as follows:
(1) Compute the consistency index (CI): CI is the negative average of the remaining eigenvalues other than the maximum eigenvalue of the judgment matrix. When the judgment matrix is completely consistent, CI = 0. Meanwhile, the larger the CI value, the worse the consistency of the judgment matrix.

$$\mathrm{CI} = \frac{\lambda_{max} - n}{n - 1} \quad (4)$$

(2) Compute the consistency ratio (CR):

$$\mathbf{CR = CI / RI} \quad (5)$$

So as to evaluate whether the different judgment matrices have satisfactory consistency, and measure the size of CI, we introduce the random index (RI). The value of RI is shown in table 3. CR is employed to evaluate the overall consistency of pairwise comparison matrices and a CR < 0.1 is acceptable for consistency. If the CR is bigger than 0.1, it means expert evaluation is random and re-evaluation or modification is required.

Table 3 Average random index (RI)

Number	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.44	1.45

Source: Chen et al. (2007)

(3) Determine membership function: in this research, the qualitative index membership function is employed, and the results of the membership function are deter-mined based on the statistics of the evaluation frequency of various risk factors by the respondent group. The most frequent evaluation value will be identified as the risk level of that risk factor. In the comments set **V**, the risk level of risk assessment

factors has been divided into five levels: 1. very low risk, 2. low risk, 3. medium risk, 4. high risk, 5. very high risk. **V** = {V_1, V_2, V_3, V_4, V_5}. Respondents will evaluate risk factors according to this standard.

$$r_{ij} = \frac{w_{ij}}{\sum_{j=1}^{5} w_{ij}} \quad (6)$$

The $\mathbf{W_{ij}}$ represents the represents the frequency that respondents rate the $\mathbf{i_{th}}$ factor index of the **R** factor set as **j**. Then, the corresponding comment set of the risk evaluation level is defined. $\mathbf{P_i}$ represents the comment matching to the $\mathbf{i_{th}}$ risk evaluation level, $\mathbf{P_i}$ = {P_1, P_2, P_3, P_4, P_5}. The comments that indicate the impact degree of risk are as follows: 1. very low level, 2. low level, 3. medium level, 4. high level, 5. very high level.

3.3 Assessment of the outcomes

According to the safety risk factors in 3.1.2, The safety risk assessment factors structure model of the IRCP supply chain shown in table 5. In order to establish this model, methods such as brainstorming, historical event analysis, Delphi method, statistical recording method, and environmental analysis method are mainly used to collect and summarize the risk factors in each phase of the supply chain. Then, based on literature research and expert interviews as well as the perspective of affecting factors those risk factors were identified. According to the current situation of IRCP supply chain safety risk, the TS risks faced by the supply chain are divided into four categories: management risks, equipment risks, technical risks and environmental risks.

A two parts self-administered questionnaire (see appendix 2) to collect first hand data were employed. The part one is “survey on the relative importance of risk assessment indicators for IRCP supply chain”. Compare the risks of each phase in the supply chain using the method described in chapter 3.2.2. The other part is “survey on the risk level of risk assessment indicators for IRCP supply chain”. Then refer to the data from the questionnaire and the formulas in chapter 3 as base to calculate the related results, and finally evaluate out the level of safety risk in all aspects of IRCP supply chain.

In this study, a total of 418 questionnaires were emailed to respondents by using Tencent online questionnaire service. The selected respondents are enterprises, farmers, distributors, experts and scholars from different locations in China and Japan. The selection of respondents is mainly based on practitioners in the IRCP industry and scholars in the FSC field. Because practitioners have more understanding of IRCP and more experience with existing system. Scholars have more comprehensive knowledge, can better analyze the impact of risk factors on the IRCP supply chain, and easily find potential problems.

According to the statistics of the questionnaire (see table 4), the status of respondents is as follows:

1. Personal information of respondent: in terms of positions, the proportions of business managers, technicians and academic experts are relatively close. Other positions are mainly composed of farmers and front-line workers. In terms of work or research time period, the participation time of the main respondents is about 1 year. Most people who have participated for a long time are senior managers and experts and professors, so the number is relatively small. In terms of education background, respondents' academic qualifications are mainly junior college and undergraduate. This part of the respondent is mainly technical staff and middle-level managers of manufacturing enterprises. The ratio of scholars is 36%.

2. Geographical distribution of respondent: the questionnaires are sent in random mode, but there are more valid questionnaires returned from Anhui, Shanghai and Japan. Because the processing companies visited during the field research are mainly in Shanghai and Anhui area. In addition, among the respondents of scholars, professors, and students of Tohoku University have more valid questionnaires.

Table 4 the statistic result of CRF respondents

Information	Percentage	Information	Percentage
Position		Junior college and undergraduate	57%
Senior manager	3%	Master	24%
Middle manager	18%	Doctor	12%
Junior manager	9%	**Location**	
Technical staff	28%	Anhui	23%
Scholar	30%	Shanghai	20%
Others	12%	Liaoning	9%
Working or research experience		Jiangsu	5%
In 1 year	52%	Shandong	5%
2-4 years	20%	Beijing	2%
5-10 years	16%	Guangdong	2%
Over 10 years	12%	Henan	2%
Education background		Sichuan	2%
High school and lower	7%	Japan	30%

The survey was conducted over a period of two months from June 2018 to August 2018. Consequently, there were 100 effective questionnaires returned with effective response rate of 23.9%.

Table 5 The structure model of safety risk assessment factors

	A_1 Risks of raw materials (grain) production phase	**A_2** Risks of raw materials transportation phase	**A_3** Risks of processing and storage phase	**A_4** Risks of end products distribution phase
B_1 Management risks	C_1 Seeds quality C_2 Pesticides and fertilizer safety C_3 The quality of employees C_4 Information acquisition C_5 Data record of the Planting process	C_1 Grain shipment inspection system C_2 Vehicle disinfection plan execution C_3 Contract's execution quality C_4 The quality of employees C_5 Information acquisition C_6 Data record of the transportation process	C_1 Raw materials and additives detection C_2 End products quality inspection C_3 Packaging material safety C_4 The quality of employees C_5 Disinfection plan execution C_6 Information acquisition C_7 Data record of the processing and storage process	C_1 Procurement quality assurance C_2 Products quality inspection C_3 Shelf life management C_4 Contract's execution quality C_5 The quality of employees C_6 Abnormal situation processing C_7 Information acquisition C_8 Data record of the sales process
B_2 Equipment risks	C_6 Irrigation C_7 Farming C_8 Storage C_9 Sterilizing	C_7 Vehicle failure C_8 Container equipment issue C_9 Disinfection equipment issue	C_8 Workshop hygiene design C_9 Processing equipment issue C_{10} Packaging Equipment issue C_{11} Warehousing and handling equipment issue C_{12} Disinfection equipment issue C_{13} Detection and monitoring equipment issue	C_9 Storage facility hygiene C_{10} Disinfection equipment issue C_{11} Handling equipment issue C_{12} Detection equipment issue
B_3 Technical risks	C_{10} Fertilizer application C_{11} Prevention and treatment of disease C_{12} The quality of technical staff C_{13} The ability of new technology application	C_{10} Loading technical problem C_{11} The quality of operator C_{12} Abnormal situation processing technology	C_{14} Hygiene control of processing operations C_{15} Inspection and detection technology C_{16} Cryogenic storage technology C_{17} The quality of operator	C_{13} Delivery time control C_{14} Rationality of disinfection measures C_{15} Rationality of detection technology C_{16} Rationality of inventory control
B_4 Environmental risks	C_{14} Natural disaster C_{15} Policies and regulations C_{16} Consumer awareness	C_{13} Traffic accident C_{14} Natural disaster C_{15} Policies and regulations C_{16} Consumer awareness C_{17} Government supervision	C_{18} Natural disaster C_{19} Air and water pollution C_{20} Policies and regulations C_{21} Consumer awareness C_{22} Government supervision	C_{17} Natural disaster C_{18} Policies and regulations C_{19} Consumer awareness C_{20} Government supervision

Note: A: Object level; B: Standard level; C: Factor level Source: Own survey 2018

3.3.1 Risk assessment in raw materials (grain) production phase

In order to avoid adding unnecessary content due to repeated calculation data, the calculation part of this research takes the management risks of raw materials (grain) production phase as an example.

(1) Based on the above-mentioned method, build up Excel modeling to calculate the results.
First, the respondents used the pairwise comparison method to determine the relative importance of each factor. Then use the AHP method to determine the weight vector of each factor (See table 6 & 7).

Table 6 The judgment matrix of management risks of raw materials (grain) production phase

B1 Management risks	C_1	C_2	C_3	C_4	C_5
C_1 Seeds quality	1	1/5	1/7	2/3	1/7
C_2 Pesticides and fertilizer safety	5	1	1/4	3	1/5
C_3 The quality of employees	7	4	1	7	3
C_4 Information acquisition	1 1/2	1/3	1/7	1	1/6
C_5 Data record of the Planting process	7	5	1/3	6	1

Table 7 Weights of evaluation factor in management risks

C_1 Seeds quality	$\sqrt[5]{0.0027}$	0.3069/ 7.5821	=0.0405
C_2 Pesticides and fertilizer safety	$\sqrt[5]{0.75}$	0.9441/ 7.5821	=0.1245
C_3 The quality of employees	$\sqrt[5]{588}$	3.5799/ 7.5821	=0.4722
C_4 Information acquisition	$\sqrt[5]{0.0119}$	0.4122/ 7.5821	=0.0544
C_5 Data record of the Planting process	$\sqrt[5]{70}$	2.3389/ 7.5821	=0.3085

λ_{max} is computed by formula (3) = 5.3273. Then, use formula (4) got:

$$\mathrm{CI} = \frac{5.3273 - 5}{5 - 1} = 0.0818$$

according to table 3, RI = 1.12, in the end, computed by formula (5) got:
CR = 0.0818 / 1.12 = 0.0731 < 0.1.

It implies that expert evaluation is not random.

2) Calculate the evaluation matrix **R** based on the summary of the risk evaluation. According to the foregoing method, the risk level of each factor is scored by respondents. The collected single factor evaluation data is as follows:

$$\textit{(Risk level)} \quad 1 \quad 2 \quad 3 \quad 4 \quad 5$$

$$R = \begin{Bmatrix} 0.07 & 0.20 & 0.34 & 0.22 & 0.17 \\ 0.00 & 0.12 & 0.19 & 0.49 & 0.20 \\ 0.03 & 0.17 & 0.32 & 0.41 & 0.07 \\ 0.10 & 0.39 & 0.36 & 0.15 & 0.00 \\ 0.07 & 0.22 & 0.49 & 0.22 & 0.00 \end{Bmatrix}$$

Adopt formula (1) & (2) and use the weight vector **A** from table 7 times evaluation matrix **R**, we got the synthetic evaluation result:

$$B' = A * R$$

$$= (0.0405\ 0.1245\ 0.4722\ 0.0544\ 0.3085) \begin{Bmatrix} 0.07 & 0.20 & 0.34 & 0.22 & 0.17 \\ 0.00 & 0.12 & 0.19 & 0.49 & 0.20 \\ 0.03 & 0.17 & 0.32 & 0.41 & 0.07 \\ 0.10 & 0.39 & 0.36 & 0.15 & 0.00 \\ 0.07 & 0.22 & 0.49 & 0.22 & 0.00 \end{Bmatrix}$$

B = [0.0424 0.1926 **0.3582** 0.3411 0.0658]

Judging by the principle of maximum membership and comment set of $\mathbf{P_i}$, the risk level of management risks of raw materials (grain) production phase is evaluated as a medium level.

The calculation results of other categories of raw materials (grain) production phase are as follows:

Table 8 Weights of evaluation factor in raw materials (grain) production phase

Category	Weight	Factors	Weight	Factors	Weight	Factors	Weight	Factors	Weight
B1	0.5299	C1	0.0405	C6	0.2698	C10	0.4357	C14	0.6157
B2	0.2214	C2	0.1245	C7	0.2831	C11	0.2283	C15	0.2843
B3	0.1897	C3	0.4722	C8	0.2674	C12	0.2282	C16	0.1000
B4	0.0591	C4	0.0544	C9	0.1797	C13	0.1078		
		C5	0.3085						

Table 9 Summary of questionnaire part 2 results of raw materials (grain) production phase (R)

Risk level	1. very low level	2. low level	3. medium level	4. high level	5. very high level
C1	0.0732	0.1951	**0.3415**	0.2195	0.1707
C2	0.0000	0.1220	0.1951	**0.4878**	0.1951
C3	0.0244	0.1707	0.3171	**0.4146**	0.0732
C4	0.0976	**0.3902**	0.3659	0.1463	0.0000
C5	0.0732	0.2195	**0.4878**	0.2195	0.0000
C6	0.0976	**0.4634**	0.3415	0.0732	0.0244

C7	0.1220	0.3902	**0.4146**	0.0732	0.0000
C8	0.0732	0.1707	**0.5122**	0.0976	0.1463
C9	0.0488	0.0976	**0.3415**	0.2439	0.2683
C10	0.0244	0.1463	**0.3659**	0.3415	0.1220
C11	0.0000	0.1220	0.1707	**0.4878**	0.2195
C12	0.0000	0.1707	0.2683	**0.3659**	0.1951
C13	0.0000	**0.3902**	0.3171	0.2439	0.0488
C14	0.0488	0.1220	0.2439	**0.3902**	0.1951
C15	0.0732	0.1463	0.2927	**0.3659**	0.1220
C16	0.0732	**0.3171**	0.2439	0.2683	0.0976

Table 10 Summary of evaluation results in raw materials (grain) production phase (B)

Risk level	1. very low level	2. low level	3. medium level	4. high level	5. very high level
B1	0.0424	0.1926	**0.3582**	0.3411	0.0658
B2	0.0892	0.2987	**0.4078**	0.1104	0.0939
B3	0.0106	0.1726	0.2938	**0.3699**	0.1530
B4	0.0582	0.1484	0.2578	**0.3711**	0.1646
A1	0.0476	0.2097	**0.3510**	0.2972	0.0944

The results in the tables indicate that the risk level of raw materials (grain) production phase is moderate. Risk level from risk factors such as pesticides and fertilizer safety, prevention and treatment of disease, natural disaster are higher. The risk level from seeds quality, storage, fertilizer application, etc. are evaluated as a medium level. The risk level from information acquisition, irrigation, the ability of new technology application, consumer awareness risk factors are lower.

