Economic Analysis of Implementing Electronic Traceability

System for Fresh Produce Importers

by

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ABSTRACT

The global demand and trade for fruits and vegetables is increasing at national and international levels. The fresh fruits and vegetables supply chain are highly vulnerable to contamination and can be easily spoiled due to their perishable nature. Due to increases in fresh fruit and vegetable trade shipment volume between countries, the fresh food supply chain area is the highly susceptible and frequently prone to food contamination. The inability of firms in the fresh food business to have a good supply chain visibility and tracking system is one of the prominent reasons for food safety failure. Therefore, in order to avoid food safety risk and to supply safe food to consumers, the firms need to have an efficient traceability system in their supply chain.

Most of the research in the food supply chain area suggests the implementation of a highly efficient tracking system called RFID (Radio frequency identification) technology to firms in the food industry. The medium scale firms in the fresh food supply chain business are skeptical about implementing the RFID technology equipped traceability system due to its high cost of investment and low margins on fresh food sales.

This research developed two methods to measure the probability of food safety risk in food supply chain. These methods use the information gain from RFID traceability systems as a tool to measure the amount of risk in the fresh food supply chain. The stochastic optimization model is applied in this study to determine the risk premium by investing in RFID technology over the electronic barcode traceability system. The results show that there is a reduction in buyer

(Type II error) and seller risk (Type I error) for RFID technology employed traceability system compared to electronic barcode system. It is found from stochastic optimization results that there is a positive risk premium by investing in RFID traceability system over the current systems and suggests the implementation of RFID traceability system for complex medium scale fresh produce imports to reduce the food safety risks. This research encourages the food industries and government agencies to evaluate alternatives to update supply chain system with RFID technology.

To my dearest mom and dad

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INTRODUCTION

Overview

The government, food companies, and international trade bodies are increasing their focus on assuring food quality, especially food safety (Julie Caswell, 1998). In the recent years, this focus is more pronounced in the perishable food supply chain because of the increasing number of illnesses due to food recalls (FDA, 2010). Food safety can be defined as a system that ensures reliability in reducing exposure to natural hazards, errors, and inspection failures (Nganje, etal, 2010).

Food Defense is the protection of food products from intentional adulteration by biological, physical, chemical or radiological agents (FSIS, 2011).

The food defense measures help in reducing the market failure risk (also called type I and II errors) of the product during its supply chain process (Nganje, etal, 2010).

Food safety risk has a significant impact because it causes economic losses to the food industry and health problems to the public that might lead to complete market failure (Nganje and Skilton, 2010). In the United States alone, every year about 1 out of 6 Americans or 48 million people get sick, 128,000 are hospitalized, and 3000 die due to food borne illnesses (CDS, 2011). At the same time, the economic losses due to unsafe food are also significantly large. The direct costs due to food losses in different stages of the supply chain account for more than $1 billion per year and the total direct and secondary economic loss due to food borne disease is $6 billion per year (Qu, 2010).

Food supply chain networks are increasingly exposed to risks. This food safety risk could be due to improper supply chain practices during large volume shipments from the domestic and imported sources (Nganje, etal., 2010). A week doesn't go by without a food borne outbreak (Shulman, 2001). In recent years the major outbreaks in perishable food products have faced several recalls. For example, *Salmonella* *enterica* outbreak of fresh jalapeno and Serrano peppers imported from Mexico have caused major losses to the perishable industry (FDA, 2008). Similarly, in 2006, the Dole baby spinach *e. coli* outbreak lead to 205 illnesses (Food Safety News, 2009) and 3 deaths. There are several other class I, II & III recalls which occurred regularly (FDA reports). Product recalls are some of the driving forces behind the more strict traceability legislation and regulations (Fremme, 2007).

In order to prevent these product recalls, the US legislation has introduced some policies to firms in the food industry. An example of such a policy is the recently passed Food Safety Modernization Act, Signed into law by President Obama in December 2010. This new law will give the FDA authority and power to do the recall for about 80% of the food supply chain except for meat and poultry products which already had mandatory pathogen reduction hazard analysis at critical control point since 2000 (Nganje, 2010). Another requirement in the new bill is that growers and food manufacturers need to implement food safety plans and foreign food importers to the US will have to meet the US standards of food quality (Food Safety News, 2011). Rapid response and targeted traceability is part of the bill, to minimize economic loss and death due to food borne pathogens.

Need for this Research

The possible reasons for food safety failures and economic losses in the food supply chain can be related to inefficiencies in different areas of the supply chain. For example, it could be due to inspection and diagnostic errors. Diagnostic error is the error that occurs when the uncontaminated lot fails inspection. Inspection error may occur when a contaminated lot passes inspection (Amanor-Boadu, 2006).

Diagnostic error is similar to Type I error or what we called seller risk in this research risk associated with false alarm. Inspection error is similar to Type II error or buyer risk that could result in illness or death.

Another possible reason for food crisis could be due to supply chain complexity. It is due to large number of produce exchangers along the supply chain (FDA, 2008). The complexity of supply chain will decrease the traceability efficiency or efficiency to trace back in case of product contamination. In the recent times, the Salmonella outbreak of jalapeno pepper is one of the most complex investigations that had been taken by FDA. It took 81 days to find the actual source of contamination due to network complexity (Njange, et al. 2010). The complexity involved in this outbreak can be show in Figure 1.

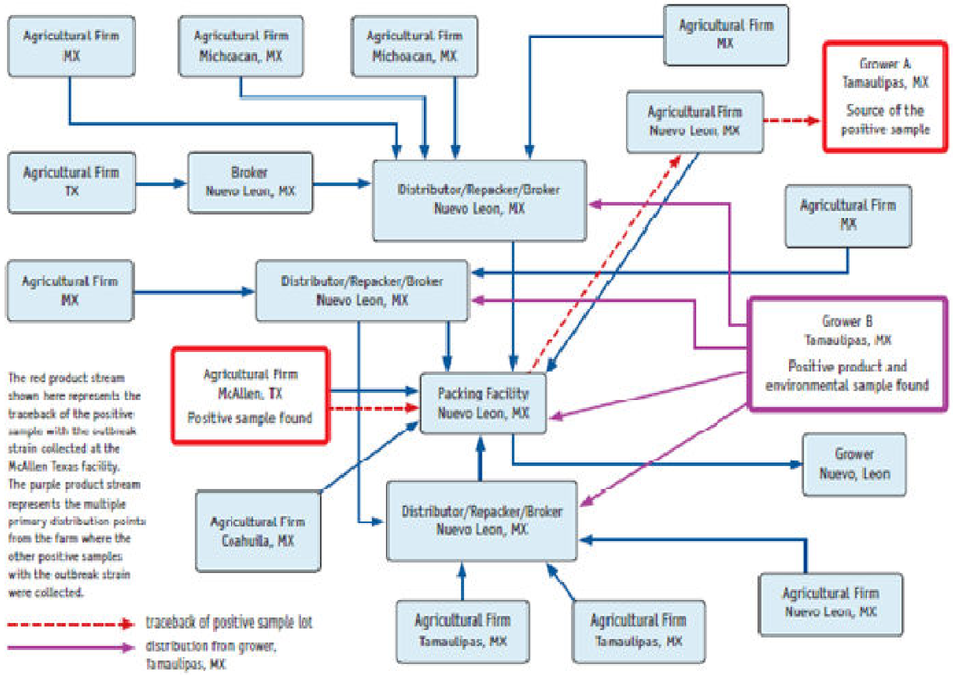

Figure 1. Salmonella Saintpaul Outbreak Traceback & Distribution

A prior research by Robisson, Nganje, and Skiliton etc suggests that one of the major problem during the food failures are due to inefficient tracing systems at every point in the supply chain. In some cases, in spite of having good traceability systems in supply chain, the firms fail to mitigate the risk of food product outbreak. The reason for this is the lack of uniform traceability throughout the supply chain. In other words, this problem occurs when the other firms in the product supply chain (like packing, warehouse etc.) try to skip some crucial food safety steps in supply chain traceability (Nganje, etal. 2010). As a remedy to these problems the U.S. government has introduced Food Safety Modernization Act for the companies in food the sectors.

These aforementioned errors in the product supply chain are responsible for unsafe food product release into market and spoilage of food. It has a huge negative impact on the economy of the entire food industry. For example, from same reports it is known that in the spinach industry financial losses due to salmonella outbreaks alone accounted for $100 million to over $350 million USD (FDA, 2006). In order to avoid these kinds of errors in supply chain system, firms may need to have a more reactive traceability mechanism when contamination problems occur. Apart from the above reasons the firms should have an efficient traceability mechanism because of new mandatory food safety laws which explicitly suggest implementation of an electronic traceability system. Additionally, in order to avoid these economic losses before buying, the retailers are checking for food safety measures taken by their suppliers (Shulman, 2001). For instance, firms like Wal-mart now uses modern traceability systems like RFID (Radio Frequency Identification) in their food supply chain. They had ordered their 100 major suppliers to adopt modern traceability like RFID technology in their supply chain (Lipsky, 2004).

Traceability is an increasing common topic of research in economics. According to ISO 9000:2000 guide lines, traceability is the ability to trace the history, application or location of that which is under consideration (Kristoff, 2004). There are two forms of traceability; 1) Forward traceability and 2) Backward traceability (Doukidis, 2007). Forward traceability is the ability to track the products movement from production to retail and consumption, to minimize the economic loss or health hazards. Backward traceability is the ability to trace back the product from retail and consumption, to identify the origin of an outbreak. Forward traceability could provide cost savings with timely and targeted recall. Backward traceability helps to assign liability, but could also facilitate targeted recalls.

One of the major goals of the forward and backward traceability is to improve efficiency of risk mitigation (Nganje, etal. 2010). The faster the reports produced or product recalled, the greater the probability of reducing illness or death rate due to that product outbreak, which in turn may help firms to reduce the cost incurred by food hazards.

Previous research by Caswell, Henson, and Khegia (2008) etc., has looked at how the efficiency in traceability can be achieved in food supply chain by adopting modern traceability systems. The information generated by good traceability systems coupled with good inspection practices can help in improving food safety. For example, in an experiment directed to learn the benefits of RFID technology for the fish supply chain that involved the cold chain transport of fish from South Africa to Spain, different types of RFID smart tags were used to measure the benefits of RFID technology. From the research results, RFID smart tags proved to be more reliable with real time traceability results and helpful for the firm to take good safety and quality control measures (Abad, etal, 2009).

Inspite of the potential benefits associated with electronic traceability systems, practitioners are skeptical about implementing them (Food news, 2011). The possible reasons for these hypothesis are investigated in this research using the case of the perishable food imports. The aim of the research is to establish the link between the observable and unobeservables food supply chain variables. Here, the observable variables are information gain about quality parameters like time, temperature, location etc, of product (from different traceability sytems) and the unobservable variables are market failure risks (type I and type II errors). This research provide a model case study which helps to determine detail costs and benefits for implementation of an electronic traceability system to a medium size fruits and vegetable imported from Mexico. Further, this paper explores the complexity of network structure of food supply chain and provide a complete frame work of cost benefit analysis

Objectives

The main goal of this paper is to investigate the risk premium of implementing an RFID traceability system to a firm with a complex and loosely coupled supply network. The model uses commodity journey based data like time temperature and location data during its supply chain process in order to measure the food risk. The objectives are,

1) To provide a model to calculate the probability of contamination of the commodity in transit using the commodity journey based data.