3.3.2 Risk assessment in raw materials transportation phase

The calculation process in this section is the same as that in section 3.3.1. The calculation results of raw materials transportation phase are as follows:

Table 11 Weights of evaluation factor in raw materials transportation phase

Category	Weight	Factors	Weight	Factors	Weight	Factors	Weight	Factors	Weight
B1	0.5682	C1	0.1170	C7	0.6212	C10	0.4614	C13	0.2372
B2	0.1978	C2	0.0781	C8	0.1041	C11	0.1334	C14	0.1123
B3	0.1515	C3	0.0499	C9	0.2747	C12	0.4052	C15	0.3093
B4	0.0825	C4	0.3898					C16	0.0574
		C5	0.0433					C17	0.2838
		C6	0.3220						

Table 12 Summary of questionnaire part 2 results of raw materials transportation phase (R)

Risk level	1. very low level	2. low level	3. medium level	4. high level	5. very high level
C1	0.0976	0.1951	**0.4390**	0.2439	0.0244
C2	0.0000	0.2439	0.3415	**0.3415**	0.0732
C3	0.0244	0.3415	**0.4634**	0.1220	0.0488

C4	0.0000	0.1707	**0.4146**	0.2195	0.1951
C5	0.0488	**0.4878**	0.3415	0.1220	0.0000
C6	0.0732	0.1951	**0.4390**	0.2927	0.0000
C7	0.0732	0.2195	**0.3902**	0.2195	0.0976
C8	0.0732	0.2683	**0.3659**	0.2927	0.0000
C9	0.0244	0.1463	0.3415	**0.3415**	0.1463
C10	0.0732	**0.3902**	0.2683	0.2683	0.0000
C11	0.0488	0.2195	0.1951	**0.4146**	0.1220
C12	0.0732	0.1951	**0.3902**	0.2927	0.0488
C13	0.0732	0.1463	0.2683	**0.3902**	0.1220
C14	0.0976	0.1951	0.1951	**0.3659**	0.1463
C15	0.1220	0.1951	**0.2927**	0.2439	0.1463
C16	0.0244	**0.3659**	0.2927	0.2439	0.0732
C17	0.0732	0.1707	0.2195	**0.3659**	0.1707

Table 13 Summary of evaluation results in raw materials transportation phase (B)

Risk level	1. very low level	2. low level	3. medium level	4. high level	5. very high level
B1	0.0383	0.2094	**0.4189**	0.2464	0.0871
B2	0.0598	0.2045	**0.3743**	0.2606	0.1008
B3	0.0699	0.2884	**0.3079**	0.2977	0.0360
B4	0.0882	0.1864	0.2552	**0.3269**	0.1433
A1	0.0515	0.2185	**0.3798**	0.2636	0.0867

The results in the tables indicate that the risk level of raw materials transportation phase is moderate. Risk level from risk factors such as vehicle disinfection plan execution, disinfection equipment issue, the quality of operator, etc. are higher. The risk level from grain shipment inspection system, vehicle failure, abnormal situation processing technology, policies and regulations, etc. are evaluated as a medium level. The risk level from Information acquisition, loading technical problem, consumer awareness risk factors are lower.

3.3.3 Risk assessment in processing and storage phase

The calculation process in this section is the same as that in section 3.3.1. The calculation results of processing and storage phase are as follows:

Table 14 Weights of evaluation factor in processing and storage phase

Category	Weight	Factors	Weight	Factors	Weight	Factors	Weight	Factors	Weight
B1	0.6415	C1	0.2101	C8	0.0720	C14	0.1458	C18	0.1106
B2	0.1563	C2	0.2067	C9	0.4610	C15	0.4314	C19	0.4253
B3	0.1319	C3	0.1050	C10	0.2511	C16	0.0717	C20	0.1839
B4	0.0704	C4	0.2755	C11	0.0780	C17	0.3511	C21	0.0572
		C5	0.0447	C12	0.0820			C22	0.2230
		C6	0.0257	C13	0.0559				
		C7	0.1324						

Table 15 Summary of questionnaire part 2 results of processing and storage phase (R)

Risk level	1. very low level	2. low level	3. medium level	4. high level	5. very high level
C1	0.0488	0.0488	0.2439	**0.4390**	0.2195
C2	0.0244	0.0732	0.3415	**0.3902**	0.1707
C3	0.0976	0.1220	0.3171	**0.3171**	0.1463
C4	0.0244	0.2439	0.2439	**0.3902**	0.0976
C5	0.0488	0.1463	0.2927	**0.4146**	0.0976
C6	0.1463	**0.4390**	0.2927	**0.1220**	0.0000
C7	0.1220	0.0976	**0.4146**	0.3415	0.0244
C8	0.0976	0.2195	**0.3415**	0.2439	0.0976
C9	0.0244	0.2683	0.2927	**0.2927**	0.1220
C10	0.0244	0.2927	**0.3415**	0.2683	0.0732
C11	0.0976	0.2439	0.3171	**0.3171**	0.0244
C12	0.0488	0.1951	0.2439	**0.3902**	0.1220
C13	0.0732	0.1951	0.3171	**0.3171**	0.0976
C14	0.0244	0.2683	**0.3171**	0.1951	0.1951
C15	0.0000	0.1951	**0.4390**	0.2927	0.0732
C16	0.0732	0.3171	**0.3415**	0.1951	0.0732
C17	0.0000	0.2927	**0.3171**	0.2439	0.1463
C18	0.1463	0.1951	0.2683	**0.3415**	0.0488
C19	0.0488	0.0488	0.2927	0.2927	**0.3171**
C20	0.0488	0.2439	**0.3659**	0.1707	0.1707
C21	0.0732	0.2439	**0.3902**	0.2195	0.0732
C22	0.0488	0.2195	0.2683	**0.2683**	0.1951

Table 16 Summary of evaluation results in processing and storage phase (B)

Risk level	1. very low level	2. low level	3. medium level	4. high level	5. very high level
B1	0.0543	0.1361	0.2978	**0.3805**	0.1312
B2	0.0401	0.2589	**0.3077**	0.2943	0.0990
B3	0.0088	0.2488	**0.3714**	0.2543	0.1166
B4	0.0501	0.1011	**0.2437**	0.2062	0.1758
A1	0.0458	0.1677	0.3052	**0.3381**	0.1274

The results in the tables indicate that the risk level of processing and storage phase is high. Risk level of air and water pollution is very high. Risk level from risk factors such as raw materials and additives detection, disinfection equipment issue, natural disaster, etc. are higher. The risk level from packaging material safety, workshop hygiene design, inspection and detection technology, policies and regulations, etc. are evaluated as a medium level. The risk level from information acquisition factor is lower.

3.3.4 Risk assessment in end products distribution phase

The calculation process in this section is the same as that in section 3.3.1. The calculation results of end products distribution phase are as follows:

Table 17 Weights of evaluation factor in end products distribution phase

Category	Weight	Factors	Weight	Factors	Weight	Factors	Weight	Factors	Weight
B1	0.6670	C1	0.0711	C9	0.4050	C13	0.1073	C17	0.1439
B2	0.1686	C2	0.1692	C10	0.3601	C14	0.2833	C18	0.3739
B3	0.1069	C3	0.1065	C11	0.0681	C15	0.4466	C19	0.0920
B4	0.0576	C4	0.0315	C12	0.1667	C16	0.1627	C20	0.3902
		C5	0.3630						
		C6	0.0350						
		C7	0.0287						
		C8	0.1950						

Table 18 Summary of questionnaire part 2results of end products distribution phase (R)

Risk level	1. very low level	2. low level	3. medium level	4. high level	5. very high level
C1	0.0488	0.2195	**0.3659**	0.2927	0.0732
C2	0.0488	0.0732	**0.3659**	0.3415	0.1707
C3	0.0488	0.0244	0.3902	**0.4146**	0.1220
C4	0.0244	0.2683	**0.4146**	0.2439	0.0488
C5	0.0244	0.2195	**0.3415**	0.1707	0.2439
C6	0.0732	0.1951	**0.4146**	0.2683	0.0488
C7	0.1220	0.3659	**0.4146**	0.0976	0.0000
C8	0.1463	0.1951	**0.4878**	0.1463	0.0244
C9	0.0976	0.1951	**0.3415**	0.2439	0.1220
C10	0.0488	0.1951	0.3415	**0.3415**	0.0732
C11	0.0976	0.2683	**0.3171**	0.2439	0.0732
C12	0.0488	0.1951	**0.3659**	0.2927	0.0976
C13	0.0732	0.2683	**0.4146**	0.1707	0.0732
C14	0.0976	0.2683	**0.2683**	0.2683	0.0976
C15	0.0488	0.1707	**0.4634**	0.2439	0.0732
C16	0.0976	0.2195	**0.4146**	0.2195	0.0488
C17	0.1707	0.2195	**0.2927**	0.2439	0.0732
C18	0.0732	0.1707	**0.3902**	0.1707	0.1951
C19	0.0732	0.2195	**0.4390**	0.1951	0.0732
C20	0.0244	0.1463	0.3415	**0.3415**	0.1463

Table 19 Summary of evaluation results in end products distribution phase (B)

Risk level	1. very low level	2. low level	3. medium level	4. high level	5. very high level
B1	0.0611	0.1741	**0.3880**	0.2331	0.1436
B2	0.0719	0.2001	**0.3439**	0.2872	0.0970
B3	0.0732	0.2168	**0.3950**	0.2390	0.0761
B4	0.0682	0.1727	**0.3617**	0.2501	0.1473
A1	0.0646	0.1830	**0.3798**	0.2438	0.1287

The results in the tables indicate that the risk level of end products distribution phase is moderate. Risk level from risk factors such as shelf life management, disinfection equipment issue, government supervision is higher. The risk level from contract's execution quality, storage facility hygiene, rationality of detection technology, consumer awareness, etc. are evaluated as a medium level.

Table 20 summarizes the highest risk level among the four categories of risk factors in each phase of the IRCP supply chain. Then, based on the results of the synthetic evaluation, the total risk factors evaluation matrix of the IRCP supply chain is shown in table 21.

Table 20 The FSE result of risk factors in standard level

Category	Raw materials (grain) production phase	Raw materials transportation phase	Processing and Storage phase	End products distribution phase
	Risk level / Result	Risk level / Result	Risk level / Result	Risk level / Result
Management risks	3 0.3582	3 0.4189	**4 0.3805**	3 0.3880
Equipment risks	3 0.4078	3 0.3743	3 0.3077	3 0.3439
Technical risks	4 0.3699	3 0.3079	3 0.3714	**3 0.3950**
Environmental risks	**4 0.3711**	**4 0.3269**	3 0.2437	3 0.3617

Table 21 The FSE result of risk factors in object level

Phase	1. very low level	2. low level	3. medium level	4. high level	5. very high level
A_1 Raw materials (grain) production	0.0476	0.2097	**0.3510**	0.2972	0.0944
A_2 Raw materials transportation	0.0515	0.2185	**0.3798**	0.2636	0.0867
A_3 Processing and Storage	0.0458	0.1677	0.3052	**0.3381**	0.1274
A_4 End products distribution	0.0646	0.1830	**0.3798**	0.2438	0.1287

In these forms we can conclude that the overall risk of the IRCP supply chain is at a medium level. Among them, the degree of risk in the processing and storage phase is the highest, and the management risks are the main reason. It shows the impact of management risk factors on the processing industry is more critical.

In table 22 is the risk level of all risk factors in the four categories of each phase. The factors with highest risk level can be considered as the most influential factor in the safety of the IRCP supply chain. The risk of raw materials (grain) production (A1) phase is at a medium level. The risk factors from pesticides and fertilizer safety, storage, prevention and treatment of disease and natural disaster are higher. The risk of raw materials transportation (A2) phase is at a medium level too. The higher risk factors are vehicle disinfection plan execution, disinfection equipment issue, the quality of operator and traffic accident. The higher risk level among the whole IRCP supply chain is processing and storage (A3) phase. Raw materials and additives detection, disinfection equipment issue, inspection and detection technology and air and water pollution are the factors with higher risk. In the end products distribution (A4) phase, the risk level is medium. The risk from shelf life management, disinfection equipment issue, rationality of detection technology and government supervision are higher. The food safety traceability system should focus on these factors as much as possible.

Table 22 The critical risk factors of infant rice cereal products supply chain

	A_1	A_2	A_3	A_4
	Risk level / Result	Risk level / Result	Risk level / Result	Risk level / Result
B_1	C_1 3 0.3415 **C_2 4 0.4878** C_3 4 0.4146 C_4 2 0.3902 C_5 3 0.4878	C_1 3 0.4390 **C_2 4 0.3415** C_3 3 0.4634 C_4 3 0.4146 C_5 2 0.4878 C_6 3 0.4390	**C_1 4 0.4390** C_2 4 0.3902 C_3 4 0.3171 C_4 4 0.3902 C_5 4 0.4146 C_6 2 0.4390 C_7 3 0.4146	C_1 3 0.3659 C_2 3 0.3659 **C_3 4 0.4146** C_4 3 0.4146 C_5 3 0.3415 C_6 3 0.4146 C_7 3 0.4146 C_8 3 0.4878
B_2	C_6 2 0.4634 C_7 3 0.4146 **C_8 3 0.5122** C_9 3 0.3415	C_7 3 0.3902 C_8 3 0.3659 **C_9 4 0.3415**	C_8 3 0.3415 C_9 4 0.2927 C_{10} 3 0.3415 C_{11} 4 0.3171 **C_{12} 4 0.3902** C_{13} 4 0.3171	C_9 3 0.3415 **C_{10} 4 0.3415** C_{11} 3 0.3171 C_{12} 3 0.3659
B_3	C_{10} 3 0.3659 **C_{11} 4 0.4878** C_{12} 4 0.3659 C_{13} 2 0.3902	C_{10} 2 0.3902 **C_{11} 4 0.4146** C_{12} 3 0.3902	C_{14} 3 0.3171 **C_{15} 3 0.4390** C_{16} 3 0.3415 C_{17} 3 0.3171	C_{13} 3 0.4146 C_{14} 3 0.2683 **C_{15} 3 0.4634** C_{16} 3 0.4146
B_4	**C_{14} 4 0.3902** C_{15} 4 0.3659 C_{16} 2 0.3171	**C_{13} 4 0.3902** C_{14} 4 0.3659 C_{15} 3 0.2927 C_{16} 2 0.3659 C_{17} 4 0.3659	C_{18} 4 0.3415 **C_{19} 5 0.3171** C_{20} 3 0.3659 C_{21} 3 0.3902 C_{22} 4 0.2683	C_{17} 3 0.2927 C_{18} 3 0.3902 C_{19} 3 0.4390 **C_{20} 4 0.3415**

Note: A: Object level; B: Standard level; C: Factor level

4. Cross-industry benchmarking research on food industry traceability system risk management

4.1 The main features of the grain-processing industry in China

Encarta (2009) pointed out that the processing industry is an industry in which raw materials are treated or made in a series of phases. As key part of the grain and food industries, the grain-processing industry is a very important step in connecting grain production, transportation, and consumption. In China, the grain-processing industry has a broad scope, including processing of paddy, wheat, corn, tuberous crop, soybean, minor cereals, traditional staple food, feed, and also the grain- & the oil machinery (the Chinese Ministry of Agriculture 2010).

According to the data of the Ministry of Agriculture of China, in 2015, there were 17,459 large grain processing and manufacturing enterprises in China, realizing main business income of 73166.17 billion JPY, an increase of 4.4%, and the top three sub-sectors accounting for main business income were grain milling, feed processing, and wine manufacturing. The main features of the Chinese grain-processing industry include: decentralisation, an unreasonable industrial structure, and many small companies with poor management. The industry is also facing difficulties such as excessive production capacities, increasing prices of raw materials, soaring processing costs, and high energy consumption (Ma 2011).