2) To provide a detail review of different types of risk and cost associated with alternative traceability systems in the food supply chain.

3) To develop a stochastic optimization model then use it to determine the risk premium and cost effectiveness of using the electronic traceability system.

Chapter 2

LITERATURE REVIEW

Food Safety Policies and Regulations that stress on traceability adoption

Due to food safety hazards at both national and International levels, the consumers have lost trust in public and private food industries (Caswell, 2008). The increased exposure to the food outbreak events and government awareness programs on food safety issues has made the consumers more conscious about choosing their food products from the supermarkets and As a result, consumers are expecting more information related to the safety attributes of food products that are manufactured and consumed around the world (Grandin, 2005). In light of these situations and to regain consumer confidence in food industries, the government agencies and private organizations are continuously revising their food safety laws and standards (Caswell, 2008).

In the US, the two major federal agencies (FDA and USDA) deal with food safety issues. As far as the measures concerned with food safety, the USDA regulates the safety of meat, poultry and egg products where as remaining food products are regulated by FDA (FDA).

There are numerous other food safety institutions at the international level which are intended to regulate the food industries for the supply of safe food. Due to growing international trade relations for food products and free trade agreements between countries, the food safety regulatory measures and safety standards are not only becoming prominent in industrialized countries but also in the developing countries (Henson, 2005). This phenomenon of food regulations is becoming a global concept due to continued globalization (Manning, 2007). Apart from their own national food standards, it would be important for firms in the food sector to know about international food standards also. Since, the food supply chain is interconnected among different countries. For example, the large food retailer like Wal-Mart imports vegetable produce from the China producers (Xue, 2009). Similarly, the perishables products like grapes are supplied by Chilean producers to US retailers. Hence, it is important for any firm in food industry (irrespective of nation) to be updated with new food safety standards in order to successfully supply food without outbreaks to other countries. Most of the food standards suggest the implementation of an efficient traceability system which can prevent food hazards by improved ability to trace and track food from farm to fork.

In this context, major policies pertaining to implementation of traceability for having a good food safety and quality standards are reviewed. They can be categorized into two types; Private initiatives and Government initiatives. Some of the major private standards at national and international level for food safety are HACCP, LGMA, GMP, BRC, Global GAP or Eurep GAP etc. These food safety standards and regulatory acts are set by government agencies and different group of retailers in food sector for their suppliers (Bennet, 2008).

The HACCP (Hazard Analysis Critical Control Point) is a method used in food sector to identify potential food safety hazards. The key actions at the critical control points of food processing are taken to reduce the risk of food safety hazard. HACCP is important because many global standards that deal with food safety and traceability include HACCP principles in several other ways in their design (Bennet, 2008). In the US, depending upon the industry, there are different types of HACCP standards. For example, Seafood HACCP regulation was introduced in 1995 in order to ensure the safety processing of fish products which includes imported sea food. Juice HACCP regulation was introduced in 1998 for the safe and sanitary processing and importing of juice products (FDA, 2001). Similarly, there are different sets of HACCP rules for retail and food services as well. The GAP (good agricultural practices) is one of the prerequisites for HACCP principles and In order to ensure food safety and quality control in any food industry, it should be coupled with an efficient traceability system (FDA). In similar way, Global GAP or EurepGAP is a private sector which sets voluntary standards for the certification of agricultural products around the world (www.globalgap.org) accessed on March, 2011. The standards of global GAP are more in demand compared to legal mandatory traceability standards. The aim of the GAP is to ensure food safety and quality of the produce from the global food suppliers and retailers. Traceability is one of the major obligations of these standards (Caswell, 2008). There are many other GAP equivalent private organizations worldwide that could demand more or less the same food safety standards.

The BRC (British Retail Consortium) is the global private food safety standard introduced by the UK retailers. According to this regulation the suppliers and retailers are jointly responsible in case of misfortunes due to release of unsafe food. This indirectly implies international suppliers to have a good traceability system along its food chain in order to prevent a food crisis (Manning, 2007). The LGMA (Leafy Green Marketing Agreement) is another nationally famed organization formed for the safe supply of leafy green vegetables. This is one of the successful private food safety programs in the recent times (FDA, marketing weekly news, 2010). It was formed when Californian farmers came together (in response to the E.coli 0157:H7 outbreak of bagged spinach) to reduce food safety hazards (Nganje, etal, 2010). Its mission is to protect public health by reducing potential sources of contamination in California leafy greens. Currently, the LGMA consists of more than 100 farmers, shippers and processors. They account for 99% of the volume of leafy greens produced in California (www.caleafygreens.ca.gov) accessed on March, 2011. It has become a model for food safety programs for different food products in other states (FDA, marketing weekly news, 2010). One of the reasons for its success is known to be good tracking systems along its supply chain.

Similarly, there are many government standards that demand more safety information from the producers, retailers, distributors in the food supply chain. Some regulations directly suggest the implementation of traceability. For example, the European Union, after facing severe damages of a food crisis, introduced a mandatory food traceability regulation (Caswell, 2008). At the international level the food safety standards are set by ISO which has a base of over in 160 countries. There are many other government standards which insist on traceability in the food supply chain.

The regulations like public health security and bioterrorism preparedness act are designed with the main objectives of tracing and tracking of food along the food chain. Very recently, in the U.S., as a result of the longstanding efforts of FDA to strengthen the food supply system a new regulation or act called Food Safety Modernization Act (FSMA) was signed into a law by the President Obama on Jan, 4, 2010. The main reasons behind implementation of this act were to urge to control or reduce the food recalls rate and to strengthen the food supply system. It is introduced with a principle to focus on preventive measures in food supply chain rather than trying to correct after occurrence of food hazard. FSMA gives FDA expanded authority and responsibility to strengthen the food supply systems. It has following objectives: 1.) Improved capacity to prevent food safety problems, 2.) improved ability to detect and respond to food safety problems, and 3.) improving the safety of imported food. The FSMA act is strongly directed towards enhancing the ability to trace and track the food supply of domestic and imported food chains. Apart from the above measures, it stresses on the record keeping requirements for facilities that manufacture, process, pack or hold high risk food items (FDA, Public health focus news, 2011). Further, Taylor says the new law will help in mitigating problems in the food chain that occur due to complexity and diversified nature of food supply system (FDA, 2011).

From the above explanation of regulatory procedures, it is clear that private and government standards explicitly suggest traceability for the food supply chain. Further, Caswell says that the regulators see traceability as a risk management tool for quicker management of unsafe food whereas retailers in food business view it with an added motivation of quality assurance along with safety (Caswell, 2008).

As discussed above, the pressure on suppliers in food industry is mounting because of the following responsibilities. i.e. 1.To have good measures to provide safe and quality food to customers, 2.To be able to faster recall of food products, and 3. Pressure to implement or practice the new government regulations etc. In order to satisfy these demands, companies in the food industry is looking forward to implement modern traceability systems and it has become a top most priority for companies to focus on improving their existing food traceability systems. In this scenario, academic people and industry people are researching explicitly on value of implementing traceability systems (Kehagia, 2009).

Brief Overview of Existing Traceability System

The concept of traceability has made its first appearance in the late 1980`s with an objective of quality management in food supply chain (Caswell, 2008). The standardized definition of traceability was given by ISO. According ISO, it is the ability to trace and follow a food, feed, food producing animal or ingredients through all stages of production and distribution.

The information developed by traceability systems is useful in controlling upstream and downstream processes of supply chain (Manzini, 2007). Nowadays, the major traceability systems used are alphanumeric codes, barcode, and RFID (Radio frequency Identification) systems.

Out of the given traceability systems barcode and Rfid systems are best systems to be adopted to have effective product traceability in food supply chain

(Manzini, 2007). Among these modern traceability systems, RFID technology is gaining importance because of its wide range of applications in food supply chain (Ampatzidis, 2009).

From the recent research papers, the prominent benefits of RFID can be illustrated as follows. 1. It ensures food quality control. 2. It ensures food safety (Qu, 2010). 3. It prevents adverse events caused by inspection errors (Amanor-Boadu, 2006).

The quality of the food in supply chain, especially for perishable food produce can be estimated by using commodity environmental data obtained through RFID technology. It is found that RFID coupled with other technologies can help in having complete supply chain visibility. In predictive microbiology studies, the levels of harmful bacteria can be known only when there is information about the environment parameters in the supply chain. This information about environment parameters can be obtained through the RFID technology. For instance, to predict the probability of contamination the temperature information of the product during different supply chain levels is very essential. Because, the dangerous microorganism like *e.coli* growth rate depends on the temperature maintenance of the data. For example, in some types of highly sensitive perishable food like grapes, it takes only few hours of abnormal temperature to spoil the food. This occurs because; too high or too low temperatures and relative humidity can create a congenial environment for the growth dormant pathogens in food and reach the saturation levels. Here, the role of RFID technology is to give data related to the temperature fluctuation during supply chain. Thus, the obtained data can be useful in predicting the amount of microbial levels in the food and probability of contamination. From the above cases, RFID equipped traceability technology can be promising for quality controlling of food during cold chain (Qu, 2010).

Network complexity and challenges of food supply risks

In this paper, we took a three level approach to explain the challenges in food supply networks from the industries point of view.

1. Level of Uncertainty, it explains about the difficulties in traceability due to type I and II errors.
2. Level of Transparency, It gives review of how the network complex will influence on the supply chain transparency or visibility.
3. Level of acceptance, it mainly discusses about the modern traceability acceptance problems by owners in food industry, due to information proprietorship and increased cost issues.

Level of Uncertainty

As noted in the above case, RFID technology has a prominent role to play in mitigating food safety risk. It can be further elaborated in the following context. Occurrence of adverse events for the firms in food supply chain is because of two main reasons, first is the diagnostic error and second one is the inspection errors. Diagnostic error is the error that occurs, when the uncontaminated lot fails inspection. While, the inspection error occurs when a contaminated lot passes the inspection process (Amanor-Boadu, 2006). These errors are also called as type I & II errors. The first type of error is associated with seller risk. Managing this kind of risk is one of the crucial steps in any food supply chain. However, despite of good measures to prevent contamination by the suppliers, improper diagnosis may represent it as contaminated and thus resulting in the dumping of the products by the seller.

The type of risk associated with inspection error is buyers risk and is even more dangerous than sellers risk because it causes health problems to buyers or public. This mainly happens, when wrongly inspected or contaminated produce passes the inspection and reaches the public but not recalled by the company (Nganje, 2010). The ultimate sufferers of these two errors are firms in the food industry (which buy and sell the food produce). In awake of these types of errors, firms need to have a good traceability system. The authors like Andrew & Amanor-Boadu, 2009, explain the necessity of efficient traceability system to prevent adverse events due to errors. They relate the essentiality of traceability in the food supply chain with a different methodology. It can be elaborated in the following context. The authors say that if the firm has the ability to trace the product source of these errors, then they can distribute the risk to those who are the actual cause of outbreak or adverse events. In other words, the suppliers who are responsible for giving false reports about produce reliability in food supply chain (Type I & II errors) are also liable to companies (which buys the product). This restriction motivates the suppliers to supply safe food and ensures food safety for firms by preventing adverse events. This is because of distribution of the risk of food failure among (improperly managed) suppliers (Andrew, 2006). The academic research theoretically proves in favor of implementing efficient traceability system but further analysis is needed to prove it practically.

Level of Transparency

The other challenges in estimating costs are complexity of Supply chain or network complexity. The supply chain networks complexity increases with increasing number of exchangers involved in supply chain. The ability to control the adverse events in supply chain becomes difficult with increasing complexity because of the reducing transparency. That is the flow of product information becomes opaque. Here, transparency means ability to trace or visualize the movement of goods along supply chain. Based on Perrows, 2000 and Robisson, Skiliton 2009 the complexity of supply chain can be explained clearly by a matrix given in the Figure 2.

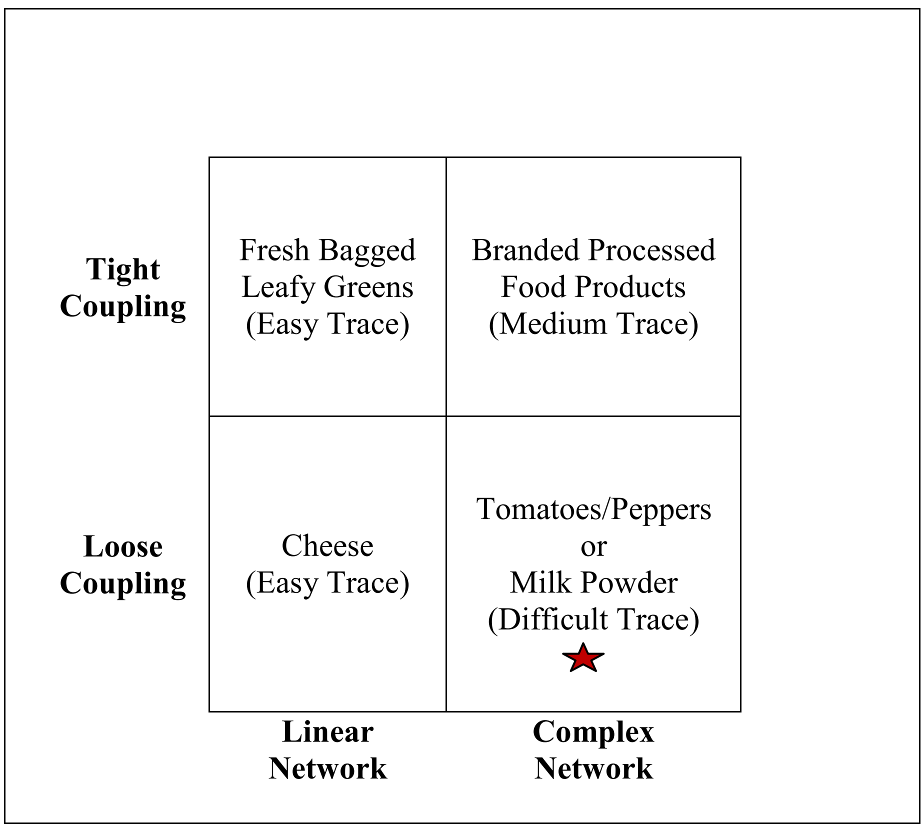

Figure 2. Food supply chain matrix

In this matrix, the parameters in the horizontal axis are based on complexity of supply chain network and the vertical axis parameters represent the firmness of traceability system. Based on severity, the supply chain networks are divided in to two networks, they are linear and complex. The linear network is a simple supply chain network with fewer number of sellers and buyers of products in the food chain. In this network, there is a free flow of product information at each and every point of supply chain. It can be shown by figure 3.

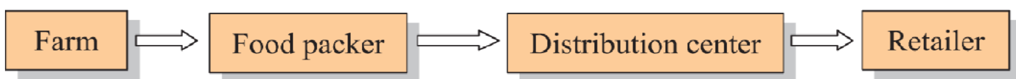

Figure 3. Example of a Linear Supply Chain Network

In the case of a complex network, it involves exchange of information between large numbers of people (buyers and sellers of produce) like producers, distributors, retailers etc. In this type of network the complexity increases because of product transformation or it may be due to requirement of a large number of ingredients to make one product so it involves multiple stages of processing and distribution (See Figure 4).

Due to involvement of a number of product exchangers, it is more likely that there is a loss of visibility of the product in the supply chain. In simple words, the transparency of supply chain decreases with increase in complexity of the network. This transparency into the supply chain networks can be improved by the help of a good traceability system. In case of the linear networks, a loosely coupled traceability system will suffice to get control over the supply chain to prevent adverse events. But, in the case of the complex supply chain networks, the tightly coupled system would enhance the supply chain transparency. The problem occurs when the firms use loosely coupled system to manage the traceability of complex networks. In order to prevent recalls and enhance visibility, complex networks supply networks should practice tightly coupled supply chain traceability system (Robinson, 2009). In order to provide practical evidence to practitioners in this study a cost benefit analysis is provided for implementing electronic traceability for a firm with a complex network with loosely coupled system.

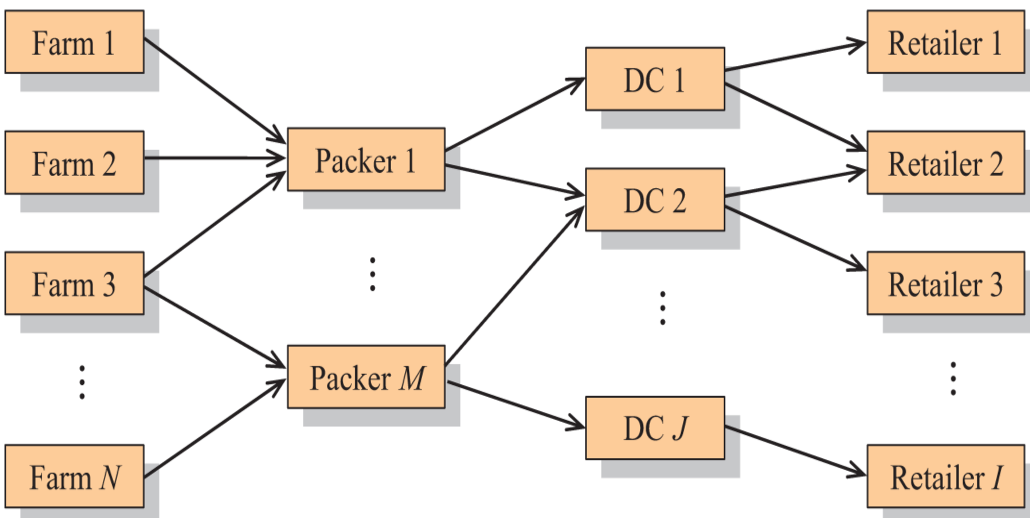

Figure 4. *Example of a Complex Supply Chain Network*

Level of acceptance

According to a research paper by Alessandro and Stefanella, 2008, the new policies by the government like implementation of mandatory traceability system may not be completely advantageous to firms in food industry. The authors say`s that under mandatory traceability system, the companies will have low vertical coordination in the food supply chain because of improper information flow among the business leaders. Further, it says that a voluntary traceability system with certain proposed agreement between business leaders (distributors, processors, retailers) will enhance their business to business relations. This is due to their increased dependency on each other. Ultimately, this increased vertical coordination between the businesses leaders coupled with efficient traceability system in food supply chain industry will lead to efficient food safety and quality control (Banterle, 2008).

From the above cases, it is understood that the implementation of a modern traceability system is the solution to the wide range of difficulties in the food supply chain. Even though the academic research papers explicitly predict that the implementation of modern traceability has several benefits, the actual value of investment in implementing traceability for the food supply chain is always an unanswered question for practitioners (Kehagia, 2009).

Brief Overview of Challenges in estimating costs of implementing traceability systems

The modern traceability systems like barcode system and RFID systems are proved to be promising technical resources for various food industries. But, according to author Manizi, etal the RFID technology can only be cost effective to high value products like dairy products. The possible reason for this is due to its high cost of implementation. The rfid tag costs dependson the type of industry, volume of produce, and type of tags (active or passive), there are range of RFID tags in the market costing from 10cents per unit to $1 per unit (RFID Journal).

The RFID tag costs in European countries are approximately 0.5 to 20 euro which is very high compared to barcode system. Since the food products like fruits and vegetable are generally on low cost and the added price due to RFID systems cost can have high negative effect on their demand (Manzini, 2007). Bar codes on the other hand are far more cost effective with associated costs of approximately $0.005 USD per tag (RFID Journal). As technology follows the time line of innovation, prices for RFID tags are subject to price decline as technology becomes cheaper and more efficient. But both technologies would be helpful for a solution to the trace back issues and traceability throughout the supply chain.

Void in Research addressing electronic traceability

The problem is due to some uncertain elements in the food supply chain for which actual value are difficult to obtain and some of the benefits are intangible (Intangible benefits are benefits for which economic values cannot be estimated, only viewed in the sense of goodwill to the company) (Kehagia, 2009). Earlier research on cost benefit analysis of traceability marginally addresses this issue and most of them are pertained to meat and high value products. We do not have successful evidence of implementation of electronic traceability technology in import products like fruit and vegetables.

Given this scenario, this paper provides a base for firms with perishable product business to choose optimal traceability system. Firms in the fruit and vegetable food industry would like to evaluate three main variables. First, the actual cost associated with implementation of electronic traceability system. Second, investigate the economic benefits of implementing a modern traceability system (Caswell, 1998). And finally, the cost effectiveness of implementing traceability could benefit to outweigh the cost associated with electronic traceability system implementation (Kehagia, 2009). To answer these questions, this research provides cost benefit analysis for importing firms with loosely coupled and complex network system.

METHODOLOGY

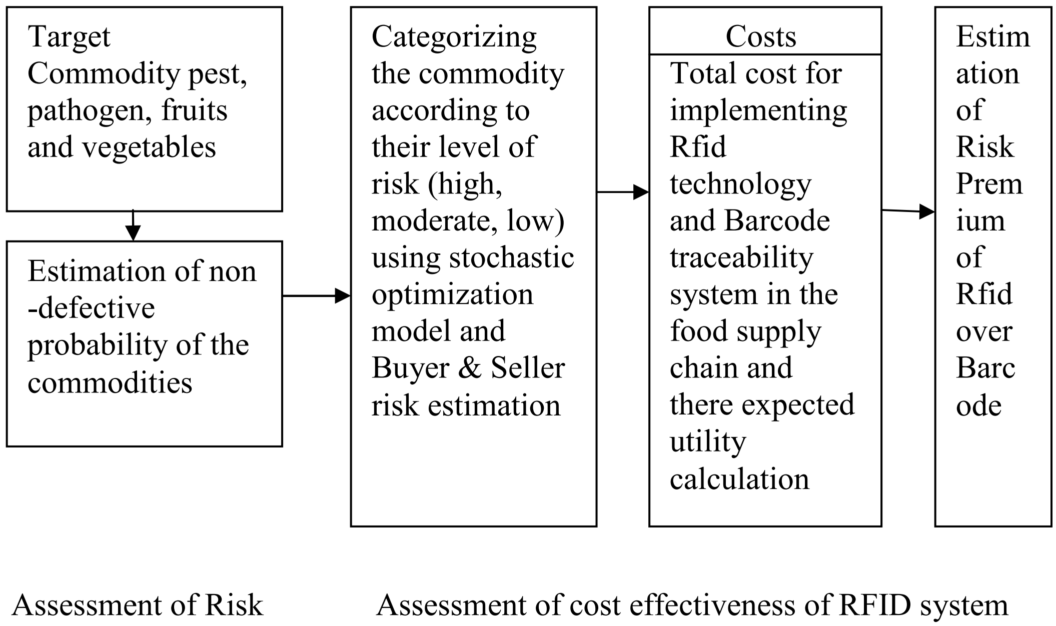

Figure 5. Conceptual Frame work

Determination of Safe Probability with the help of Journey based data of Produce Container

The task of estimating the non defective probability of target commodity needs product container data from farm to retailer provided by various sources. The sources would be the companies in fruits and vegetable sectors, sensor manufacturing (like Cold track) and trucking companies etc. Here, we have used the previously available data collected in DHS project report. It has been collected from Mexican companies in the food sector. Out of the data the temperature data play an important role in calculation of safe probability. The temperature records data is obtained from RFID (radio frequency identification technology) sensors installed in containers. The data consists of temperature, time and location relevant information of the produce container during its supply chain. The sample data can be seen in Table 1.The sensors read the temperature for every five minutes interval. (Nganje, Richards, Bravo, Hu, Kagen, Acharya, & Edwards, 2009).