4.2 The traceability system risks management of the Chinese food industry

China's food safety traceability system has formed a certain scale after more than ten years of construction. It is mainly based on a shared method to transmit information in the supply chain. Led by governments and administrative departments at all levels to develop and establish a traceability information platform within a certain field. Its characteristic is that the traceability information is taken charge by a third party, and unified management is carried out to meet the multi-party traceability needs of related parties, regulatory authorities and consumers.

Golan (2004) designed the evaluation criteria of breadth, depth and precision in order to measure the implementation effect of the traceability system. The breadth is used to describe the amount of information recorded by the traceability system. The depth is used to describe the distance that the system can trace forward or backward. The precision is used to describe the ability of a system to accurately determine the source of a problem or a certain characteristic of a product. Using Golan's evaluation criteria to analyze the quality of the safety traceability system in China's food industry, there are three problems as follows:

1) The government's limited investment in technology, equipment, and manpower limits the breadth of the traceability system. At present, national and local shared

traceability systems are mostly based on the establishment of electronic information platforms and collection of various information. The system’s technical requirements run through, requiring information platform construction and maintenance, testing equipment purchase, terminal information collection equipment construction and maintenance, software development and other technical and capital investment, and such investment is a long-term continuous process, otherwise it is difficult to guarantee the normal operation of the system. On the other hand, the technical nature of the electronic information TS also determines the importance of technical guidance and knowledge popularization for operators. Especially the primary agricultural producers at the beginning stage, due to the prevalence of low education levels, require the government to continue support and guidance (Chen et al. 2013). The current situation is that the government usually invests in the early construction of the TS at one time, but the later maintenance and operation are often insufficient. Therefore, the limited investment by the government in the traceability system limits the continuous operation and effective use of the TS, limits the sustainability and quantity assurance of information records, and limits the breadth of the TS.

2) The government's regulatory function limits the depth of the traceability system. In 2013, the State Council reformed the functions and institutions of food and drug supervision and management, and adopted a segmented supervision model for the quality and safety of edible agricultural products. However, the segmented supervision model limits the fluent construction of the edible agricultural product traceability system in the entire supply chain to a certain extent. There is no unified TS between the agricultural supervision department and the food and drug supervision department, which affects the depth of traceability activities. In addition, territorial supervision of food safety also limits the depth of traceability of local food safety TS, especially for edible agricultural products, which are mostly for bulk wholesale export and sent to wholesale markets across the country. It is difficult to achieve full traceability. Local food traceability systems are difficult to coordinate. When food safety problems arise, it is difficult for a single system to play its due role.

3) The lack of motivation of enterprises to participate restricts the precision of the traceability system. Firstly, the balance of costs and benefits incurred by enterprises joining the shared traceability system determines their motivation for participation. In the case of limited government subsidies, the operation of the TS will undoubtedly increase the additional costs of all companies in the supply chain, and food and agricultural product production companies lack the inherent economic power to develop a food safety traceability system (Liu et al. 2012; Ma et al. 2016). Secondly, as food is a fast-moving consumer product, food safety information is generated quickly and has a large amount of information. Therefore, in order to ensure the integrity of the big data in the system, the supervisory authority will require the enterprises to upload food safety information to the platform in a timely manner. For example, in the "Shanghai Food Safety Information Traceability Management Measures" promulgated by the Shanghai Municipal Government in July 2015, all companies in

the supply chain need to upload relevant traceability information within 24 hours. This not only increases the additional burden on enterprises, but also increases the opportunity for enterprises to expose their shortcomings to the government. Reduce the willingness of enterprises to join the TS (Wu et al. 2014). In addition, companies are also worried that the data and information uploaded to the official database will be stolen or destroyed, and are reluctant or resist to provide complete traceability information.

Based on the above three points, it can be seen that in the real development process of the shared food safety traceability system led by the Chinese government, there are systemic problems in the realization of traceability breadth, depth and precision. There is a clear gap between ideal and reality. The effectiveness of the traceability system is subject to many constraints (Li et al. 2017).

4.3 Review successful traceability system risks management cases of automobile industry

Benchmarking can be defined as the process of analysing the best products or processes of leading companies in the same or other industries (Camp 1995). Its main purpose is to improve customer's satisfaction, process effectiveness and efficiency, and control costs. Cross-industry benchmarking holds the potential to provide innovative and adoptable ideas from companies across industries (Mann et al. 2010). If practices and data across industries can be understood indifferent contexts, to deliver meaningful insights. A generic benchmarking process consists of three steps (Stanley et al. 2007):

1) Define the "attribute" to be benchmarked and identify a best-in-class comparison company.
2) Document the comparison company's process at strategic and operational levels. Compare the best-in-class practices with the company's own methods, specifying any and all differences.
3) Develop a strategy, complete with specific methods, for adopting best practices and improving the organisation's own process and performance.

So far, the approach has been applied to a variety of issues (Krishnamoorthy et al. 2014). Such as: to examine how property rights institutions affect economic development; to study the link between human capital and comparative advantage; to investigate the effect of labor market institutions on comparative advantage and productivity; and to examine the economic consequences of firm size, entry regulation, transaction costs, fiscal policy, risk-sharing, and foreign aid.

Here is an example, a winery in California, established an intelligent fermentation logic control system. The system based on a submarine industrial technology. They installed a tuning fork probe in the fermentation tank to collect relevant data about the density of liquid by vibrative method. It tracks the wine status changes in molecular level, and provides accurate information in different parts of the wine for the enologist. So that they can adjust the temperature in time and control the yeast (Yi 2016). It shows that different viewpoints may generate an unexpected result.

The automobile industry was selected as the reference research industry, it has a fairly similar operational and managerial process with food industry. The automobile industry has a high requirement for the supply chain, such as product design, hygiene standards, procurement and storage of raw materials, logistics and distribution, and quality of employees. Meanwhile, the traceability system of automobile industry is more maturity and there are many applicable standards and specifications. Such as: ISO/TS 16949 Supplier-oriented quality management standards; Iso26262; Functional safety standards in the field of electrical and electronic; Title 49 USC chapter 301 motor vehicle safety; Transportation recall enhancement, accountability, and documentation Act.

4.3.1 Toyota Motor Corporation

Toyota Motor Corporation is an automobile manufacturing company headquartered in Toyota City, Aichi Prefecture, Japan, and Bunkyo District, Tokyo, and is affiliated to the Mitsui Chaebol of Japan. The company was established in 1937. Toyota is currently the world's number one car production company. In 2019, Toyota sold approximately 10.74 million units, making it the first vehicle segment to reach an annual output of more than 10 million units. Toyota's sales in fiscal year 2019 were approximately 29.9 trillion JPY. In 2020, Fortune Global 500 ranked tenth. The Toyota Consortium owns 5 Fortune 500 companies, and the industrial chain covers all aspects of the automotive industry from upstream raw materials to downstream logistics. Toyota's product range covers automobiles, steel, machine tools, pesticides, electronics, textile machinery, textiles, household goods, chemicals, chemistry, construction machinery and construction industries.

In order to strengthen quality risk management, in 2010, Toyota set up the first global quality control team. Akio Toyoda is personally responsible for leadership. The main tasks of this team include: improving quality inspection procedures; strengthening customer research; setting up an automotive quality training center in each key regional market to improve the professional skills of quality management personnel; external expert support; strengthening communication with regional governments; improve the ability of regional market autonomy. After that, Toyota established the Global Quality Special Committee. The main responsibilities of the committee are: intensify efforts to collect information about car defects and breakdowns, and meet regularly to discuss the collected problems and countermeasures. In addition, external expert reviews and new employee training institutions are also adopted to deal with quality issues. At the same time, Toyota uses "standardized training" to improve the competence of employees. From the parent company training subsidiary, it has developed into a specialized training center for unified and standardized training of production workers in each factory.

In supply chain management, Toyota's cautious and complete V4L system has created its first-class performance. The v4L principle combines various Toyota supply chain management processes, and it is composed of variety, velocity, variability and visibility.

- Variety-Product varieties need to be carefully selected to balance market needs and production efficiency. When we recognize the impact of product varieties on market demand, manufacturing and processing and supply chain costs, we must take this into consideration when making decisions about varieties. In a sense, choosing a variety means choosing a key supply chain, which affects the participants in all links of the supply chain.
- Velocity—The speed of supply chain flow is an important concept. It is reflected in all processes of the entire supply chain. The focus is on stabilizing the entire system, and it is necessary to ensure that the capacity plan is synchronized with the entire supply chain.
- Variability—The changes in orders and transportation in the supply chain process can be refined to how to implement individual processes. Reducing variability allows the entire supply chain process to operate at a low-risk level. In addition, it can also ensure that the quality improvement process is not disturbed, thereby continuously reducing costs and continuously improving service quality. It is worth noting that variety, velocity and variability are all for stabilizing the overall performance of the supply chain.
- Visibility—The visualization of all processes is to ensure that the correct indicators and requirements are used, so all parties can reach a consensus before making any plan changes. In Toyota, 50% of performance indicators are based on results, and the other 50% is based on process compliance. This method can promptly observe the company's "bottleneck" and get it quickly reflected to ensure proactive changes and efficiency optimization, synchronization of product varieties and demand, and minimization of emergencies. Visibility ensures the company's continuous learning, thereby ensuring that the execution of the process is synchronized with the actual market conditions.

Toyota’s successful experience shows that competitive advantages can be created and sustained through knowledge sharing in the supply chain. If any company wants to go ahead of its competitors, it is the key to effectively share knowledge with suppliers and improve the company's dynamic learning ability. (Toyota Motor Corporation 2019)

4.3.2 Volkswagen Company

Volkswagen is an automobile manufacturing company headquartered in Wolfsburg, Germany, and a core enterprise of Volkswagen Group, one of the world's four largest automobile manufacturers. The company was founded in 1937. It is the largest company in Germany. The Volkswagen Group's annual sales revenue in 2019 was 32475.77 billion JPY and the net profit was 1803.65 billion JPY. The entire automobile group produced and sold more than 9.07 million vehicles in 2012, and the Volkswagen brand exceeded 5.74 million vehicles. In 2019, the global sales volume was 10.97

million, a year-on-year increase of 1.3%. The Volkswagen Group has 68 wholly-owned and share-holding companies around the world. Its business areas include automotive research and development, production, sales, logistics, services, auto parts, auto leasing, financial services, auto insurance, banking, and IT services.

The concept and principle of "Quality Leadership" run through the entire business chain of Volkswagen's product development, suppliers, production, sales and after-sales service. The company has established a complete quality assurance system and quality evaluation system, from production planning, process equipment determination to equipment maintenance, from raw material storage to finished product delivery, everything is under careful monitoring.

Volkswagen's corporate risk management, internal control and compliance management systems follow the principle of "three lines of defense". The responsibility for each of these three lines of defense falls on a specific department. Each line of defense has a clear focus.

- The first line of defense is the business risks and countermeasures of the Volkswagen Group's business units. At this level, the business unit and each individual are responsible for business risk management/internal control (RMS/ICS) and compliance business activities. They need to comply with the corresponding compliance requirements and provide reports to relevant management personnel on a regular basis or as needed. The Volkswagen Risk Control and Compliance Department formulates risk control strategies and tools, and provides support to various business departments when necessary.
- The second line of defense, through the Governance、Risk and Compliance (GRC) process, is jointly promoted by the risk control and compliance departments to build a risk control and compliance management system. The general GRC process uses the IT system to record group-related risks, including compliance risks, and evaluate the effectiveness of the risk management system/internal control system. The second line of defense is responsible for setting standards and testing the effectiveness of risk management systems and internal control systems.
- The third line of defense focuses on monitoring the effectiveness of the organization and implementation of the risk management system/internal control system. The group's internal audit is the third line of defense. (Volkswagen Company 2019)

4.3.3 General Motors Company

General Motors (GM) is an American car manufacturer headquartered in Detroit, Michigan. It is the world's largest automobile manufacturer. It was developed by William Durant on the basis of Buick Motor Company in 1908, with a total of more than 180,000 employees worldwide. Before 2008, GM had the highest global auto sales for 77 consecutive years. In 2016, global annual sales reached the milestone of 10 million vehicles. In 2019, the annual turnover was 15036.53 billion JPY, and General

Motors ranked 13th in the Fortune 500. General Motors is the only company in the industry that has a complete set of solutions and is capable of mass-producing driverless cars. A full range of models of multiple brands under GM are sold in 120 countries and regions around the world, including electric vehicles, mini-cars, heavy-duty trucks, compact cars and convertibles.

General Motors' definition of comprehensive risk management refers to the establishment of a good risk management culture through the implementation of the basic procedures of risk management in all aspects of the company's various business activities and management activities around the company's overall strategy and business objectives. Improve the organization system of risk management, risk management information system and internal control system, establish a system to prevent loss of corporate value and a guarantee system to pursue risk returns under certain conditions, and provide reasonable assurance processes and methods for achieving the overall goals of the company.

When considering a risk response plan, GM first considers a risk portfolio to deal with it, and has a comprehensive and in-depth understanding of the causes of risks, including direct causes and some hidden factors, so as to design corresponding solutions at the source to solve possible risks.

- Regarding the elimination or reduction of the possibility of risk occurrence. Design some business activity processes, strengthen supervision and execution, and increase training. Perform power checks and balances to reduce the occurrence of procurement risks. The increase in market share and profits may be brought about by developing a new car brand, etc. Since the source of risk is the main cause of the risk, it can be dealt with by eliminating, mitigating or improving methods. Risk sources such as interest rate increases or natural disasters are events that occur outside the scope of corporate control. Sending out signals as early as possible through the alarm system, improving the design of the plant to withstand a certain level of earthquake, or establishing refuges to prevent the occurrence of natural disasters are also very important protection methods. A feasible response plan will increase the company's ability to withstand such incidents.
- Regarding the adverse effects of mitigating risks. In order to reduce the adverse effects of risks, it is necessary to adopt emergency plans and business continuity plans to deal with incidents as soon as possible. In addition, in order to minimize the company's financial losses, it is also necessary to consider the use of insurance or other financial instruments, contracts and other means.
- The combined concept of overall risk. Each business unit or functional department needs to identify and evaluate risks, and then issue a comprehensive evaluation report that reflects the main risks of the business unit or department and its relevance to other departments. Then, the risk management department sorts out and analyses these reports. Finally, after discussion between the risk

management department and relevant departments, suggestions are made to the senior management to make the decision.

When GM selects one or several appropriate risk management measures, it needs to consider whether the risk can be controlled within the tolerance range. Moreover, the effects and costs of different treatment measures need to be considered. In principle, the cost of risk management is required to match the benefits it brings. (General Motors Company 2019)

4.4 The analysis of critical success factors method for the Chinese infant accessory food industry

Critical success factors analysis is one of the information system development planning methods. It was proposed by Harvard University professor William Zani in 1970 and has been widely used in performance evaluation in recent years. Based on the description of Leidecker et al. (1984), CSF is "those characteristics, conditions or variables that, when properly sustained, maintained, or managed, can have a significant impact on the success of a firm competing in particular industry." And also "events, circumstances, conditions, or activities that require special attention because of their significance to the corporation. They can be internal or external and can influence the success of the corporation either positively or negatively." (Dickinson et al. 1984). CSF analysis is a method of general planning based on key factors to determine and evaluate system information needs. CSF method is to identify the critical factors that make the company successful and then determine the requirements of system according to these core elements.

4.4.1 The design and model of critical success factors method

The methods for formulating CSF analysis mainly include literature research, interviews and questionnaire. Those are the main methods to collect useful research data. In table 23, there are the top 15 critical success factors summarized from various 42 pieces of literature. These factors will constitute the important analysis points of IRCP traceability system risk management. And it is the core basis of the questionnaire design.

A self-administered questionnaire to collect first hand data was employed (see appendix 3). The questionnaire includes two parts. First part is "Survey on the importance value of critical success factors for supply chain traceability system". 15 influencing factors are listed here, and respondents will evaluate the importance of each factor based on their own understanding. The importance value of factors is divided into 5 levels: 1. not important, 2. little important, 3. important, 4. very important, 5. extremely important. The second part is use to collects respondent's personal basic information about this survey. The results of the survey will be used to locate the important level of CSF.

Table 23 Top 15 CSF for information system implementation reported in the literature

Critical success factors	Frequency
1. Top management support	31
2. (User)Training and education	28
3. Change management	24
4. Project management	23
5. Business process reengineering	16
6. Project team competence/capability	16
7. Communications	14
8. Project champion	13
9. User involvement	11
10. Business plan and vision	9
11. Testing and troubleshooting	7
12. Clear goals and objectives	6
13. Vendor support	5
14. Careful package selection	5
15. Use of consultants	5

Source: Duan et al, 2017

A total of 500 questionnaires were emailed to respondents by using Tencent online questionnaire service. The selected respondents involved people who has participated in the implementation of traceability system in automobile enterprises or the FSC from different locations in China and Japan. The selection of respondents is mainly based on practitioners in the automobile industry and scholars in the food supply chain field. Because practitioners have more experience in TS risk management, they have a more accurate evaluation and cognition of success factors. The scholars of FSC with rich and comprehensive knowledge can better analyze the requirements of solving the risk problems of the IRCP supply chain and create more constructive solutions. The detailed statistical results are shown in Table 24.

Table 24 the statistic result of CSF respondents

Information	Percentage	Information	Percentage
Position		Junior college and undergraduate	59%
Senior manager	2%	Master	19%
Middle manager	20%	Doctor	12%
Junior manager	8%	**Location**	
Technical staff	28%	Shanghai	24%
Scholar	20%	Anhui	21%
Others	22%	Liaoning	8%
Working or research experience		Jiangsu	5%
In 1 year	34%	Beijing	4%
2-4 years	28%	Guangdong	4%
5-10 years	25%	Henan	2%
Over 10 years	13%	Shandong	2%
Education background		Sichuan	2%
High school and lower	10%	Japan	28%

The survey was conducted over a period of two months from June 2019 to August 2019. There were 127 effective questionnaires returned with effective response rate of 25.4%.

4.4.2 Analysis of descriptive statistics

The CSF of traceability system implementation is divided into 5 aspects for analysis according to the different subjects.

1) Government aspect.

- Complete and adequate food traceability laws and standards: the fundamental guarantee for the quality of traceability activities must be based on sound laws and standards.
- Comprehensive food traceability regulations and government policy guidance: For small and medium-sized enterprises, complete regulations and government guidance are the prerequisites for increasing business participation and quickly establishing a qualified traceability system.
- Government's comprehensive food traceability campaign for the public: Based on the characteristics of China's national conditions, the government has an irreplaceable role and absolute right to speak in propaganda activities. Its influence is not available in other links.

2) Enterprise aspect.

- Goal-oriented and full support by all functional departments in enterprises: Traceability activities run through every functional department of the enterprise, and clear mission objectives will make the cooperation between various departments more effective.
- The level of timeliness in problem solving: The ability and experience to deal with various incidents is an important reference factor for evaluating an enterprise's risk management level.
- Responsible and positive administrators: Any success or failure of an enterprise has an inevitable connection with the quality of employees. Responsible and proactive managers are the key to the smooth progress of traceability activities.
- The investment level of traceability system operation and maintenance: The construction of the traceability system is a long-term process, and the level of capital investment is the basis for the growth and existence of the TS.

3) Supply chain aspect

- Higher trust between upstream and downstream companies: Driven by interests, the degree of trust is the fundamental condition for ensuring the quality of traceability activities in every link of the supply chain.
- Timely and convenient communication between enterprises in the supply chain: In an increasingly complex supply chain environment, whether companies can communicate in a timely and convenient manner is an important indicator for evaluating the quality of the traceability system.
- Information sharing between enterprises in the supply chain: Since the

implementation of the quality and safety of edible agricultural products in China adopts a segmented supervision model, it has increased the difficulty of smooth traceability activities. The value of information sharing between supply chains has become more important.

4) Consumer aspect

- Consumers' willingness to pay for traceable products: Consumers' willingness to pay is the driving force behind the establishment of a traceability system.
- Consumers have adequate awareness of food traceability activities: The level of understanding of food traceability will directly affect consumers' willingness to pay. This is an important factor driving the growth of the traceability system.

5) Traceability information and system aspect

- The authenticity, integrity, and effectiveness of traceability information: Only true, complete, and high-quality traceability information can better meet the needs of users.
- Full-featured and easy-to-use traceability system to meet user needs: Since the users of traceability information come from every link of the supply chain, the users' own needs and capabilities are also different. Therefore, a TS with comprehensive functions and easy operation can better meet the requirements of all users.
- Widely applicable standardized traceability information identification: The traceability information standard that can prevail in every link of the supply chain is a necessary condition for the completion of complex traceability activities. It is an urgently needed factor for China's food industry to build a traceability system.

According to the results of literature research and questionnaire, the ranking of key CSF based on the statistical results are listed in table 25. All variables mean value is more than 3 point, it means all of these factors are considered important for implementing TS by participants.

From the table 25, we can find that the top-ranked CSF is mainly concentrated in Traceability information and system, Government, and Enterprise aspect. This shows that information quality, full-featured, easy-to-use, and reliable system, and standardized traceability information identification are the main determinants for the success of TS. These factors not only reflect information/system quality but also influences the trust between enterprises and users. Meanwhile, the Chinese food traceability system application is in the early stage, available laws, standards, and regulations, are required for high quality traceability activities. In addition, the management quality of an enterprise is also a fundamental element of the success of TS. Cooperation among the departments, problem-solving efficiency, and administrators' quality are all indispensable. Furthermore, in the supply chain aspect, timely and convenient communication and the level of information sharing are also important conditions for establishing a high-quality traceability system. At the same time, although the consumer aspect ranks last, the active participation and awareness level of the consumer is also an essential part of the development of the traceability system. In the end, the situation of critical success factors obtained by the above analysis will become the main reference material for setting the scenario analysis.

Table 25 The rank of CSF of traceability system implementation

Rank	Critical success factors	Mean	Std. D	Aspect
1	The authenticity, integrity, and effectiveness of traceability information	4.53	0.857	⑤
2	Complete and adequate food traceability laws and standards	4.39	0.825	①
3	Full-featured and easy-to-use traceability system to meet user needs	4.19	0.884	⑤
4	Comprehensive food traceability regulations and government policy guidance	4.18	0.769	①
5	Goal-oriented and full support by all functional departments in enterprises	4.11	0.836	②
6	Widely applicable standardized traceability information identification	4.08	0.849	⑤
7	The level of timeliness in problem solving	3.95	1.001	②
8	Higher trust between upstream and downstream companies	3.91	0.966	③
9	Responsible and positive administrators	3.90	1.025	②
10	Timely and convenient communication between enterprises in the supply chain	3.87	1.031	③
11	Government's comprehensive food traceability campaign for the public	3.83	0.860	①
12	The investment level of traceability system operation and maintenance	3.79	1.054	②
13	Information sharing between enterprises in the supply chain	3.68	0.918	③
14	Consumers' willingness to pay for traceable products	3.66	0.895	④
15	Consumers have adequate awareness of food traceability activities	3.64	0.775	④

①: Government aspect ②: Enterprise aspect ③: Supply chain aspect ④: Consumer aspect
⑤: Traceability information and system aspect

5. Scenario design and the stochastic model

5.1 Scenarios description

Scenarios are used in organizational planning and decision making. It involves the creation and description of alternative future realities. Establishing scenarios will lead to collecting and synthesizing of complex information (Harries, 2003). Shell used scenario analysis successfully for predicting crude oil prices at the time of the emergence of OPEC (Organization of Petroleum Exporting Countries) in the 1970s, and for predicting the decline of crude oil prices due to the rupture of the OPEC oil-supply quota agreement in the 1980s (Tian 2008). Therefore, reasonable and feasible scenarios may be useful for infant rice cereal products enterprises.

Based on the previous research in chapter 2, 3, 4, three different scenarios for the Chinese IRCP enterprises are defined, and they all have the same goal to improve the response ability and accuracy of food traceability system. Its effect is measured by the level of user satisfaction. However, their management tools differ.

The government support scenario (1)
The government support scenario means depending on multi-level government intervention to manage TS risks. It makes full use of the policy terms and conditions to strengthen management power of enterprises, and support it against all kinds of risks. Based on Chinese national conditions, seeking the support of the government is a necessary means for the development of companies. However sometimes it lacks timeliness, and over-reliance on this approach is not conducive to healthy development of the market.

The industry guild scenario (2)
The industry guild scenario means to adopt common industry regulations to build a horizontal joint-business network. This scenario may increase the comprehensive competitiveness of small and medium-sized enterprises in the early stage, quickly develop and standardize the market, and protect the reasonable benefit ratio of the industry. The disadvantage of this scenario is that it may bring unnecessary pressure or violations to other phases in the supply chain. The management quality and objectivity of the industry guild are very important.

The supply chain combination scenario (3)
The supply chain combination scenario means to use contracts and agreements to build a vertical joint-business network. It introduces the contract method to extend the industrial chain, and to take the initiative to participate in the activities of the industry chain, to improve the ability of risk control, and resilience. This scenario requires efficient management and implementation capacity to control the changes of the partners and market to reduce and avoid risks. It explains better how to deal with the risks caused by human factors.

5.2 The normative stochastic model

Stochastic modelling is a technique of presenting data or predicting outcomes that take into account a certain degree of randomness, or unpredictability (Raghavan et al. 2011). This method can clearly represent the process of risk management to fulfil the requirement of objective four. This research will establish a normative stochastic model of the IRCP supply chain, using empirical and assumed data to simulate the effect of the different scenarios by @Risk software. The scenarios are developed from the feasible food and automobile industry risk management, for the Chinese IRCP industry. And then, a sensitivity analysis of inputs and outputs will attempt to determine which scenario has the highest reliability and practical value.

5.2.1 Parameterization of model

1) ***Variables.***
The traceability system risk simulation model consists of two kinds of variables, input and output. They are given in the first column of Table 26, together with their unit of measurement in the second column. In the input part, variable 1, it is the user's initial satisfaction of TS risk management of the IRCP supply chain. The research used 100% as the start point to parameterize this variable. It refers to the state of TS users before they are affected by risk factors. The sources are given in the fourth column. Variable 2.1, it is the probability of risk of traceability system of IRCP supply chain. Variable 2.2, it is the impact of risk on the IRCP supply chain. Based on the analysis of historical information and the literature study in previous chapter, the research estimated sources to parameterise these variables. Most variables are defined as stochastic variables, including Poisson and Triangular probability distribution functions. They are given in the third column of Table 26. Variable 2.3 is the satisfaction losses due to TS risk. In the output part, the variable "User's final satisfaction" is the remain satisfaction after adjustment.

2) ***Parameterization.***
The columns eight, 10, and 12 of Table 26 refer to the quantification of variables. The parameter of variable 2.1 is the frequency of occurrence of TS risk in one circulation period. Assume that all TS risks occur once in a circulation period. The purpose is to evaluate the defense capabilities of different scenarios against risks. The parameters of variable 2.2 reflects the minimum, most likely, and maximum degree of impact of TS risks on Chinese IRCP supply chain. Those values were based on different weight vectors and times of probability of TS risks (See annotation ③). The weight vector is calculated based on the questionnaire survey data. It regarded as the influence of risk factors on the quality of the traceability system and the user's attention. The closer this value is to one, the greater the damage caused after the risk occurs. The variation of risk probability is individual estimates, they are approximations, based on the analysis of interviews, field investigation and literature research. Detailed explanations of default values are given in Table 26. The impact values and probability frequency data of the three scenarios are based on the default values, estimated with

their different characteristics. Values in the default situation means that the satisfaction of TS users from the initial 100%, after being affected by all risk factors, drops to 0. “0” represents an original state of the final satisfaction of users of the TS, not a null value. Because in the current Chinese IRCP industry, there has not been a specialized and widely applicable traceability risk management system.

In scenario 1, the government support mainly works on the multi-level government intervention to manage TS risks. It is not very useful to control the risks when natural disasters occurred and sometimes it lacks timeliness. Its value estimation is related to the CSF in the government aspect, and based on the effectiveness of the policy, regulation, and regulatory control for the IRCP supply chain.

In scenario 2, the industry horizontal joint business network can increase the comprehensive competitiveness, especially for the small and medium-sized companies. By referring to the CSF of enterprise aspect, such as goal-oriented implementation, problem solving ability, quality of employees and investment level. Its value estimation is based on to deal with the risk factors between different phases of IRCP supply chain, mainly to protect one's own interests.

In scenario 3, the risks have been shared thanks to collaboration in the supply chain, and extension of the supply chain by international trade. But the premise of this scenario is based on the CSF of the supply chain aspect. The level of trust, timely and convenient communication, and complete information sharing. so its value estimation is based on the cooperative adjustment of risks. However, due to the uncertainty of each unit in the supply chain, the fluctuation level of risk management in the traceability system has been increased.

5.2.2 The model design

The following tables give the traceability system risk simulation model of the Chinese infant rice cereal products supply chain. All information is summarised from previous analysis.

Table 26 The simulation model of raw materials (grain) production phase (A1)

Variable	Unit	Probability distribution	Source(s)	Parameters	Default Data	Scenario 1 Data	Scenario 1 Result	Scenario 2 Data	Scenario 2 Result	Scenario 3 Data	Scenario 3 Result
INPUT											
1. User's initial satisfaction	100%		Estimation ①	Set value	1	1		1		1	
2. TS risk											
2.1 Probability of risk	Times	Poisson	Estimation ②	Mean	1	1		1		1	
2.2 Impact of risk	100%/ time	Triangular	Estimation ③	Minimum Most likely Maximum	1	0.4184 0.6277 0.8040		0.2864 0.4715 0.6855		0.2604 0.4150 0.6518	
2.3 Satisfaction losses due to TS risk	100% (Probability of risk * Impact of risk)						______		______		______
OUTPUT User's final satisfaction	100% (User's initial satisfaction – Satisfaction losses due to TS risk)				0		______		______		______

Annotation:

① Estimation: the user's initial satisfaction is 100% by default.

② Estimation: assume that all TS risks occur once in a circulation period.