In order to describe container quality using the data, two different methods are developed. The methods are based upon mathematical and probability theories. These methods describe quality by using best feature of data like mean, covariance, standard deviation etc. Further, the methods are described in the following section.

Mahalanobis Distance Method

The mahalanobis approach is adopted from the Villalobus et al (2003) and McLachlan (1999) research. The mahalanobis distance is mainly used in classification problems, when there are several groups and the investigation concerns the affinities between groups. Based on mahalanobis distance, the group is assigned or identified to a particular population. The higher the mahalanobis distance from reference population higher it does not belong to that population and vice versa. For example, consider that there are two different kinds of groups with p characteristics and X be the multivariate random vector that gives the measurement based on the given population under study. The X is having the same variation about its mean within either group. Then, the formula for distance between the groups is determined based on the $\mu 1$, $\mu 2$ and $\sum$ of the groups. It is given as follows,

$$D(x) = \sqrt{(x-\mu)^T \Sigma^{-1} (x-\mu)} \tag{1}$$

Where μ1 is mean of population 1, μ2 is mean of population 2, ∑ is covariance, T is the transpose of the matrix obtained from difference of the means of random vector of each populations (with same characteristics within group) and D is the mahanobolis distance.

In this model, the food produce containers are divided into two groups of reference populations called G1 safe and G2 unsafe containers. Each population is a multivariate vector with ρ =3 characteristics. Those are time, temperature, and location of the produce containers. The mahanalobis distance is calculated for each truck temperature data by finding the difference in the means (μ) of the characteristics of each population and covariance matrices of the two populations with characteristically similar random vectors. The farther the distance from the reference data point (safe container), the more is the chance that the group does not belong to particular reference group i.e. safe or unsafe.

$$D(x) = \sqrt{(x-\mu)^T \Sigma^{-1} (x-\mu)}$$

From the above calculated distances, we can find the safe and unsafe probability of containers by using the following equations.

$$P_0 = \frac{D_0^{-1}}{D_1^{-1} + D_0^{-1}} \qquad P_1 = \frac{D_1^{-1}}{D_1^{-1} + D_0^{-1}} \tag{2\&3}$$

P_0 is safe probability and P_1 is unsafe probability of the food carrying container.

Probability Distribution Fitting Method

The method in this model is suggested by the Pape, (2008) and Vodopivec , (2005). To check whether the above obtained probability is consistent along different procedures and to minimize the errors and increase the accuracy of calculations. This model is developed to estimate the actual safe probability of container in food supply chain. The model is based on probability theory and it is a good way to determine the non defective probability of the containers. This methodology can be described in detail below.

The temperature observations obtained from sensors as continuous random variable because the temperature values can take any value between intervals or within the intervals. The continuous random variables (observations) can take Uniform, Normal, Pearson, Logistic and Exponential distribution etc. But, to know what would be the best fit distribution for the container temperature data there is need to conduct statistic tests for data. There are three standard approaches for testing whether a set of data is consistent with a proposed distribution. They are Chi square test for discrete random variables, Kolmogorov-Smirnor test for continuous random variables, and Anderson darling test to test skewness of data. Out of these tests, in this case the K-S test is considered to be a good method in finding the best fit probability distribution for continuous random variable data. For example, consider normal distribution curve is best fit for the container temperature data. The data is subjected to normal distribution using @risk palisade decision tools, to find the safe and unsafe probability of different temperature data from the produce containers. Then, temperature range is defined depending on the product of concern. The next step is to calculate the Z values for the defined ranges. Thus obtained Z values can help, find the probability of observations in the given range. Same procedure is applied to each container data and the containers with the maximum probability are chosen over the other. These probabilities explicitly predict that the temperature values are kept within the specified temperature range during different stages of produce supply chain.

It can be clearly explained by the following example. Suppose the product of concern are potatoes so retailers at the receiving end expects the temperature range of 38-50 ˚F to be maintained by container suppliers along its supply chain stages like trailer transit and warehouse etc. Unlike other perishable products, potatoes have a problem with too low as well as too high temperatures. Because, the temperature below 38˚F may cause sprouting and above 50 ˚F may lead to different diseases like bruising, soft rot etc. (USDA, 2011).accessed on August 16, 2011 from USDA website. Hence, it is important to have our truck temperature values within this range. This can be easily explained by probability distribution since it helps in finding the probability with which the observations can be within the specified range. The procedure can be explained in the following hypothetical model example.

First, conduct K-S tests to select the best fit distribution for temperature data. The test values can be seen in the Table 1.

Table 1

Example of K-S test for sample temperature data

S.No	Distribution	K-S Test Values
1	Normal	0.0299
2	Pearson	0.0185
3	Logistic	0.0106
4	Uniform	0.0100

Based on the K-S values calculated, the best fit distribution seems to be Normal Distribution. Hence, fit the normal distribution to the data containing temperature observations. By applying this bell shaped curve is obtained and can be shown in Figure 6

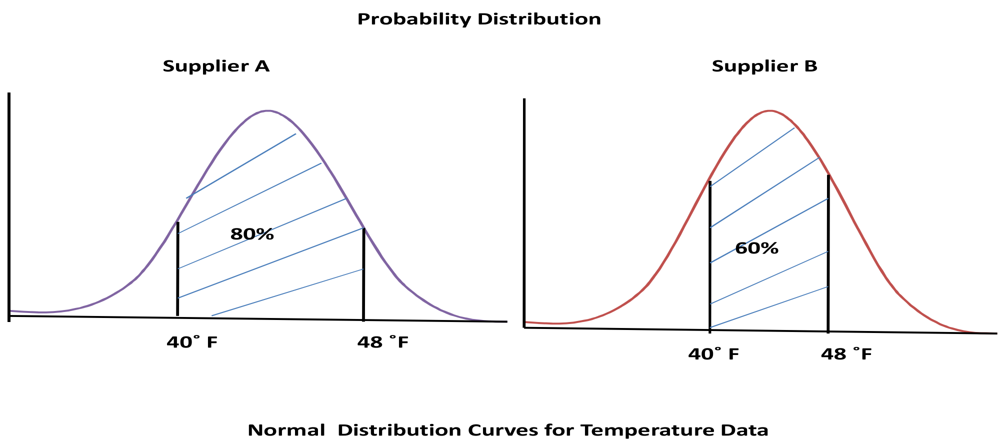

Figure 6. Example of normal distribution curves for temperature data

Third step would be to calculate the area under the curve using the Z values formula= X-μ/σ. Since, we need only the area under the curve within given range i.e. 40-48 ˚F, Z values for that particular temperature`s is calculated. The zeta values at 40 ℃ and 48 ℃ are Z_{40} =0.0710, Z_{48} =0.1801. Then, subtract values Z40 from Z48. Look for the Z values in the Z table, In order to find the probability with which the temperature observations are in the given range.

Suppose from the given Zeta values, the calculated probability for container A is 0.80 or 80% and container B is 0.60 or 60%. Finally, the decision is made based on the calculated probabilities and other probability statistics variables like standard deviation and variance etc.

Our client may choose container A over B because the probability distribution method gives good insight about the container`s maintenances of temperature. From above method, it is proved that the container `A` maintained at consistent temperature with little outliers compared to container `B’. Not only probabilities but also other parameters like variance, standard deviation and temperature value at 95% confidence interval etc are considered in estimation.

Note: All these steps can be done using @risk palisade decision tools for real data.

Introducing Time Component

After the successful selection of container from the above mentioned methods. There is a still need of analysis. Even though, the container maintained the produce within the given range of temperature, the quality can be compromised. It occurs when the produce is subjected to higher durations of panic temperature`s.

For example, grapes shelf life decrease by threefold at 10 ° C and it also increases the pathogen content in the product. Hence, it is important to check the shelf life and pathogen levels of container for their entry into border to supply U.S. market. It can be checked by including time component along with the temperature.

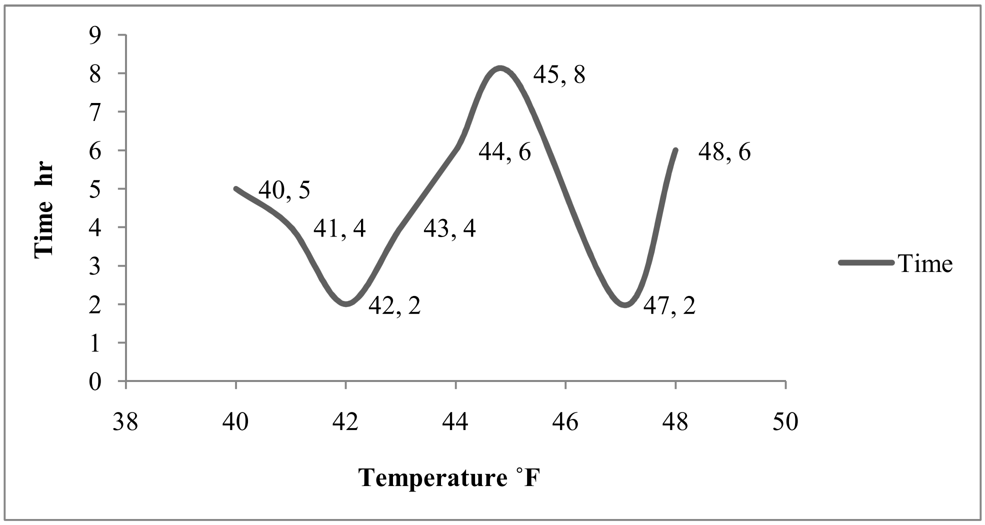

Figure 7. The temperature Vs time graph

Given the time component in the data along with temperature, the time can be found for which the produce is subjected to certain temperature values. This can be done by the simple use of sorting and chart functions in excel. For example, from the above graph in figure 7 (based on sample data points) it is known that the produce is subjected to 8 hours of 45.8 F temperature, 5 hrs of 40.5 F, 4 hrs of 41.4, 6 hrs of 48.6 F and so on. Though, the procedure is simple, it has good weightage in measuring the quality of product. Let us suppose that the potato products are spoiled, if it is kept at 48.6 F for 20 hrs. From the Figure 2, it is clear that the product is maintained at 48.6 for 6hrs only. So, it can be predicted that the produce is free of danger.

Hence, by applying above two methods, the safe probabilities (π) can be determined. Though, the product`s safe probability appears to be reliable value but there may be chance of errors. Because, there is chance that the product is subjected to Type I and Type II errors during inspection. Then, the Bayesian conditional probability theorems would be good measure to find the actual safe probability of the containers Villalobus etal, (2003). It can be illustrated in the following example.