③ Estimation: The weight vector is calculated based on the questionnaire survey data; the variation of risk probability is individual estimates, they are approximations, based on the analysis of interviews, field investigation and literature research. (Times) (100%) (PoR: Probability of risk; SL: Satisfaction losses; ML: most likely)

	Risk factor	Weight vector		Default Set value	Scenario 1			Scenario 2			Scenario 3		
					Max	ML	Min	Max	ML	Min	Max	ML	Min
B1 Management risks	C1	0.0405	PoR	1.00	0.80	0.50	0.30	0.50	0.35	0.15	0.70	0.40	0.25
			SL	0.0405	0.0324	0.0203	0.0122	0.0203	0.0142	0.0061	0.0284	0.0162	0.0101
	C2	0.1245	PoR	1.00	0.90	0.60	0.35	0.60	0.40	0.20	0.60	0.35	0.30
			SL	0.1245	0.1121	0.0747	0.0436	0.0747	0.0498	0.0249	0.0747	0.0436	0.0374
	C3	0.4722	PoR	1.00	0.90	0.75	0.50	0.70	0.50	0.35	0.75	0.40	0.25
			SL	0.4722	0.4250	0.3542	0.2361	0.3305	0.2361	0.1653	0.3542	0.1889	0.1181
	C4	0.0544	PoR	1.00	0.80	0.65	0.40	0.55	0.30	0.20	0.60	0.40	0.25
			SL	0.0544	0.0435	0.0354	0.0218	0.0299	0.0163	0.0109	0.0326	0.0218	0.0136
	C5	0.3085	PoR	1.00	0.70	0.50	0.30	0.70	0.50	0.25	0.60	0.35	0.20
			SL	0.3085	0.2160	0.1543	0.0926	0.2160	0.1543	0.0771	0.1851	0.1080	0.0617
		0.5299	Subtotal SL	0.52995	0.43923	0.33845	0.21521	0.35575	0.24939	0.15062	0.35765	0.20051	0.12761
B2 Equipment risks	C6	0.2698	PoR	1.00	0.80	0.70	0.60	0.75	0.50	0.25	0.70	0.55	0.30
			SL	0.2698	0.2158	0.1889	0.1619	0.2024	0.1349	0.0675	0.1889	0.1484	0.0809
	C7	0.2831	PoR	1.00	0.75	0.65	0.55	0.75	0.50	0.30	0.70	0.55	0.35
			SL	0.2831	0.2123	0.1840	0.1557	0.2123	0.1416	0.0849	0.1982	0.1557	0.0991
	C8	0.2674	PoR	1.00	0.70	0.50	0.35	0.60	0.40	0.20	0.70	0.50	0.25
			SL	0.2674	0.1872	0.1337	0.0936	0.1604	0.1070	0.0535	0.1872	0.1337	0.0669
	C9	0.1797	PoR	1.00	0.80	0.70	0.55	0.75	0.40	0.30	0.65	0.45	0.30
			SL	0.1797	0.1438	0.1258	0.0988	0.1348	0.0719	0.0539	0.1168	0.0809	0.0539
		0.2214	Subtotal SL	0.22140	0.16807	0.14001	0.11292	0.15717	0.10080	0.05751	0.15299	0.11483	0.06659
B3 Technical risks	C10	0.4357	PoR	1.00	0.80	0.60	0.25	0.65	0.40	0.20	0.50	0.35	0.25
			SL	0.4357	0.3486	0.2614	0.1089	0.2832	0.1743	0.0871	0.2179	0.1525	0.1089
	C11	0.2283	PoR	1.00	0.70	0.50	0.35	0.50	0.35	0.20	0.65	0.50	0.30
			SL	0.2283	0.1598	0.1142	0.0799	0.1142	0.0799	0.0457	0.1484	0.1142	0.0685
	C12	0.2282	PoR	1.00	0.80	0.65	0.40	0.80	0.60	0.40	0.50	0.25	0.15
			SL	0.2282	0.1826	0.1483	0.0913	0.1826	0.1369	0.0913	0.1141	0.0571	0.0342
	C13	0.1078	PoR	1.00	0.90	0.70	0.55	0.75	0.60	0.40	0.50	0.40	0.25
			SL	0.1078	0.0970	0.0755	0.0593	0.0809	0.0647	0.0431	0.0539	0.0431	0.0270
		0.1897	Subtotal SL	0.18970	0.14947	0.11370	0.06438	0.12535	0.08646	0.05069	0.10135	0.06958	0.04526
B4 Environmental risks	C14	0.6157	PoR	1.00	0.90	0.75	0.60	0.80	0.60	0.50	0.65	0.50	0.35
			SL	0.6157	0.5541	0.4618	0.3694	0.4926	0.3694	0.3079	0.4002	0.3079	0.2155
	C15	0.2843	PoR	1.00	0.60	0.30	0.10	0.85	0.60	0.45	0.75	0.55	0.40
			SL	0.2843	0.1706	0.0853	0.0284	0.2417	0.1706	0.1279	0.2132	0.1564	0.1137
	C16	0.1000	PoR	1.00	0.75	0.55	0.40	0.65	0.50	0.30	0.60	0.45	0.25
			SL	0.1000	0.0750	0.0550	0.0400	0.0650	0.0500	0.0300	0.0600	0.0450	0.0250
		0.0591	Subtotal SL	0.05910	0.04726	0.03558	0.02588	0.04723	0.03487	0.02753	0.03980	0.03009	0.02093
	Total satisfaction losses			**1.0000**	**0.8040**	**0.6277**	**0.4184**	**0.6855**	**0.4715**	**0.2864**	**0.6518**	**0.4150**	**0.2604**

Table 27 The simulation model of raw materials transportation phase (A2)

Variable	Unit	Probability distribution	Source(s)	Parameters	Default Data	Scenario 1 Data	Scenario 1 Result	Scenario 2 Data	Scenario 2 Result	Scenario 3 Data	Scenario 3 Result
INPUT											
1. User's initial satisfaction	100%		Estimation ①	Set value	1	1		1		1	
2. TS risk											
2.1 Probability of risk	Times	Poisson	Estimation ②	Mean	1	1		1		1	
2.2 Impact of risk	100%/ time	Triangular	Estimation ③	Minimum Most likely Maximum	1	0.3972 0.5589 0.7743		0.3216 0.4841 0.7119		0.3010 0.4736 0.7134	
2.3 Satisfaction losses due to TS risk	100% (Probability of risk * Impact of risk)						______		______		______
OUTPUT User's final satisfaction	100% (User's initial satisfaction – Satisfaction losses due to TS risk)				0		______		______		______

Annotation:

① Estimation: the user's initial satisfaction is 100% by default.

② Estimation: assume that all TS risks occur once in a circulation period.

③ Estimation: The weight vector is calculated based on the questionnaire survey data; the variation of risk probability is individual estimates, they are approximations, based on the analysis of interviews, field investigation and literature research. (Times) (100%) (PoR: Probability of risk; SL: Satisfaction losses; ML: most likely)

	Risk factor	Weight vector		Default Set value	Scenario 1 Max	Scenario 1 ML	Scenario 1 Min	Scenario 2 Max	Scenario 2 ML	Scenario 2 Min	Scenario 3 Max	Scenario 3 ML	Scenario 3 Min
B1 Management risks	C1	0.1170	PoR	1.00	0.80	0.55	0.35	0.65	0.45	0.25	0.70	0.50	0.30
			SL	0.1170	0.0936	0.0644	0.0410	0.0761	0.0527	0.0293	0.0819	0.0585	0.0351
	C2	0.0781	PoR	1.00	0.85	0.60	0.45	0.70	0.50	0.30	0.75	0.55	0.30
			SL	0.0781	0.0664	0.0469	0.0351	0.0547	0.0391	0.0234	0.0586	0.0430	0.0234
	C3	0.0499	PoR	1.00	0.75	0.60	0.40	0.70	0.55	0.40	0.60	0.40	0.25
			SL	0.0499	0.0374	0.0299	0.0200	0.0349	0.0274	0.0200	0.0299	0.0200	0.0125
	C4	0.3898	PoR	1.00	0.80	0.60	0.45	0.70	0.45	0.35	0.75	0.45	0.30
			SL	0.3898	0.3118	0.2339	0.1754	0.2729	0.1754	0.1364	0.2924	0.1754	0.1169
	C5	0.0433	PoR	1.00	0.80	0.55	0.35	0.70	0.45	0.30	0.60	0.40	0.25
			SL	0.0433	0.0346	0.0238	0.0152	0.0303	0.0195	0.0130	0.0260	0.0173	0.0108
	C6	0.3220	PoR	1.00	0.75	0.50	0.35	0.70	0.50	0.30	0.70	0.45	0.25
			SL	0.3220	0.2415	0.1610	0.1127	0.2254	0.1610	0.0966	0.2254	0.1449	0.0805
		0.5682	Subtotal SL	0.56826	0.44626	0.31810	0.22689	0.39446	0.26992	0.18106	0.40578	0.26083	0.15868
B2 Equipment risks	C7	0.6212	PoR	1.00	0.85	0.60	0.45	0.75	0.45	0.30	0.75	0.50	0.35
			SL	0.6212	0.5280	0.3727	0.2795	0.4659	0.2795	0.1864	0.4659	0.3106	0.2174
	C8	0.1041	PoR	1.00	0.70	0.50	0.30	0.70	0.45	0.30	0.70	0.45	0.30
			SL	0.1041	0.0729	0.0521	0.0312	0.0729	0.0468	0.0312	0.0729	0.0468	0.0312
	C9	0.2747	PoR	1.00	0.80	0.60	0.40	0.75	0.55	0.35	0.70	0.50	0.30
			SL	0.2747	0.2198	0.1648	0.1099	0.2060	0.1511	0.0961	0.1923	0.1374	0.0824
		0.1978	Subtotal SL	0.19780	0.16232	0.11662	0.08320	0.14732	0.09444	0.06206	0.14460	0.09787	0.06548
B3 Technical risks	C10	0.4614	PoR	1.00	0.70	0.55	0.35	0.60	0.45	0.25	0.65	0.50	0.30
			SL	0.4614	0.3230	0.2538	0.1615	0.2768	0.2076	0.1154	0.2999	0.2307	0.1384
	C11	0.1334	PoR	1.00	0.85	0.70	0.50	0.70	0.50	0.35	0.65	0.45	0.30
			SL	0.1334	0.1134	0.0934	0.0667	0.0934	0.0667	0.0467	0.0867	0.0600	0.0400
	C12	0.4052	PoR	1.00	0.85	0.65	0.55	0.75	0.45	0.30	0.70	0.45	0.30
			SL	0.4052	0.3444	0.2634	0.2229	0.3039	0.1823	0.1216	0.2836	0.1823	0.1216
		0.1515	Subtotal SL	0.15150	0.11829	0.09250	0.06833	0.10213	0.06919	0.04297	0.10154	0.07167	0.04545
B4 Environmental risks	C13	0.2372	PoR	1.00	0.65	0.45	0.25	0.85	0.60	0.45	0.80	0.55	0.40
			SL	0.2372	0.1542	0.1067	0.0593	0.2016	0.1423	0.1067	0.1898	0.1305	0.0949
	C14	0.1123	PoR	1.00	0.75	0.60	0.40	0.70	0.50	0.35	0.65	0.50	0.30
			SL	0.1123	0.0842	0.0674	0.0449	0.0786	0.0562	0.0393	0.0730	0.0562	0.0337
	C15	0.3093	PoR	1.00	0.50	0.30	0.15	0.85	0.65	0.45	0.75	0.55	0.40
			SL	0.3093	0.1547	0.0928	0.0464	0.2629	0.2010	0.1392	0.2320	0.1701	0.1237
	C16	0.0574	PoR	1.00	0.70	0.55	0.35	0.70	0.50	0.30	0.65	0.45	0.25
			SL	0.0574	0.0402	0.0316	0.0201	0.0402	0.0287	0.0172	0.0373	0.0258	0.0144
	C17	0.2838	PoR	1.00	0.50	0.30	0.20	0.85	0.65	0.45	0.75	0.50	0.40
			SL	0.2838	0.1419	0.0851	0.0568	0.2412	0.1845	0.1277	0.2129	0.1419	0.1135
		0.0825	Subtotal SL	0.08250	0.04745	0.03165	0.01877	0.06802	0.05055	0.03549	0.06145	0.04327	0.03136
	Total satisfaction losses			**1.0000**	**0.7743**	**0.5589**	**0.3972**	**0.7119**	**0.4841**	**0.3216**	**0.7134**	**0.4736**	**0.3010**

Table 28 The simulation model of processing and storage phase (A3)

Variable	Unit	Probability distribution	Source(s)	Parameters	Default Data	Scenario 1 Data	Scenario 1 Result	Scenario 2 Data	Scenario 2 Result	Scenario 3 Data	Scenario 3 Result
INPUT											
1. User's initial satisfaction	100%		Estimation ①	Set value	1	1		1		1	
2. TS risk											
2.1 Probability of risk	Times	Poisson	Estimation ②	Mean	1	1		1		1	
2.2 Impact of risk	100%/ time	Triangular	Estimation ③	Minimum Most likely Maximum	1	0.2492 0.4533 0.6675		0.2700 0.5058 0.7262		0.2989 0.5076 0.6965	
2.3 Satisfaction losses due to TS risk	100% (Probability of risk * Impact of risk)						______		______		______
OUTPUT **User's final satisfaction**	100% (User's initial satisfaction – Satisfaction losses due to TS risk)				0		______		______		______

Annotation:

① Estimation: the user's initial satisfaction is 100% by default.

② Estimation: assume that all TS risks occur once in a circulation period.

③ Estimation: The weight vector is calculated based on the questionnaire survey data; the variation of risk probability is individual estimates, they are approximations, based on the analysis of interviews, field investigation and literature research. (Times) (100%) (PoR: Probability of risk; SL: Satisfaction losses; ML: most likely)

	Risk factor	Weight vector		Default Set value	Scenario 1			Scenario 2			Scenario 3		
					Max	ML	Min	Max	ML	Min	Max	ML	Min
B1 Management risks	C1	0.2101	PoR	1.00	0.65	0.45	0.20	0.75	0.55	0.30	0.65	0.50	0.25
			SL	0.2101	0.1366	0.0945	0.0420	0.1576	0.1156	0.0630	0.1366	0.1051	0.0525
	C2	0.2067	PoR	1.00	0.65	0.40	0.25	0.70	0.50	0.25	0.65	0.50	0.25
			SL	0.2067	0.1344	0.0827	0.0517	0.1447	0.1034	0.0517	0.1344	0.1034	0.0517
	C3	0.1050	PoR	1.00	0.60	0.40	0.20	0.80	0.60	0.40	0.75	0.60	0.35
			SL	0.1050	0.0630	0.0420	0.0210	0.0840	0.0630	0.0420	0.0788	0.0630	0.0368
	C4	0.2755	PoR	1.00	0.70	0.50	0.25	0.65	0.40	0.15	0.70	0.50	0.35
			SL	0.2755	0.1929	0.1378	0.0689	0.1791	0.1102	0.0413	0.1929	0.1378	0.0964
	C5	0.0447	PoR	1.00	0.60	0.45	0.25	0.60	0.35	0.15	0.75	0.50	0.25
			SL	0.0447	0.0268	0.0201	0.0112	0.0268	0.0156	0.0067	0.0335	0.0224	0.0112
	C6	0.0257	PoR	1.00	0.75	0.50	0.25	0.60	0.45	0.20	0.60	0.40	0.20
			SL	0.0257	0.0193	0.0129	0.0064	0.0154	0.0116	0.0051	0.0154	0.0103	0.0051
	C7	0.1324	PoR	1.00	0.75	0.55	0.30	0.80	0.50	0.25	0.70	0.45	0.20
			SL	0.1324	0.0993	0.0728	0.0397	0.1059	0.0662	0.0331	0.0927	0.0596	0.0265
		0.6415	Subtotal SL	0.64156	0.43119	0.29686	0.15453	0.45771	0.31146	0.15587	0.43888	0.32162	0.17973
B2 Equipment risks	C8	0.0720	PoR	1.00	0.55	0.35	0.20	0.80	0.50	0.25	0.70	0.50	0.25
			SL	0.0720	0.0396	0.0252	0.0144	0.0576	0.0360	0.0180	0.0504	0.0360	0.0180
	C9	0.4610	PoR	1.00	0.60	0.40	0.25	0.70	0.55	0.35	0.70	0.50	0.30
			SL	0.4610	0.2766	0.1844	0.1153	0.3227	0.2536	0.1614	0.3227	0.2305	0.1383
	C10	0.2511	PoR	1.00	0.60	0.40	0.25	0.75	0.60	0.25	0.75	0.55	0.35
			SL	0.2511	0.1507	0.1004	0.0628	0.1883	0.1507	0.0628	0.1883	0.1381	0.0879
	C11	0.0780	PoR	1.00	0.65	0.40	0.25	0.75	0.60	0.30	0.75	0.55	0.35
			SL	0.0780	0.0507	0.0312	0.0195	0.0585	0.0468	0.0234	0.0585	0.0429	0.0273
	C12	0.0820	PoR	1.00	0.55	0.35	0.15	0.65	0.45	0.25	0.75	0.50	0.35
			SL	0.0820	0.0451	0.0287	0.0123	0.0533	0.0369	0.0205	0.0615	0.0410	0.0287
	C13	0.0559	PoR	1.00	0.60	0.40	0.30	0.75	0.50	0.35	0.80	0.55	0.35
			SL	0.0559	0.0335	0.0224	0.0168	0.0419	0.0280	0.0196	0.0447	0.0307	0.0196
		0.1563	Subtotal SL	0.15630	0.09319	0.06132	0.03767	0.11290	0.08626	0.04776	0.11350	0.08116	0.04998
B3 Technical risks	C14	0.1458	PoR	1.00	0.70	0.55	0.35	0.75	0.50	0.25	0.75	0.55	0.35
			SL	0.1458	0.1021	0.0802	0.0510	0.1094	0.0729	0.0365	0.1094	0.0802	0.0510
	C15	0.4314	PoR	1.00	0.75	0.50	0.30	0.75	0.55	0.30	0.70	0.50	0.35
			SL	0.4314	0.3236	0.2157	0.1294	0.3236	0.2373	0.1294	0.3020	0.2157	0.1510
	C16	0.0717	PoR	1.00	0.70	0.45	0.20	0.80	0.55	0.40	0.70	0.50	0.30
			SL	0.0717	0.0502	0.0323	0.0143	0.0574	0.0394	0.0287	0.0502	0.0359	0.0215
	C17	0.3511	PoR	1.00	0.80	0.55	0.35	0.70	0.45	0.25	0.70	0.50	0.35
			SL	0.3511	0.2809	0.1931	0.1229	0.2458	0.1580	0.0878	0.2458	0.1756	0.1229
		0.1319	Subtotal SL	0.13190	0.09981	0.06875	0.04190	0.09708	0.06695	0.03724	0.09329	0.06691	0.04569
B4 Environmental risks	C18	0.1106	PoR	1.00	0.80	0.65	0.40	0.85	0.60	0.35	0.75	0.50	0.25
			SL	0.1106	0.0885	0.0719	0.0442	0.0940	0.0664	0.0387	0.0830	0.0553	0.0277
	C19	0.4253	PoR	1.00	0.70	0.45	0.25	0.80	0.55	0.40	0.75	0.55	0.35
			SL	0.4253	0.2977	0.1914	0.1063	0.3402	0.2339	0.1701	0.3190	0.2339	0.1489
	C20	0.1839	PoR	1.00	0.50	0.25	0.15	0.85	0.60	0.40	0.75	0.55	0.35
			SL	0.1839	0.0920	0.0460	0.0276	0.1563	0.1103	0.0736	0.1379	0.1011	0.0644
	C21	0.0572	PoR	1.00	0.85	0.55	0.45	0.70	0.50	0.35	0.65	0.45	0.25
			SL	0.0572	0.0486	0.0315	0.0257	0.0400	0.0286	0.0200	0.0372	0.0257	0.0143
	C22	0.2230	PoR	1.00	0.40	0.15	0.05	0.90	0.65	0.50	0.65	0.55	0.35
			SL	0.2230	0.0892	0.0335	0.0112	0.2007	0.1450	0.1115	0.1450	0.1227	0.0781
		0.0704	Subtotal SL	0.07040	0.04336	0.02634	0.01514	0.05852	0.04113	0.02914	0.05083	0.03793	0.02346
	Total satisfaction losses			**1.0000**	**0.6675**	**0.4533**	**0.2492**	**0.7262**	**0.5058**	**0.2700**	**0.6965**	**0.5076**	**0.2989**

Table 29 The simulation model of end products distribution phase (A4)

Variable	Unit	Probability distribution	Source(s)	Parameters	Default Data	Scenario 1 Data	Scenario 1 Result	Scenario 2 Data	Scenario 2 Result	Scenario 3 Data	Scenario 3 Result
INPUT											
1. User's initial satisfaction	100%		Estimation ①	Set value	1	1		1		1	
2. TS risk											
2.1 Probability of risk	Times	Poisson	Estimation ②	Mean	1	1		1		1	
2.2 Impact of risk	100%/ time	Triangular	Estimation ③	Minimum Most likely Maximum	1	0.2952 0.5293 0.7358		0.2403 0.5191 0.7351		0.2245 0.4738 0.6843	
2.3 Satisfaction losses due to TS risk	100% (Probability of risk * Impact of risk)						______		______		______
OUTPUT User's final satisfaction	100% (User's initial satisfaction – Satisfaction losses due to TS risk)				0		______		______		______

Annotation:

① Estimation: the user's initial satisfaction is 100% by default.

② Estimation: assume that all TS risks occur once in a circulation period.

③ Estimation: The weight vector is calculated based on the questionnaire survey data; the variation of risk probability is individual estimates, they are approximations, based on the analysis of interviews, field investigation and literature research. (Times) (100%) (PoR: Probability of risk; SL: Satisfaction losses; ML: most likely)

	Risk factor	Weight vector		Default Set value	Scenario 1 Max	Scenario 1 ML	Scenario 1 Min	Scenario 2 Max	Scenario 2 ML	Scenario 2 Min	Scenario 3 Max	Scenario 3 ML	Scenario 3 Min
B1 Management risks	C1	0.0711	PoR	1.00	0.80	0.55	0.30	0.75	0.50	0.20	0.55	0.40	0.15
			SL	0.0711	0.0569	0.0391	0.0213	0.0533	0.0356	0.0142	0.0391	0.0284	0.0107
	C2	0.1692	PoR	1.00	0.70	0.45	0.25	0.70	0.55	0.30	0.65	0.50	0.20
			SL	0.1692	0.1184	0.0761	0.0423	0.1184	0.0931	0.0508	0.1100	0.0846	0.0338
	C3	0.1065	PoR	1.00	0.75	0.45	0.20	0.70	0.50	0.25	0.70	0.40	0.25
			SL	0.1065	0.0799	0.0479	0.0213	0.0746	0.0533	0.0266	0.0746	0.0426	0.0266
	C4	0.0315	PoR	1.00	0.80	0.60	0.30	0.65	0.50	0.15	0.70	0.45	0.20
			SL	0.0315	0.0252	0.0189	0.0095	0.0205	0.0158	0.0047	0.0221	0.0142	0.0063
	C5	0.3630	PoR	1.00	0.75	0.60	0.40	0.75	0.50	0.20	0.70	0.45	0.20
			SL	0.3630	0.2723	0.2178	0.1452	0.2723	0.1815	0.0726	0.2541	0.1634	0.0726
	C6	0.0350	PoR	1.00	0.85	0.65	0.45	0.70	0.55	0.35	0.70	0.50	0.25
			SL	0.0350	0.0298	0.0228	0.0158	0.0245	0.0193	0.0123	0.0245	0.0175	0.0088
	C7	0.0287	PoR	1.00	0.75	0.55	0.40	0.65	0.45	0.25	0.65	0.45	0.20
			SL	0.0287	0.0215	0.0158	0.0115	0.0187	0.0129	0.0072	0.0187	0.0129	0.0057
	C8	0.1950	PoR	1.00	0.80	0.50	0.20	0.70	0.50	0.15	0.65	0.45	0.20
			SL	0.1950	0.1560	0.0975	0.0390	0.1365	0.0975	0.0293	0.1268	0.0878	0.0390
		0.6670	Subtotal SL	0.66700	0.50687	0.35745	0.20398	0.47937	0.33935	0.14514	0.44668	0.30104	0.13575
B2 Equipment risks	C9	0.4050	PoR	1.00	0.75	0.60	0.35	0.75	0.50	0.25	0.70	0.55	0.25
			SL	0.4050	0.3038	0.2430	0.1418	0.3038	0.2025	0.1013	0.2835	0.2228	0.1013
	C10	0.3601	PoR	1.00	0.75	0.55	0.35	0.70	0.50	0.30	0.70	0.50	0.25
			SL	0.3601	0.2701	0.1981	0.1260	0.2521	0.1801	0.1080	0.2521	0.1801	0.0900
	C11	0.0681	PoR	1.00	0.80	0.60	0.30	0.70	0.60	0.30	0.70	0.50	0.25
			SL	0.0681	0.0545	0.0409	0.0204	0.0477	0.0409	0.0204	0.0477	0.0341	0.0170
	C12	0.1667	PoR	1.00	0.70	0.55	0.30	0.75	0.60	0.25	0.70	0.55	0.25
			SL	0.1667	0.1167	0.0917	0.0500	0.1250	0.1000	0.0417	0.1167	0.0917	0.0417
		0.1686	Subtotal SL	0.16858	0.12561	0.09671	0.05702	0.12283	0.08825	0.04576	0.11801	0.08911	0.04215
B3 Technical risks	C13	0.1073	PoR	1.00	0.80	0.65	0.30	0.75	0.55	0.20	0.75	0.40	0.20
			SL	0.1073	0.0858	0.0697	0.0322	0.0805	0.0590	0.0215	0.0805	0.0429	0.0215
	C14	0.2833	PoR	1.00	0.50	0.40	0.10	0.80	0.55	0.25	0.75	0.55	0.30
			SL	0.2833	0.1417	0.1133	0.0283	0.2266	0.1558	0.0708	0.2125	0.1558	0.0850
	C15	0.4466	PoR	1.00	0.70	0.50	0.25	0.85	0.55	0.25	0.75	0.50	0.30
			SL	0.4466	0.3126	0.2233	0.1117	0.3796	0.2456	0.1117	0.3350	0.2233	0.1340
	C16	0.1627	PoR	1.00	0.75	0.55	0.25	0.65	0.45	0.25	0.70	0.45	0.25
			SL	0.1627	0.1220	0.0895	0.0407	0.1058	0.0732	0.0407	0.1139	0.0732	0.0407
		0.1069	Subtotal SL	0.10689	0.07078	0.05301	0.02275	0.08472	0.05705	0.02615	0.07930	0.05294	0.03005
B4 Environmental risks	C17	0.1439	PoR	1.00	0.80	0.60	0.40	0.75	0.55	0.35	0.70	0.50	0.25
			SL	0.1439	0.1151	0.0863	0.0576	0.1079	0.0791	0.0504	0.1007	0.0720	0.0360
	C18	0.3739	PoR	1.00	0.60	0.40	0.20	0.85	0.60	0.40	0.70	0.55	0.30
			SL	0.3739	0.2243	0.1496	0.0748	0.3178	0.2243	0.1496	0.2617	0.2056	0.1122
	C19	0.0920	PoR	1.00	0.75	0.55	0.30	0.65	0.45	0.30	0.70	0.45	0.25
			SL	0.0920	0.0690	0.0506	0.0276	0.0598	0.0414	0.0276	0.0644	0.0414	0.0230
	C20	0.3902	PoR	1.00	0.40	0.25	0.10	0.90	0.65	0.45	0.70	0.55	0.30
			SL	0.3902	0.1561	0.0976	0.0390	0.3512	0.2536	0.1756	0.2731	0.2146	0.1171
		0.0576	Subtotal SL	0.05760	0.03252	0.02212	0.01146	0.04820	0.03447	0.02322	0.04032	0.03074	0.01660
	Total satisfaction losses			**1.0000**	**0.7358**	**0.5293**	**0.2952**	**0.7351**	**0.5191**	**0.2403**	**0.6843**	**0.4738**	**0.2245**

5.3 Analysis of the results

The simulation results produced by @Risk with 5,000 iterations are given in table 30 31, and 32. In Table 30, "Impact of risk" is the average of three parameters (Minimum, Most Likely, Maximum) with a Triangular distribution. In annotation ③, the values of these three parameters in different situations are the sum of each subtotal satisfaction losses of the four categories risk (Total satisfaction losses). The subtotal satisfaction losses are the sum of satisfaction losses of every risk factor in the category multiplied by the weight vector of the category. The satisfaction loss of a risk factor is equal to the weight vector of the risk factor multiplied by the value of adjusted probability of risk. For example, in raw materials (grain) production phase (table 26):

The max satisfaction loss due to C1 risk factor in the Scenario 1 are:

$$0.0405 \times 0.80 = 0.0324$$

The max subtotal satisfaction losses of the management risks in the Scenario 1 are:

$$(0.0324 + 0.1121 + 0.425 + 0.0435 + 0.216) \times 0.5299 = 0.43923$$

The max total satisfaction losses of the Scenario 1 are:

$$0.43923 + 0.16807 + 0.14947 + 0.04726 = 0.8040$$

The value of "satisfaction losses due to TS risk" are calculated by the formula:

$$\text{Probability of risk} \times \text{Impact of risk}$$

The data of "user's final satisfaction" are calculated by the formula:

$$\text{User's initial satisfaction} - \text{Satisfaction losses due to TS risk}$$

In Table 31, the value of "average of user's final satisfaction" is the average value of the four phases of the user's final satisfaction. In Table 32 variation results produced by the model are given. Due to the change of standard deviation, the results of each iteration are different. After 5,000 iterations, average results for the 5% and 95% percentiles are given.