Let, N be number of products in the shipment, K is the number of stages of inspection and Mij is defined as the actual quality of the produce whether the product is contaminated or not and this parameter is a binary random variable with the values of 0, when the inspection unit is safe and 1 otherwise. Further, the inspection outcome can be represented by another random variable Iij in the same manner the variable is given a value of 0 or 1, based on the inspection outcome at the last stage of inspection at U.S. Port of Entry. Notice that the probability of error results of the inspection change as the inspection unit passes through different stages of food supply chain. However, we only consider that all probability values confined to inspection unit at the last stage of the inspection (Nogales POE). Let, the rij be defined as the probability that the inspection unit is safe to release into US market.

$$Rij = Pr\ (Mij = 1) \qquad (3)$$

As discussed in literature review any inspection procedure no matter how perfect is traceability system, it cannot avoid the diagnostic and inspection errors. To find the accurate measure of contamination probability Bayesian conditional probability theory is used.

$$\Pr\,[I_{ij}^{k} = s \; l \; M_{ij}^{k} = \text{m}] = \begin{cases} \alpha_i & \text{if s=0 , m =1} \\ 1-\alpha_i & \text{if s=1, m=1} \\ \beta_i & \text{if s=1, m=0} \\ 1-\beta_i & \text{if s=0, m=0} \end{cases} \qquad (4)$$

As defined above there are two outcomes in the inspection process, s means the inspection outcome and m is actual outcome. Under this conditional probability theorem, the four probability outcomes are possible. They are given equation 4 and can be defined as follows αi (s=0, m=1), it is the probability of inspection outcome, when the inspection unit is declared as unsafe but in actual it is safe, 1-αi, s=1,m=1, it is the probability of safe item declaring it as safe, βi is the probability of unsafe item declaring it as unsafe in the inspection process and 1-βi is the probability of unsafe item declaring as unsafe in the inspection process (see equation 6). Further, if the inspection outcomes are known for inspection units in shipment, then, the probability of the item declaring it as safe ($r_{i,j}^{k}$) can be updated according to three different scenarios.

Scenario one, if the inspection unit (i,j) passes the inspection process, then actual contamination probability can be determined by equation 5.

$$r_{i,j}^{k} = \frac{(1-\alpha_i) r_{i,j}^{k}}{(1-\alpha_i)\, r_{i,j}^{k-1} + \beta_i\, (1-r_{i,j}^{k-1})} \qquad (5)$$

Scenario two, if the inspection unit fails the inspection process, then actual contamination probability can be given equation 6.

$$r_{i,j}^{k} = \frac{(\alpha_i r_{i,j}^{k-1}}{\alpha_i\, r_{i,j}^{k-1} + (1-\beta_i)(1-r_{i,j}^{k-1})} \qquad (6)$$

Scenario 3, if the unit is not inspected, then the actual contamination probability is calculated by using equation 7.

$$r_{i,j}^{k} = r_{i,j}^{k-1} \qquad (7)$$

$r_{i,j}^{k}$ is the probability of non defective item which can be helpful in calculating the information gain factor. But, for this research, we have used the safe probability (π) values obtained from the first two approaches due to data limitations.

Cost Model

The ideal traceability system is the system that could help in completely mitigating Type I and Type II errors problems during food supply. This type of traceability system is needed in food supply business to supply 100 percent pest and pathogen free food to US market. There are advanced traceability systems in market which can serve as ideal traceability system. However, due to high cost of implementation and skeptical about their economic benefits, retailers in food supply is not implementing these types of traceability systems into their supply chain systems. But, the benefits due to information gain from this system could outweigh the costs.

Among modern traceability systems, RFID equipped technology is gaining importance due to their wide range of benefits. In an attempt to known the economic use of RFID traceability implementation, this cost model is developed. This model is based upon the concept of Information gain developed by Verduzco etal, (2001). As a component of this study, the expansion of the model is used for the research purpose with some modifications.

To better explain the cost model and information gain strategy, a brief overview of the problem is given below. Due to increasing food recalls, food safety risk has become one of the prominent issues for food industries as well as for federal agencies. In an attempt to mitigate the food recalls, federal government has introduced new policies. These policies give FDA improved or extended authority to better mitigate the food safety risk FDA (2011). The major food risk can be of two types, seller risk or type I error that is when safe food produce is declared as unsafe and buyer risk or type II error that is when unsafe item is declared safe. In this model the key to reduction of risk is based on the information gain concept. The traceability system is useful only when the information gain about produce from farm to retailer is genuine or reliable to high extent so that it will reduce the probability of making risk. Because, any traceability system can provide information but it may not be reliable enough to reduce classification errors. Here, the information gain from the RFID traceability system is considered genuine and excepted to be helpful in the reduction of the risk. It is assumed that the benefits from this system can outweigh their cost of implementation. For this purpose, the cost model is developed to prove the assumption using hypothetical data. The cost model allows classifying the produce containers according to their risk levels. This makes easy for US border inspection department to make rational decisions regarding produce entry and further, helps in allocating resources productively.

The technical construction of the model can be illustrated in the following context using necessary terminology. The purpose is to measure the amount of the risk reduction and economic benefit of RFID traceability system over existing traceability systems. As mentioned above there are two types of errors in food supply business, i.e. Type I and Type II error. In order to measure the amount of these errors, the probabilities statistics parameters are used. The probability of type I error (Safe declaring as unsafe) is denoted by Greek letter α and the probability of the type II error is denoted by β and π is the non-defective probability of the produce containers and it is calculated using mahalanobis and probability theory statistics which are explained in previous section.

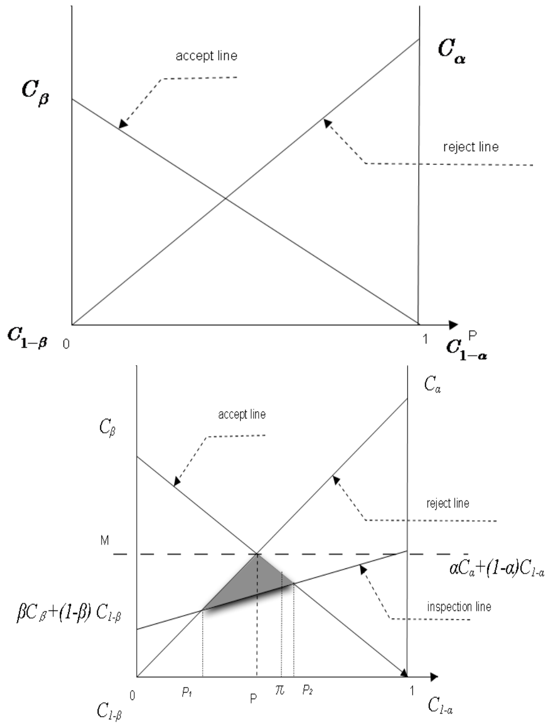

Figure 8a & b. Stochastic Optimization Cost Model

In Figure 8, the x-axis represents the safe probability mark. The y-axis represents the expected costs associated with different types of classification errors. C_{α}, C_{β}, $C_{1-\alpha}$, and $C_{1-\beta}$ represents the costs associated with seller risk, buyer risk and their not occurrence. The $C_{1-\alpha}$, and $C_{1-\beta}$ are negative costs because in actual sense they are benefits so here it is considered as zero cost. The line with its intersection point on Y axis at C_{β} and $C_{1-\alpha}$ on X axis is called as accept line. In similar way, the line defined by the points C_{α} and $C_{1-\beta}$ is called reject line and another line represented by the cost function $\beta C_{\beta} + (1-\beta)C_{1-\beta}$ and $\alpha\, C_{\alpha} + (1-\alpha)C_{1-\alpha}$ is called inspection line. The optimal information gain occurs at the point of intersection of accept line and reject line and the probability associated with it represented by the P on X axis. The intersection of the inspection line with acceptation line is represented by probability P_1 on X axis and at this level the non-defective probability is very low and it is unsafe to release the produce for entry into US. The intersection point of the inspection line with reject line is represented by the probability P_2 on X axis. The non-defective probability at this point is maximum and it is safe to release the produce with this probability. The shadow triangle is the information gain from traceability systems. The central theme of using the advanced traceability systems is to reduce triangle area (to reduce risk) by more information gain. The more is the information gain, lesser is the risk.

The reasoning behind the concept of cost functions of three lines in the cost model can be given as follows. In general the cost of buyer risk is the amount spent on medical costs when the product is recalled and cost associated with seller risk is amount loss due to product diversion or dumping. It is logical to see in figure 8 that the cost of buyer risk is maximum at zero non defective probability (rij) and decreases gradually along the X axis with the increase in the non defective probability. Because, as mentioned earlier, buyer risk occurs when product is declared as safe but it is actually not safe. If we declare an item as safe when its probability of actual safety is zero, then the costs associated with it (medical and recall costs) is also high. Hence, the $C\beta$ decreases when the product is declared safe at more actually safe probabilities (rij) due to reduction in food recalls and food contamination losses. The $C\beta$ will be minimum at the 100 percent actual safe probability of the item. In the same way, the $C\alpha$ is minimum at zero percent actual safe probability (rij) because, in this case the product is declared as unsafe when its actual safe probability is zero and gradually increases and becomes maximum at 100 percent actual safe probability (rij) (See figure 8). The diversion cost is high due to loss of the product, if the product is declared safe when it is actually 100 percent safe or at 100 percent rij value.

$$\pi = EVi - CEi$$

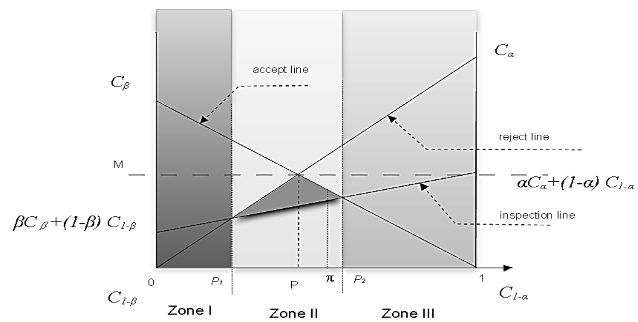

Figure 9: Zonal Classification of Cost Model

Further from figure 9, the product containers are classified into three zones. The zonal division is according to the level of risk associated with containers. The risk level can be determined based on the safe probabilities (π) calculated by the methods mentioned in first section. The product containers with safe probability below P1 (π> p1) comes under high risk zone, the products with safe probability between P1 and P2 (P1> π <P2) comes under moderate risk zone and the product containers with probability greater than P2 is categorized as low risk zone. This zonal division of produce containers approach has lot of advantages. It helps in sorting of the containers according to risk level. It makes efficient use of the inspections resources by concentrating more on high risk produce and gives more scope to reduce the classification errors or Type I and II errors (Nganje et al, 2010). The next step is to calculate the total cost

In this scenario, the approach to reduce the cost would be by decreasing the buyer risk and seller risk. i.e. by using smarter traceability systems. Every traceability system gives information which can aid in decreasing the risk but some are more efficient than other. To capture the difference between the benefits and cost associated with various traceability systems the stochastic optimization procedures would be meaningful to use in these situations.

Stochastic Optimization Model

In general, the multinational companies are not highly risk adverse compared to mid-sized firms. For example, firms like Wal-Mart have already implemented the RFID traceability system into their supply chain though it is has high implementation costs Grocer, (2004). Because, it has option to shift the risk to their shareholders and it is individually very less. The medium sized companies are more risk averse due to inability to hedge the risk. In this scenario, it is important to measure the risk averseness of the investors in mid-sized companies. One of the best approaches to known the risk averseness behavior could be estimating expected utility of wealth of firm.

According to Saha (1993), the expo power utility function is a good measure to calculate the expected utility of the wealth compared to other methods (like Arrow- Pratt). Here, this method is adopted because the stochastic simulated parameters can be effectively useful in maximum utility function calculation. In addition to this advantage, it provides the certainty equivalent info for the risk premium estimation. Here, the maximum utility of the risky investment is the utility of the wealth that is certain in any conditions. The expo power utility function can be given in the following equation.

$$Max\ EU(W) = E(\gamma - e^{(-\alpha NR^{\beta})}) \tag{8}$$

Where: EU is the maximum expected utility; W is the wealth of the mid-sized firm in food business; γ is a parameter determining the value of the function is positive; E is the expected value; e is the exponential function, γ , α and β are the parameters which depends on the absolute and relative risk aversion of the utility function and these parameters are fixed with values of 2, 0.01 and 0.5. NR is the net revenue function Saha etal, (1993).

In order to determine the risk premium of implementing modern traceability system, the total costs and certainty equivalent values are required. In this model the techniques used by Nganje, Na hu, Dahl, Wilson, Siaplay, & Lewis, (2006) are modified and adopted. The total cost depends on the medical costs due to product contamination, investment in new technology, inspection or testing costs and quality loss cost due to buyer risk and seller risk. It is estimated by aggregating the cost at each stage of food supply chain from farm to retailer. The equation for the total cost can be given by the equation 9.

$$C = \sum_{j=1}^{n} Ti\,.TCi.Si.Vi + QLi + TSC + MC \tag{9}$$

Here, i represents the stage of the supply chain; Ti represents tests or no test conditions and it is a binary variable; TCi is the per unit cost of testing; Si is the sampling intensity at stage i; Vi is the lot size at stage i; QLi is the total cost of seller risk that includes diversion costs; TSC represents the implementation costs of traceability system and MC represents medical cost (Buyer risk costs). Each variable in the total cost estimation is the result of the stochastic simulation. Finally, the risk premium of the investment in implementation of modern traceability is over the existing traceability system (called electronic barcode traceability system) and it is calculated by subtracting the expected value of the mid-sized company investment in modern technology from the certainty equivalent of the firm. Here, the expected value is nothing but the certainty equivalent obtained from investing in modern traceability system.

$$\pi = EVi - CEi \tag{10}$$

In equation 10, the π represents risk premium, i is the investment for a traceability system, EV is the expected value and CE is the certainty of a risky investment for particular traceability system implementation.

Data and Procedure

The temperature data are obtained from the private trucking companies. The temperature data represents the commodity temperature read during transportation and storage process. RFID logs are used to read the temperature (at particular set time intervals) of the commodity in transit and storage. The truck temperature data mainly consists of temperature, location, time variables with more than 3000 observations on an average. In most of the potato supply chain stages, the temperature in trailers are set at 34-36 °f, the temperature is set slightly lower than same range such that the potato pulp temperature can be in the specified range 40 to 50 °f and under immediately after pre cooling conditions, the temperature is set at 70 °f. It is assumed that these trucks represent the entire potatoes volume shipment trucks. As noted in methodology section, the probability of contamination can be calculated with the help of this temperature data using the mahalanobis and probability distribution fitting methodologies that were discussed in the methodology part. Apart from the probability calculations, the data can be used to plot the time and temperature graphs for the purpose of measuring the commodity shelf life.

As discussed in methodology section, the mahalanobis method aims at measuring the mahalanobis distance. In the first step, the mahalanobis distance of the original truck temperature data from the safe and unsafe population temperature data can be found and these distances can be used for contamination probability determination. It can be done using MATLAB 7.11.0 R2010b by assigning and coding functions to truck temperature data (Math Work Corporation, 2010) and MS Office Excel 2010 can be used to conduct filtering and other data analysis functions.

Whereas in the probability distribution model, the contamination probability of the commodity can be found using @risk functions, the best fit distribution is used for probability calculations. The probability of contamination at 5% and 95% confidence interval can be used to define safe and unsafe probability of the commodity in truck (Palisade Corporation, 2010).

The data for cost models and stochastic optimization models are collected from different U.S. government data open sources websites and the data for unknown variables or parameters are found by running simulation models and optimization functions.

The shipment volume of the commodity of medium sized firm is assumed to be equal to the size of the domestic shipments of Idaho State in USA. The shipment volume from 2005 to 2011 of the modeled commodity was collected from USDA, www.AMS.USDA.com market news portal. Producer price and retail price details from 2004 to 2010 were collected from USDA`S NASS, U.S. Department of labor`s and Bureau of labor statistics seasonal data base.

The container compartment is assumed to be delivering 40,000 lbs per shipment across U.S.-Mexico Border. The quality loss cost is calculated by multiplying the diversion costs and potato volume diverted. The diversion cost is the expenses associated with cleaning and disposal of the product rejected during inspections (Nganje et al., 2007). The disposal costs are calculated by adding 6.5 percent to the commodity price and a cleaning cost is calculated by adding 25 percent to the price of the impacted produce.

Since the testing costs, test accuracies, and medical costs are uncertain, it is represented by the specific probability distribution curves. Cost of testing can be given by triangular distribution with a minimum $15/ test, most likely of $25/test and maximum cost of $35/test (Mostrum, 2005; Nganje et al., 2007). Test accuracies are assumed to be uniform distribution ranging between 0.9 to 1 and 0.8 to 0.85 for RFID and barcode traceability systems. Medical costs for RFID traceability system is assumed to zero because it triggers faster traceability of contamination source and avoid buyer risk by reducing product recalls time.

The cost of implementing the RFID system (passive tags) for members with shipment volume more than one million pounds have fixed cost of $21,168,106 and Variable costs of 87,450,419 and the costs of implementing barcode traceability system for members with shipment volume more than one million pounds have fixed costs of $1,393,258 and variable cost of 1,585,133. The RFID and Barcode system costs in the model are calculated by adding the fixed costs and variables cost for five year period since the traceability system takes five years to depreciate once implemented (Nganje, Skeleton, Robinson and etal.,). For modeling purpose, the costs of traceability system calculation is simplified into cost per unit volume and represented by triangular distribution.

For actual contamination probability evaluation, the reliability and accuracy parameter of respective traceability system are considered in the probability method calculations. Therefore, the contamination probability can provide nearly accurate values. These probability values are used to calculate the buyer risk and seller risk in the stochastic optimization model.

The stochastic optimization model is optimized using RISK Optimizer applications. For this process, the model values are set to be simulated in a time frame of 45minutes and every simulation iterates 5000 times. For the utility, and risk premium calculations of RFID traceability system, the Microsoft Excel 2007 is used.

The Stochastic optimization model procedure can be summarized as follows, the first step is to calculate the contamination probabilities of the commodity. These probability values are used to calculate the buyer and seller risk in cost model. In turn the risk values can be helpful in determination of cost parameter for the company. Therefore, the cost parameters are optimized to find the expected utility, certainty equivalent and risk premium values of each traceability system.

Chapter 4

RESULTS AND DISCUSSION

Contamination probability and market risks

As discussed in the chapter III, the probability distribution fitting and mahalanobis method is used to calculate the contamination probabilities at various stages of supply chain. The results obtained from the analysis are presented below.

It is considered that the potato in the containers and at warehouse stages of the supply chain has good chance of spoilage, if and only if the resultant values of temperature data distributions are not accepting the standardized parameter values. The threshold variance is 4.5, the threshold standard deviation is 10.5, temperature range is 36-53 ° f, 15 and 22 hours of exposure of produce to abnormally high and low temperatures. The threshold values related to probability distribution statistics are obtained by applying the simulation models to reference safe and unsafe journey based temperature data.

Table 2. *Probability distribution fitting method results obtained by analyzing the potato temperature data from commodity containers during its transit from farm to packing house*

@risk results	Probability Fitting Method			
Variables	Container 1	Container 2	Container 3	Container 4
Distribution Stats	Normal	Beta	lognormal	Lognormal
K-S value	0.250	0.246	0.099	0.070
Probability	97.6	91	97.9	90
P value	0.004	< 0.01	0	0
Variance	1.809945	3.363	2.106537	1.94
Stand Dev	3.2759	11.3117	4.4375	3.768
Max	50.1	76.4	72.6	77.4
Min	35.5	32.5	33.0653	34.7869
Mean	37.6119	44.507	36.8784	36.6391
5 percent	32.2236	26.1441	33.6078	34.8866
95 percent	43.0002	62.8699	44.4511	41.4885

The probability distribution fitting method mentioned in the chapter III was conducted for temperature data obtained from RFID logs installed in different potato carrying containers. Table 2 shows probability distribution results of each potato container at farm to packing house stage. The container temperature data took a particular distribution based on best fit distributions test for continuous random variables known as K-S test. The container one, container two data took normal and beta distributions whereas container three and four data can be defined by the lognormal probability distribution. From table 1 results, it can be declared that on an average the safe probability of potato in the containers during farm to packing house stage is 94.12, the average mean temperature maintained in the potato containers is 38.9. The results show that variance and standard deviation are within the threshold range mentioned in the Chapter IV except for container two. Further, the values at 95 percent and 5 percent confidence interval for all the containers is within the desired safe temperature range i.e. 36 to 53 ˚f except for the container two that predicts 95 percent of chance the produce is maintained at 26.14 °f and only 5 percent chance that it is maintained at 62.86 °f. The results obtained are significant because the p value is <0.05 for cases.

Table 3

Probability distribution fitting method results obtained by analyzing the potato temperature data from commodity container during its transit from packinghouse to warehouse

@risk results	Probability Fitting Method			
Variables	Container 1	Container 2	Container 3	Container 4
Distribution Stats	LogNormal	Logistic	ExtVal	Lognormal
K-S value	0.1858	0.1803	0.3684	0.2201
Probability	98.8	97.8	96	99.1
P value	0	< 0.01	< 0.01	0
Variance	0.650231	1.377897	1.28	1.151086
Stand Deviation	0.4228	1.8986	1.6447	1.325
Max	45.8	69	70	68.3
Min	35.4	31.9	31.85	34.786
Mean	36.0462	36.0854	34.9473	35.4947
5 percent	35.5675	33.6067	32.8001	34.8305
95 percent	36.783	39.6277	38.0161	37.297

Table 3 indicates the probability statistics of containers at packing to warehouse stage of supply chain. According to best fit test the temperature data of container one and container four has lognormal distribution where as the container 2 and containers 3 has logistic and Extval distribution. The results of all container data are significant because the p-value is <0.05. From the results the average safe probability of containers is 97.9. The minimum and maximum variance of all the containers combined is 0.65 and 1.151 which are below the threshold variance. The minimum and maximum mean temperatures for all the containers combined are 35.4 and 36.04 that is within the desired temperature range. Further, the values at 95 percent and 5 percent confidence interval for all the containers are also within the desired safe temperature range.