Table 30 The results of TS risk simulation model (5,000 @Risk iterations) (100%)

Phase	Scenario	Impact of risk	Satisfaction losses due to TS risk	User's final satisfaction
A1	1	0.6167	0.6167	0.3833
	2	0.4811	0.4811	0.5189
	3	0.4424	0.4424	0.5576
A2	1	0.5768	0.5768	0.4232
	2	0.5059	0.5059	0.4941
	3	0.4960	0.4960	0.5040
A3	1	0.4567	0.4567	0.5433
	2	0.5007	0.5007	0.4993
	3	0.5010	0.5010	0.4990
A4	1	0.5201	0.5201	0.4799
	2	0.4982	0.4982	0.5018
	3	0.4609	0.4609	0.5391

Table 31 The summary of user's final satisfaction results (5,000 @Risk iterations) (100%)

Phase	Scenario 1	Scenario 2	Scenario 3
A1	0.3833	0.5189	**0.5576**
A2	0.4232	0.4941	**0.5040**
A3	**0.5433**	0.4993	0.4990
A4	0.4799	0.5018	**0.5391**
Average of user's final satisfaction	0.4574	0.5035	**0.5249**

Table 32 The variation results of TS risk simulation model (5% percentile, 95% percentile), (5,000 @Risk iterations)

Phase	Scenario	Impact of risk			Satisfaction losses due to TS risk	
		5% percentile	95% percentile	Difference value	5% percentile	95% percentile
A1	1	0.4811	0.7479	**0.2669**	0	1.8781
	2	0.3483	0.6213	0.2729	0	1.435
	3	0.3183	0.5859	0.2676	0	**1.2956**
A2	1	0.4542	0.7117	**0.2576**	0	1.6805
	2	0.3765	0.6437	0.2672	0	1.5295
	3	0.3602	0.6419	0.2816	0	**1.5019**
A3	1	0.3128	0.6028	0.2900	0	**1.3181**
	2	0.3452	0.6557	0.3105	0	1.4588
	3	0.3623	0.6352	**0.2729**	0	1.4594
A4	1	0.3684	0.6673	**0.2990**	0	1.5712
	2	0.3233	0.6578	0.3345	0	1.4665
	3	0.2995	0.6122	0.3128	0	**1.3867**

5.3.1 Scenario results analysis

Results in Table 31 show that the average of user's final satisfaction of scenario 1 is 0.4574. Although Scenario 1 has the lowest satisfaction, however, its performance in the processing and storage phase is the most prominent. This shows that government support and supervision are more helpful to processing enterprises and can improve the quality of TS more. Scenario 2 predicts 0.5035, about 10.07% better than scenario 1. The performance of scenario 2 in each phase is at a moderate level. The highest amount of user's final satisfaction is predicted by scenario 3, 0.5249, and it is slightly better than scenario 2 (4.25%). But scenario 3 has the best satisfaction score in the three phases (A1, A2, A4). This proves that with the positive cooperation of all parts of the supply chain, the quality of traceability activities can be more assured and smoother.

Table 32 listed the variation results of the TS risk simulation model. The results of "Impact of risk" of scenario 1 in table 30 are the highest in the three phases (A1, A2, A4). However, in table 32, the "difference value" of scenario 1 in the same phases are the smallest. This shows that scenario 1 has the smallest fluctuation range and better stability when it is affected by risks. In the variation results of "Satisfaction losses due to TS risk", zero (5%) means that when no risk occurs the losses are also zero. So it is impossible to compare the effect of the three scenarios. When the risks frequently occur, the variation results showed that scenario 3 has the lowest occurrence of risk in three phases (A1, A2, A4) of the IRCP supply chain, and the occurrence of risk of scenario 1 is the highest in the same three phases. This means that scenario 1 is most susceptible to the occurrence of risks, and scenario 3 is the most risk resilient. Therefore, scenario 3 can better control the TS risks and reduce the pressure on IRCP enterprises.

5.3.2 Sensitivity analysis of the output

This analysis focuses on the sensitivity of the output of user's final satisfaction. The responses of the three scenarios to changes in input factors are different. The coefficients listed in Table 33 are normalised regression coefficients associated with each user's final satisfaction in four phases. A regression value of zero indicates that there is no significant relationship between the input and the output. It also means the change of that input will have less impact on the related output of the scenario. A regression value of 1 or -1 indicates a 1 or -1 standard deviation changes in the output for a 1 standard deviation change in the input. Sensitivity analysis can be used to better judge the true effect of the scenarios.

Table 33 The sensitivity analysis results of TS risk simulation model (5,000 @Risk iterations)

	User's final satisfaction of Scenario 1	User's final satisfaction of Scenario 2	User's final satisfaction of Scenario 3	R-squared
A1	**-0.126**	-0.166	-0.181	0.968
A2	**-0.132**	-0.156	-0.168	0.973
A3	-0.186	-0.183	**-0.16**	0.966
A4	**-0.167**	-0.198	-0.195	0.962
Rank 1	3	0	1	
Rank 2	0	3	1	
Rank 3	1	1	2	

R-squared is a statistical measure. It represents how well a regression line approximates real data points. R-squared values range from zero to one (explaining in between 0 and 100% of the variance of the data). A high R-squared between 0.85 and 1.0 indicates a good to ideal fit. An R-squared lower than 0.70 indicates that a regression line does not fit the data very well (Steel et al. 1960). The R-squared values in Table 31 are all higher than 96%, so the linear regression sufficiently explains the relationship between the inputs and outputs. The simulation results (See table 31) show that scenarios 2 and 3 have a similar tendency to reduce the negative influences and improve user satisfaction of TS risks for the IRCP supply chain. Meanwhile, the average of user's final satisfaction of scenario 3 is 0.0675 higher than scenario 1.

However, the sensitivity analysis results show that scenario 1 has the least sensitivity to the influence of user's final satisfaction in three phases (A1, A2, A4) of IRCP supply chain. The regression value for scenario 1 is closer to zero than for scenario 3 in the same phases. Its sensitivity is about 22% less than scenario 3 on average. This result means that scenario 1 is more stable, even strong fluctuations of external factors will not change the effects of risk management too much. This can also be proved from the result of "Difference value" in Table 32. So the reliability and practical value of scenario 1 is higher than those of the other scenarios.

In the end, the outputs of simulations performed by the stochastic model show that the best approach to control and reduce the traceability system risk is: to use contracts and agreements to build a vertical joint-business network (scenario 3) as the core, and to appropriately combine it with multi-level government support (scenario 1). In the initial stage of TS construction, government policies, regulations, and investment capabilities are the fundamental guarantee for achieving high-quality TS. Without the macro-control of government functional departments, the unilateral establishment of TS by enterprises and individuals will be incomplete and weak. The structure of the food supply chain is long and complex. When large-scale difficulties or impacts arise, the cooperation between enterprises in the supply chain will bring new factors into play. This affects the enthusiasm of participants in the traceability activities and reduces the quality of TS. Therefore, the perfect combination of the advantages of the government and the units in the food supply chain can create the most optimized traceability system that meets China's national conditions.

6. Discussion, Conclusion and Recommendations

Discussion

According to the research questions, the discussion consists of six aspects.

1. There are three main characteristics to the food supply chain. First, the supply chain is long and complex. It means the food supply chain contains a number of stages, and at each stage, the main actors must deal with many problems. Second, the scale, operation situation and management standards of enterprises are different throughout the chain. It increases the probability of food safety risks and traceability risks. Third, the proportion of logistics outsourcing is large and the consumption cycle is short in the FSC management. The logistics outsourcing increases the length of the food traceability process, and the short consumption cycle increases the difficulty of food traceability activities. These characteristics involve risks and compromises food safety in the supply chain. These three characteristics need to be taken into account when looking at the food traceability process.

2. Traceability is the ability of using the registered marks to trace products history, status of use, location, similar products and activities. The characteristics of traceability include: It covers a wide range of products. The degree and accuracy of food traceability is higher and higher. The traceability technology is improving. The traceability system will become the new standard for the international trade. These characteristics proved the importance of food traceability, and also from this experience arises the need for a higher requirement for the quality of food traceability.

3. The risk factors that affect food safety mainly includes: the food additives problem. The non-food materials problem. The food safety regulations and standards problem. The primary products and agricultural inputs problem. The processing, storing, transporting and environment pollution problem. The application and safety testing system problem. The food safety analysis, assessment and early warning system problem. These problems are concerned by the activities of food traceability. To solve those problems a good quality of food traceability is very important.

4. The risk factors that affect food traceability can be divided into two main aspects, technical risk factors and managerial risk factors. The technical risk factors are the factors that occur due to applying and innovating food traceability technology. The managerial risk factors are focus on the existing and potential human-centered risk factors. During the process of food traceability, they are located in the various parts of the FSC. This research mainly paid attention to analysing the managerial risk factors in the FSC.

These managerial risk factors contain three parts: in the planting and breeding part, the risks in the process of agricultural raw materials input and production of primary products are the main problems to influence the quality of food traceability. The uneven distribution of profits is the main cause of these risks. In order to increase their own benefits, some farmer may use inferior feed and tampering the traceability information. In the processing part, the key to ensuring the quality of food traceability is the management quality of processing enterprises. But the poor collaboration and the low transparency affected the management quality. In the distribution part, the situations of storage and transportation, and the management of the sales places have an important impact on the quality of the food traceability. The differences in laws, regulations and management systems in different phases will increase the risk of food traceability. When these risk factors exist in the food supply chain, they will cause all kinds of damages, efficiently avoiding and reducing these risks will better guarantee the quality of the food traceability.

5. According to the summaries of the literature study, field research and the three scenarios, a normative stochastic model has been established. This model was used to predict the user's final satisfaction in the different scenarios. In different scenarios, the influences of TS risks and the method of adjustment are also different. The effect of the scenario can be evaluated by the score of the user's final satisfaction. The results show that scenario 3 can effectively improve the satisfaction of traceability activities in three phases (Raw materials (grain) production phase, Raw materials transportation phase, End products distribution phase) and reduce safety risks. Scenario 1's performance in the Processing and Storage phase is even more prominent. Moreover, scenario 1 has better stability and ability to resist fluctuations. The performance of scenario 2 in each phase is at a moderate level. Therefore, the perfect combination of the advantages of scenario 1 and scenario 3 will be the key to establishing China's traceability system. This task has a long way to go.

6. This research takes IRCP supply chain as an example of the complex system behind food traceability. The IRCP supply chain comprises a vertical extension, which involves the primary industry (agriculture), secondary industry (food processing industry) and tertiary industry (distribution, logistics, etc.). Any stage of the IRCP supply chain can imply a potential food safety issue. The IAF market is very broad, so the requirements for the quality of the food traceability are also high.

According to the identification and analysis of the risk factors in the IRCP supply chain, the research further confirms the main managerial risk factors that affect the quality of food traceability, and also the reasons and the negative effects for these risks. It provides a reference to strengthen the management of food traceability activities. However, the study of IRCP supply chains can only be achieved by analyzing current literature and reports, and limited field research and expert interviews. Therefore, one of the limitations of this research was that without sufficient and long term field research, the information available is not comprehensive enough. For example, enterprises in order to solve practical problems need to adjust these basic principles to their own situation.

Conclusion

Traceability system is an information system. It helps achieving product traceability by correctly identifying, accurately recording and effectively communicating product information. It was developed as a solution following the food safety crisis, consumers demanding for food safety standards. It is the result of the study of market behaviors among enterprises and government regulation of food safety (Dong et al. 2011). There exists a wide variety of food traceability technology, such as EAN • UCC system, barcode technology, RFID, GPS, GIS. Traceability system records the history of food in the supply chain. In this way, food traceability can assist enterprises to effectively monitor the internal process of food production and accurately identify the source of the problem. In the entire supply chain, with the principle of "one step forward, one step back" it can help identify who are the enterprises responsible at each stage in the chain, and provide sufficient information for them to protect their own benefits when incident occurred.

The objective of this research is to enhance the companies' ability of food traceability by analysing and understanding the risk factors that affect food traceability. In order to achieve this goal, a wide range of literature was studied and a case study of one specific industry was analysed. The Fuzzy Synthetic Evaluation method was used to determine the critical risk factors in the infant rice cereal products supply chain. Then the method of cross-industry benchmarking was being applied to transfer the successful experiences and critical success factors gained from the automobile industry showing how TS risks can be dealt with, to the IRCP companies. Based on the results of literature research, case study, and cross-industry benchmarking, three different scenarios were defined to predict the ability of Chinese IRCP enterprises to manage and control TS risks in the food supply chain.

In order to compare effects of the three scenarios, a normative stochastic model was being built. The simulation results show that the predicted user's final satisfaction is different in the different scenarios. Scenario 1 is the government support scenario; it means depending on multi-level government intervention and assist to manage TS risks. The predicted average of user's final satisfaction in scenario I is 0.4574. It has the lowest sensitivity to the TS risks in three phases of IRCP supply chain. Scenario 2 is the industry guild scenario; it means to adopt common industry regulations to build a horizontal joint-business network to abate the TS risks. The predicted average of user's final satisfaction in scenario II is 0.5035. The performance of scenario 2 in each phase is at a moderate level. Scenario 3 is the supply chain combination scenario, which focuses on building a vertical joint-business network to improve the ability of risk control, and resilience. The predicted average of user's final satisfaction of scenario 3 is 0.5249. It is predicted to be slightly better than scenario 2 (4.25%). But scenario 3 has the best satisfaction score in the three phases of IRCP supply chain.

According to the analysis of critical risk factors, we can conclude that the overall risk of the IRCP supply chain is at a medium level. Among them, the degree of risk in the processing and storage phase is the highest, and the management risks are the main reason. It shows the impact of management risk factors on the processing industry is more critical. Therefore, the best approach to control and reduce the traceability system risk is: to use contracts and agreements to build a vertical joint-business network (scenario 3) as the core, and to appropriately combine it with multi-level government support (scenario 1).

Many food industry firms comply with the "one step forward, one step back" process, which means that each actor involved in the food supply chain needs to be able to accurately trace back its products or ingredients one step back and one step forward. This process allows them to be able to be competitive on the market, because of export requirements, private standards, or internal food safety practices. In this way it lessens the financial risks companies must take (European Commission 2007). Traceability systems can also strengthen the strategic partnership among each enterprise, increase customer satisfaction and improve the competitive advantage of the entire supply chain. Food traceability is also beneficial for companies in the food industry as it allows them to ensure of the quality of their product, which is essential in a fiercely competitive market. In the same manner, food traceability ensures public trust but to be effective, all actors in the chain must comply and link together in order for the whole chain to be covered.

Recommendations

In order to enhance the accuracy and consistency of food traceability, this study proposed following recommendations concerning the different aspects:

- The findings from the field survey and interviews show that in the IRCP supply chain, the proportion of profits distribution for production sectors, processing sectors, and distribution sectors is around 1: 4: 5. This situation brings a huge potential risk in the entire supply chain. Due to this unequal distribution of profits, many are tempted to alter the production and sell counterfeits products, which can have a serious impact on the quality of food traceability. The way to solve this problem is to improve the system of revenue distribution, and enhancement of the internal stability of the supply chain. Monopolies of individual companies in one particular stage of the supply chain should be prevented, to ensure that the benefits in each stage will be controlled and distributed more equally. The industry associations and government regulators need to play an active role in this issue.