Table 4

Probability distribution fitting method results obtained by analyzing the potato RFID data for the commodity during its storage in the warehouse

@risk results	Probability Fitting Method		
Variables	Warehouse 1	Warehouse 2	Warehouse 3
Distri Stats	LogNormal	Normal	Logistic
K-S value	0.1251	0.2942	0.2104
Probability	92.3	100	95.7
P value	0	< 0.01	< 0.01
Variance	1.299769	1.457292	2.14
Stand Dev	1.6894	2.1237	4.5796
Max	41.3	42.9	74.5
Min	35.4	-Infinity	46.5
Mean	36.5009	36.1046	66.763
5 perc	35.4429	32.6115	59.3286
95 perc	39.1544	39.5977	74.1973

Table 4 indicates the probability statistics of potato produce from various containers in the warehouse stage of supply chain. According to K-S best fit distribution test the temperature data of warehouse one, two, and three has lognormal, normal and logistic distribution. The results of all container data are significant because the p-value is <0.05. From the results the average safe probability of containers is 97.9. The minimum and maximum variance of all the containers combined is 1.299 and 2.14 which are below the threshold variance. The minimum and maximum mean temperatures for all the containers combined are 36.104 and 36.50 that is within the desired temperature range except for the warehouse three produce which is 66.7, but it agrees with temperature range for pre cooled products as discussed in chapter IV. Further, the values at 95 percent and 5 percent confidence interval for all the containers are also within the desired safe temperature range i.e. 36 to 53 °f except for the potato produce in warehouse three.

Table 5

Probability distribution fitting method results obtained by analyzing the potato temperature data of commodity containers during its transit from warehouse to retail

	@risk results		Probability Fitting Method		
Variables	Container 1	Container 2	Container 3	Container 4	Container 5
Distri Stats	Lognormal	Logistic	Pearson	Log logistic	Normal
K-S value	0.3139	0.2938	0.2437	0.2227	0.3056
Probability	97.5	97.7	97.8	99.6	97
P value	0	< 0.01	0	0	<0.01
Variance	1.824034	1.005932		0.872067	2.209
Stand Dev	3.3271	1.0119	1.1112	0.7605	4.882
Max	45.8	46.5	56.1	42.5	83.7
Min	35.8	33.4	34.5888	34.7744	39.2
Mean	38.7282	35.1065	35.2369	35.1117	41.91
5 perc	35.4037	33.4639	34.7135	34.833	33.88
95 perc	45.1549	36.7492	36.2765	35.6759	47.21

Table 5 indicates the probability statistics of potato produce from various containers during warehouse to retail stage of supply chain but for containers 5 the results are for farm to retail stage. According to K-S best fit distribution test the temperature data of container one, two, three four and five has Lognormal, Logistic, Pearson, Log logistic and Normal distribution. The results of all container data are significant because the p-value is <0.05. From the results the average safe probability of containers is 97.8.The minimum and maximum variance of all the containers combined is 0.7605 and 3.3271 which are below the threshold variance except for container 5 which is 4.882. The container 5 high variance is due to conducting analysis for all stages at a time because of absence of location specific data. The minimum and maximum mean temperatures for all the containers combined are 36.104 and 36.50 that is within the desired temperature range except for the warehouse three produce that is 66.7, but it agrees with temperature range for pre cooled products as discussed in chapter IV. Further, the values at 95 percent and 5 percent confidence interval for all the containers are also within the desired safe temperature range i.e. 36 to 53 ° f.

Table 6

Comparison of contamination probabilities of Probability distribution fitting and Mahalonibis method during different stages of commodity supply chain

Supply Chain	Probability Fitting Method		Mahalanobis Method			
Stage	Safe	Unsafe	Safe	Unsafe	Safe	Unsafe
Farm to PackingHouse	0.95	0.05	0.92	0.08	0.93	0.06
PackingHouse to WareHouse	0.98	0.02	0.86	0.14	0.91	0.08
Ware House	0.96	0.04	0.91	0.09	0.93	0.06
Ware House to Retail	0.98	0.02	0.92	0.08	0.94	0.05

The probability distribution fitting and mahalanobis method discussed in chapter III were conducted for potato temperature data. The table 6 shows the comparison between mahalanobis and probability distribution fitting method. The overall safe and probability of contamination estimates by probability distribution fitting method at different stages of supply chain like farm, packing house to warehouse, warehouse, and warehouse to retail are given as (0.95, 0.05), (0.98 0.02), (0.96, 0.04), and (0.98,0.02). Whereas, the probability estimates obtained through mahalanobis method at different stages in sequence are (0.94, 0.06), (0.97, 0.08), (0.94, 0.06), and (0.95, 0.05) (see appendix for m-distance values). The slight differences are observed between the probability estimates of probability distribution fitting method and mahalanobis distance method obtained from analysis of same temperature data. To increase the accuracy of probability calculation the average of two methods is considered for cost model estimation.

Table 7

Safe and Unsafe probability values for different traceability systems along potato supply chain stages

Supply Chain	RFID Probabilities		Barcode Probabilities	
Stage	Safe	Unsafe	Safe	Unsafe
Farm	0.998	0.002	0.995	0.005
Farm to Packinghouse	0.998	0.002	0.991	0.009
Packinghouse	0.999	0.001	0.996	0.004
Packinghouse to warehouse	0.993	0.007	0.975	0.025
Warehouse	0.996	0.004	0.982	0.018
Warehouse to Retail	0.997	0.003	0.989	0.011
Retail	0.999	0.001	0.995	0.005

The table 7 shows the results of the safe and unsafe probabilities at different stages of supply chain for two traceability systems. The probabilities are estimated using the methods discussed in the chapter IV. The safe and unsafe probabilities for RFID traceability system at farm , farm to packing house, packing house, packinghouse, packing house to warehouse, warehouse, warehouse to retail, retail are (0.998, 0.002), (0.998, 0.002), (0.999, 0.001), (0.993, 0.001), (0.993, 0.007), (0.996, 0.004), (0.997, 0.003), (0.999, 0.001). In the same sequence the safe and unsafe probabilities for the barcode system are given as (0.995, 0.005), (0.991, 0.009), (0.996, 0.004), (0.975, 0.025), (0.982, 0.018), (0.989, 0.011), (0.995, 0.005).

Time Vs Temperature Results

As discussed in chapter III, the Time Vs Temperature graphs are plotted by using the temperature data and they are plotted for each stage of supply chain. Here, set point temperature is the temperature set by the supply chain specialists during potato supply chain to avoid spoilage and commodity temperature is the actual temperature of the commodity during transit and ware house stage of supply chain.