- Due to the impact of the financial crisis, economic downturns, and political upheaval, the operation and management of the enterprise is more conservative and self-protection awareness is stronger. The excessive sense of crisis and the pressures of competition affected the overall interests of the supply chain (Zheng 2008). Food traceability needs to be carried out in the entire supply chain. Low transparency management and unfavorable collaboration relationship greatly reduced the efficiency of food traceability. Refer to Toyota company's experience, the way to solve this problem is to strengthen the collaboration in the different links of the supply chain, and gradually establish a profit and risk sharing chain alliance should be stimulated. Key parts in achieving this would be strengthening communication, sharing supply chain information, avoiding confrontation and seeking common ground and resolving differences along the supply chain. For example, this can be achieved through contractual agreements, informal cooperation (includes exchange visits, short-term exchange of employees etc.), joint ventures, equity participation, and international cooperation. In order to build and maintain a long term and close enterprises collaboration.

- Because of the impact of economic globalization, the scale and complexity of the food supply chain is also increasing. Enterprises and products in a supply chain may come from anywhere of the world. The differences between countries, regions and industries, especially in the development of laws and regulations, the functioning of the regulatory department, and the standards of the industry self-regulation will increase the risk of food traceability.

  The way to solve this problem is to increase legislative speed, setting up international food safety laws and regulatory system mainly aimed at covering all stages of food production, from processing to distribution all the way to consumption. Food regulatory departments should be centralized to ensure this system could efficiently operate. Meanwhile, governments need to strengthen the day-to-day supervision for the food industry, improve the methods of management, and develop a management system based on laws to increase the intensity of penalties for violations. State authorities also need to encourage enterprises to comply with the laws on this subject, and improving the responsibility awareness of food safety. Food regulatory departments should encourage the reform of the existing industry associations to truly become non-governmental public organizations because it would play a role in decreasing risk factors. Food regulatory departments should play the role of industry self-regulators, and become a bridge between companies and government, to assist the government in establishing and maintaining market order.

  In addition, the moral level of the supply chain participants is also very important. Whether the employees work attitude is rigorous enough, the business is focused on integrity, and the development of the industry is constructive are all keys factors that come into play.

Finally, there are also some recommendations for the relevant researches in the future. This research only focuses on the managerial risk factors, it does not take into account the technical risk factors. It is also important to take into account the factors that affect the quality of traceability. Thus, further study should look at adding more factors to satisfy the different requirements. Furthermore, this study takes IRCP supply chain as the example, but the characteristics of the IAF supply chain will be different with the other food supply chain, such as meat or wine supply chain. Thus, the adaptation range of the research is not wide enough. Therefore, a multiple food supply chain analysis would be useful for further study and it could help obtain a more convincing result.

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Appendix

1 The Food Traceability System

2 Questionnaire 1+2

Note: This is an academic research questionnaire, and takes Chinese infant rice cereal products as an example. The objective is to identify and analyze the critical risk factors which affect traceability system in the infant accessory food supply chain. This research will help enterprises to ensure the accuracy and consistency of the food traceability. This survey is totally anonymous and the results are only for academic research. Please read each question carefully, and select the response that best reflects your reaction to the question or item. If you have any questions or concerns about completing the survey, you may contact me at (ma.he.q1@dc.tohoku.ac.jp). I would very much appreciate it if you could fill in the following questionnaire.

Part 1: Survey on the relative importance of risk assessment indicators for food industry supply chain

The scale and meaning of the judgment matrix

Evaluation of indicator comparison	Value	Meaning	Reciprocal value*
a is as important as b	1	Same contribution to the overall goal	1
a is slightly more important than b	3	The contribution of a is unapparent greater than b	1/3
a is more important than b	5	The contribution of a is greater than b	1/5
a is very important than b	7	The contribution of a is obvious greater than b	1/7
a is extremely important than b	9	The contribution of a is enormously obvious greater than b	1/9
a and b are the intermediate value of the above 2 adjacent judgments	2, 4, 6, 8	a compromise between two adjacent judgments	1/2, 1/4, 1/6, 1/8

*Reciprocal value: it means compare the importance of the 2 indicators after changing the order. For example: The factor u_i is compared with u_j to obtain the judgment matrix u_{ij}, then change the order of u_i and u_j, the new judgment matrix is $u_{ji}=1/u_{ij}$.

Example: if you think that a is very important than b, fill in 7 in the form; if you think that b is very important than a, fill in 1/7 in the form. If you think the importance of a compare b is between in very important and extremely important, then fill in 8 in the form. If on the contrary, fill in 1/8 in the form.

1. Risk assessment indicators of grain (raw materials) production part

Evaluation index	**a**. Management risks	**b**.Equipment risks	**c**.Technical risks	**d**.Environmental risks
a. Management risks	1			
b.Equipment risks		1		
c.Technical risks			1	
d.Environmental risks				1

1.1 Management risk factors

Evaluation index	**a.**	**b.**	**c.**	**d.**	**e.**
a. Seeds quality	1				
b. Pesticides and fertilizer safety		1			
c. The quality of employees			1		
d. Information acquisition*				1	
e. Data record of the Planting process					1

*Information acquisition: The ability of grain producers to acquire market and technical information. It will affect the management level of production. Insufficient ability will result in reduced competitiveness and increased management risk.

1.2 Equipment risk factors

Evaluation index	**a.**	**b.**	**c.**	**d.**
a. Irrigation	1			
b. Farming		1		
c. Storage			1	
d. Sterilizing				1

1.3 Technical risk factors

Evaluation index	**a.**	**b.**	**c.**	**d.**
a. Fertilizer application	1			
b. Prevention and treatment of disease		1		
c. The quality of technical staff			1	
d. The ability of new technology application				1

1.4 Environmental risk factors

Evaluation index	**a.**	**b.**	**c.**
a. Natural disaster	1		
b. Policies and regulations		1	
c. Consumer awareness*			1

*Consumer awareness: the level of awareness about grain production and food safety will improve producers' emphasis on quality and safety.

2. Risk assessment indicators of grain (raw materials) transportation part

Evaluation index	a. Management risks	b.Equipment risks	c.Technical risks	d.Environmental risks
a. Management risks	1			
b.Equipment risks		1		
c.Technical risks			1	
d.Environmental risks				1

2.1 Management risk factors

Evaluation index	a.	b.	c.	d.	e.	f.
a. Grain shipment inspection system	1					
b. Vehicle disinfection plan execution		1				
c. Contract's execution quality			1			
d. The quality of employees				1		
e. Information acquisition					1	
f. Data record of the transportation process						1

2.2 Equipment risk factors

Evaluation index	a.	b.	c.
a. Vehicle failure	1		
b. Container equipment issue		1	
c. Disinfection equipment issue			1

2.3 Technical risk factors

Evaluation index	a.	b.	c.
a. Loading technical problem	1		
b. The quality of operator		1	
c. Abnormal situation processing technology			1

2.4 Environmental risk factors

Evaluation index	a.	b.	c.	d.	e.
a. Traffic accident	1				

b. Natural disaster		1			
c. Policies and regulations			1		
d. Consumer awareness				1	
e. Government supervision					1

3. Risk assessment indicators of processing and storage part

Evaluation index	**a**. Management risks	**b**.Equipment risks	**c**.Technical risks	**d**.Environmental risks
a. Management risks	1			
b.Equipment risks		1		
c.Technical risks			1	
d.Environmental risks				1

3.1 Management risk factors

Evaluation index	**a.**	**b.**	**c.**	**d.**	**e.**	**f.**	**g.**
a. Raw materials and additives detection	1						
b. End products quality inspection		1					
c. Packaging material safety			1				
d. The quality of employees				1			
e. Disinfection plan execution					1		
f. Information acquisition						1	
g. Data record of the processing and storage process							1

3.2 Equipment risk factors

Evaluation index	**a.**	**b.**	**c.**	**d.**	**e.**	**f.**
a. Workshop hygiene design	1					
b. Processing equipment issue		1				
c. Packaging Equipment issue			1			
d. Warehousing and handling equipment issue				1		
e. Disinfection equipment issue					1	
f. Detection and monitoring equipment issue						1

3.3 Technical risk factors

Evaluation index	a.	b.	c.	d.
a. Hygiene control of processing operations	1			
b. Inspection and detection technology		1		
c. Cryogenic storage technology			1	
d. The quality of operator				1

3.4 Environmental risk factors

Evaluation index	a.	b.	c.	d.	e.
a. Natural disaster	1				
b. Air and water pollution		1			
c. Policies and regulations			1		
d. Consumer awareness				1	
e. Government supervision					1

4. Risk assessment indicators of end products distribution part

Evaluation index	**a**. Management risks	**b**.Equipment risks	**c**.Technical risks	**d**.Environmental risks
a. Management risks	1			
b.Equipment risks		1		
c.Technical risks			1	
d.Environmental risks				1

4.1 Management risk factors

Evaluation index	a.	b.	c.	d.	e.	f.	g.	h.
a. Procurement quality assurance *	1							
b. Products quality inspection		1						
c. Shelf life management			1					
d. Contract's execution quality				1				
e. The quality of employees					1			
f. Abnormal situation processing						1		
g. Information acquisition							1	
h. Data record of the sales process								1

*Procurement quality assurance: The sellers ask for quality-related certification from the supplier to ensure the quality and safety of the product.

4.2 Equipment risk factors

Evaluation index	a.	b.	c.	d.
a. Storage facility hygiene	1			
b. Disinfection equipment issue		1		
c. Handling equipment issue			1	
d. Detection equipment issue				1

4.3 Technical risk factors

Evaluation index	a.	b.	c.	d.
a. Delivery time control	1			
b. Rationality of disinfection measures		1		
c. Rationality of detection technology			1	
d. Rationality of inventory control				1

4.4 Environmental risk factors

Evaluation index	a.	b.	c.	d.
a. Natural disaster	1			
b. Policies and regulations		1		
c. Consumer awareness			1	
d. Government supervision				1

Part 2: Survey on the risk level of risk assessment indicators for food industry supply chain

In this survey, the risk level of risk assessment indicators is divided into 5 levels: 1. very low risk, 2. low risk, 3. medium risk, 4. high risk, 5. very high risk. The risk value is represented by the numbers 1, 2, 3, 4, and 5 respectively.

Example: if you consider the risk of "seeds quality" in the "Risk assessment indicators of grain (raw materials) production part" is low, then fill in 2 in the form.

1. Risk assessment indicators of grain (raw materials) production part

Evaluation index	Risk value
Seeds quality	
Pesticides and fertilizer safety	
The quality of employees	
Information acquisition	
Data record of the Planting process	
Irrigation	
Farming	
Storage	
Sterilizing	
Fertilizer application	
Prevention and treatment of disease	
The quality of technical staff	
The ability of new technology application	
Natural disaster	
Policies and regulations	
Consumer awareness	

2. Risk assessment indicators of grain (raw materials) transportation part

Evaluation index	Risk value
Grain shipment inspection system	
Vehicle disinfection plan execution	
Contract's execution quality	
The quality of employees	
Information acquisition	
Data record of the transportation process	
Vehicle failure	
Container equipment issue	
Disinfection equipment issue	
Loading technical problem	
The quality of operator	
Abnormal situation processing technology	
Traffic accident	
Natural disaster	
Policies and regulations	
Consumer awareness	
Government supervision	

3. Risk assessment indicators of processing and storage part

Evaluation index	Risk value
Raw materials and additives detection	
End products quality inspection	
Packaging material safety	

The quality of employees	
Disinfection plan execution	
Information acquisition	
Data record of the processing and storage process	
Workshop hygiene design	
Processing equipment issue	
Packaging Equipment issue	
Warehousing and handling equipment issue	
Disinfection equipment issue	
Detection and monitoring equipment issue	
Hygiene control of processing operations	
Inspection and detection technology	
Cryogenic storage technology	
The quality of operator	
Natural disaster	
Air and water pollution	
Policies and regulations	
Consumer awareness	
Government supervision	

4. Risk assessment indicators of end products distribution part

Evaluation index	Risk value
Procurement quality assurance	
Products quality inspection	
Shelf life management	
Contract’s execution quality	
The quality of employees	
Abnormal situation processing	
Information acquisition	
Data record of the sales process	
Storage facility hygiene	
Disinfection equipment issue	
Handling equipment issue	
Detection equipment issue	
Delivery time control	
Rationality of disinfection measures	
Rationality of detection technology	
Rationality of inventory control	
Natural disaster	
Policies and regulations	
Consumer awareness	
Government supervision	

Part 3: Personal basic information

Please mark the corresponding option in ☐ according to your actual situation.

1. Your current position

☐ a. Senior manager ☐ b. Middle manager ☐ c. Junior manager
☐ d. Technical staff ☐ e. Scholar ☐ f. Others________

2. How long have you participated in (or monitor or research on) supply chain risk management (including traceability system) or agriculture business related work?

☐ a. In 1 year ☐ b.2-4 years ☐ c.5-10 years ☐ d. Over 10 years

3. Your education background

☐ a. High school and lower ☐ b. Junior college and undergraduate

☐ c. Master ☐ d. Doctor

The questionnaire has been completed; thank you again for your cooperation and support!

3 Questionnaire 3

Questionnaire of critical success factors in supply chain traceability system

Note: This is an academic research questionnaire, and takes Chinese infant rice cereal products as an example. The objective is to identify and analyze the critical success factors which affect traceability system in the infant accessory food supply chain. This research will help infant accessory food processing enterprises to build a higher quality traceability system. This survey is totally anonymous and the results are only for academic research. Please read each question carefully, and select the response that best reflects your reaction to the question or item. If you have any questions or concerns about completing the survey, you may contact me at (ma.he.q1@dc.tohoku.ac.jp). I would very much appreciate it if you could fill in the following questionnaire.

Part 1: Survey on the importance value of critical success factors for supply chain traceability system

In this survey, the importance value of critical success factors is divided into 5 levels: 1. not important, 2. little important, 3. important, 4. very important, 5. extremely important. The importance value is represented by the numbers 1, 2, 3, 4, and 5 respectively.

Example: if you consider the importance of "Comprehensive food traceability regulations and government policy guidance" is higher, then fill in 4 in the form.

Critical success factors	Importance value
Comprehensive food traceability regulations and government policy guidance	
Complete and adequate food traceability laws and standards	
Government's comprehensive food traceability campaign for the public	
The investment level of traceability system operation and maintenance	
The level of timeliness in problem solving	
Goal-oriented and full support by all functional departments in enterprises	
Responsible and positive administrators	
Timely and convenient communication between enterprises in the supply chain	
Information sharing between enterprises in the supply chain	
Higher trust between upstream and downstream companies	

Consumers have adequate awareness of food traceability activities	
Consumers' willingness to pay for traceable products	
The authenticity, integrity, and effectiveness of traceability information	
Widely applicable standardized traceability information identification	
Full-featured and easy-to-use traceability system to meet user needs	

Part 2: Personal basic information

Please mark the corresponding option in ☐ according to your actual situation.

1. Your current position

☐ a. Senior manager ☐ b. Middle manager ☐ c. Junior manager
☐ d. Technical staff ☐ e. Scholar ☐ f. Others________

2. How long have you participated in (or monitor or research on) supply chain risk management (including traceability system) or agriculture business related work?

☐ a. In 1 year ☐ b.2-4 years ☐ c.5-10 years ☐ d. Over 10 years

3. Your education background

☐ a. High school and lower ☐ b. Junior college and undergraduate

☐ c. Master ☐ d. Doctor

The questionnaire has been completed; thank you again for your cooperation and support!