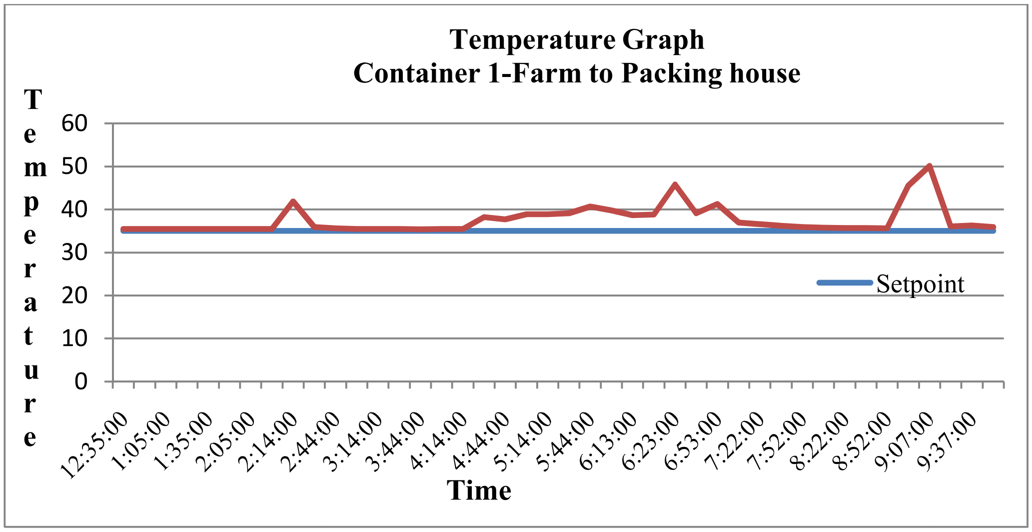

Figure 10

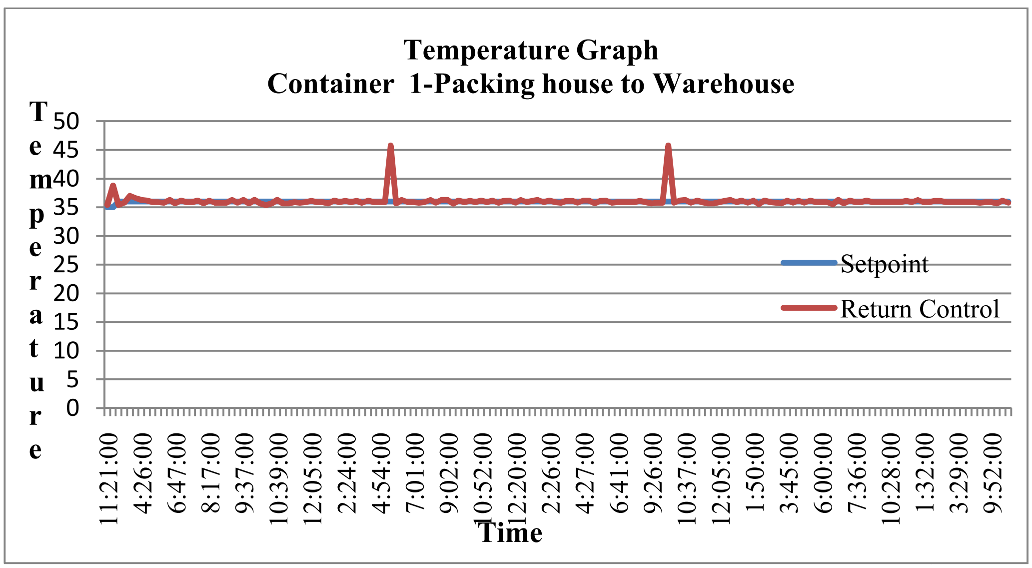

Figure 11

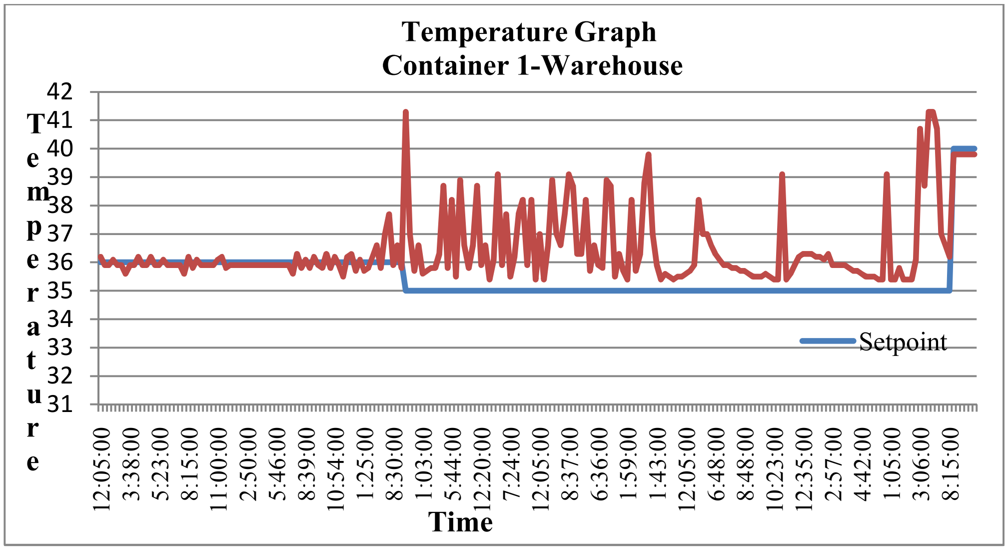

Figure 12

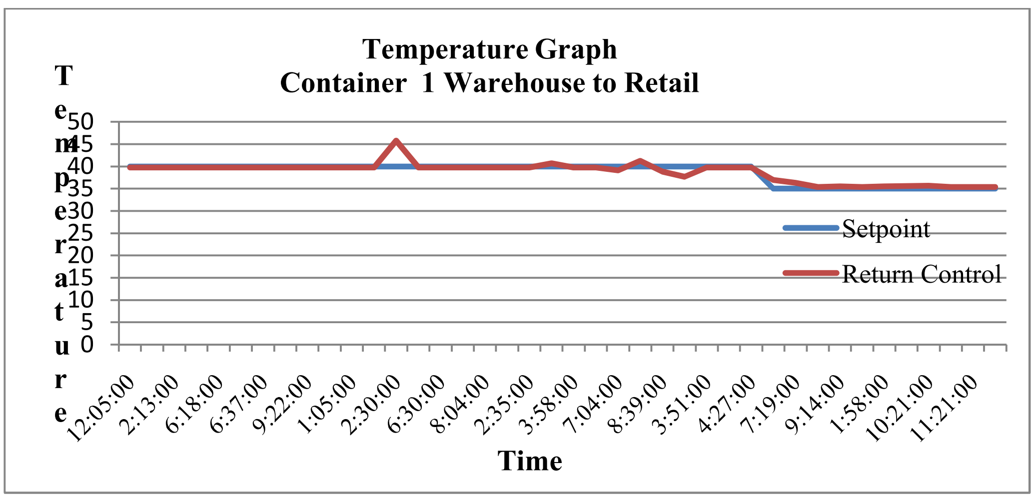

Figure 13

Figure 10-13. Container 1 temperature graphs

The figure 10, figure 11, figure 12, and figure 13 shows that the temperature graphs for the container 1 potato produce during different stages of supply chain that is farm, farm to packing house, warehouse, and warehouse to retail. The intuition behind these graphs can be summarized as follows. The maximum spike in the temperature that is reached during the container supply chain is 50 ° F and the lowest spike in temperature during container 1 supply chain is at 35 ° f and most of the time temperature line overlaps with the set point temperature line. These graphs predict that the potato produce container 1 maintained USDA specified temperature range through its supply chain, in order to avoid risk of spoilage.

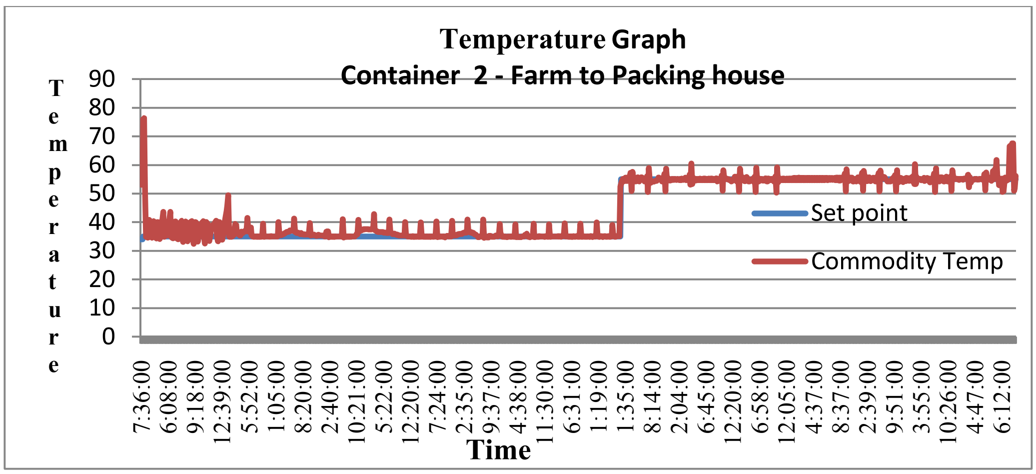

Figure 14

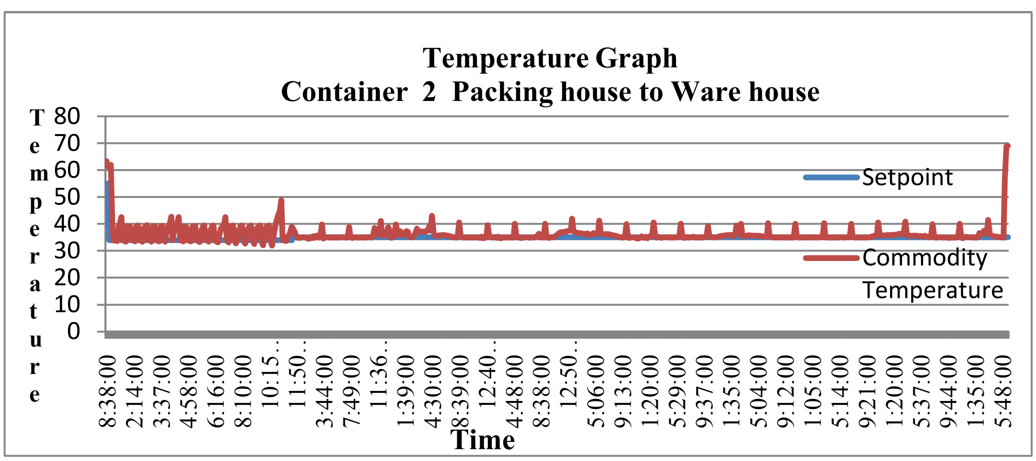

Figure 15

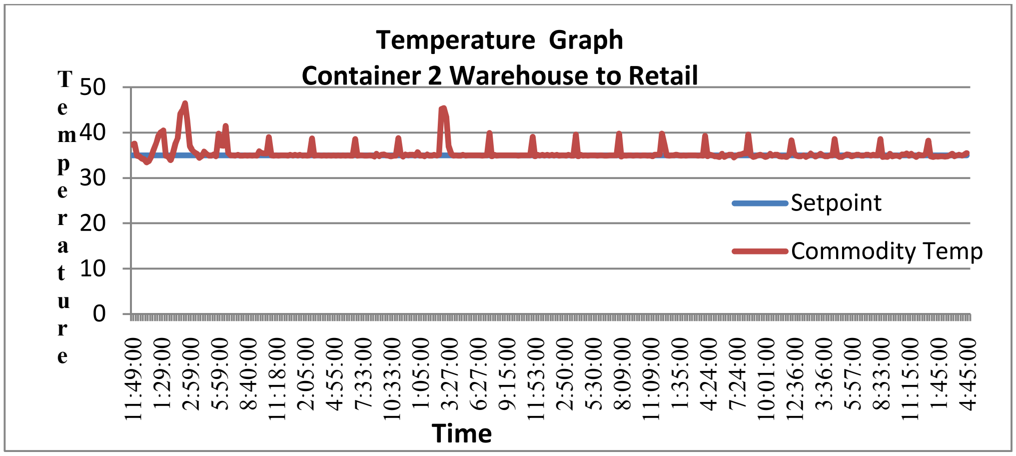

Figure 16

Figure 14-16. Container 2 temperature graphs

The Figure 14, Figure 15, and Figure 16 shows the temperature graphs for the container 2 potato produce during different stages of supply chain that is farm, farm to packing house, and warehouse to retail. The intuition behind these graphs can be summarized as follows. The maximum spike in the temperature during the container supply chain is 75 ° F (see fig 5) whereas the lowest spike in temperature is 32 ° f (see fig 5) and there are range of high temperature spikes in graphs that is due to opening of the door for technical corrections like alarm check, to check the defrost temperatures etc. It can be said that the potato is maintained at good temperature because the produce is not subjected to abnormal temperatures and most of the spikes in the temperature are within the USDA specified range.

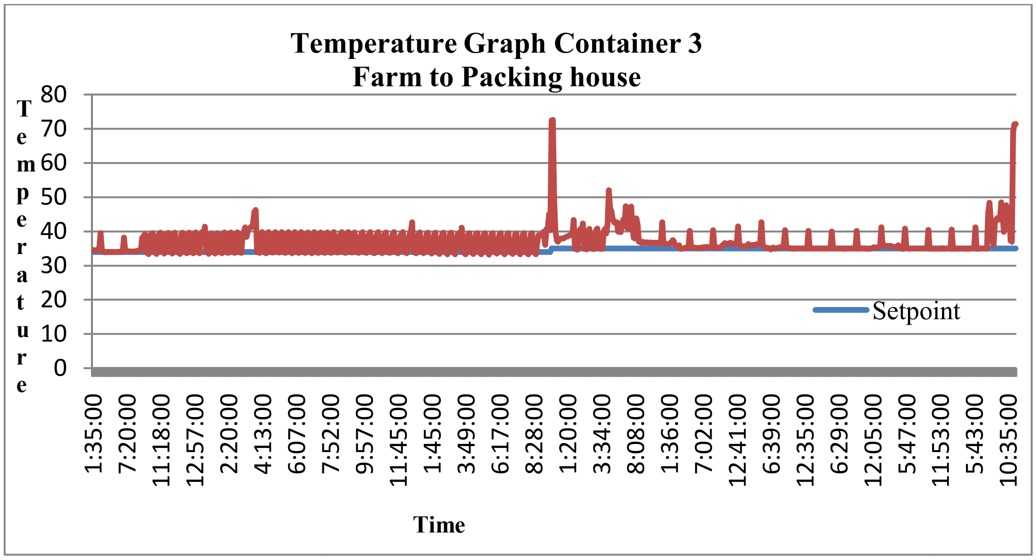

Figure 17

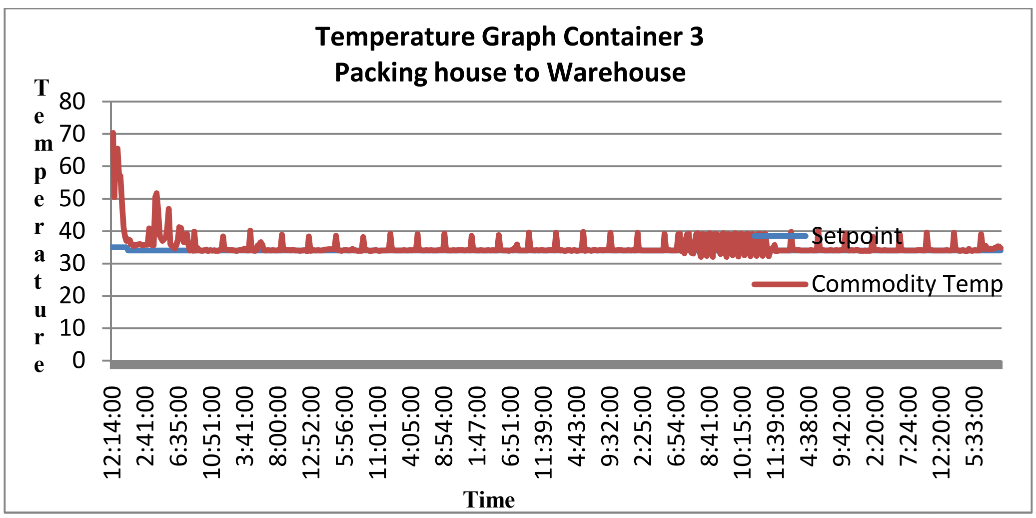

Figure 18

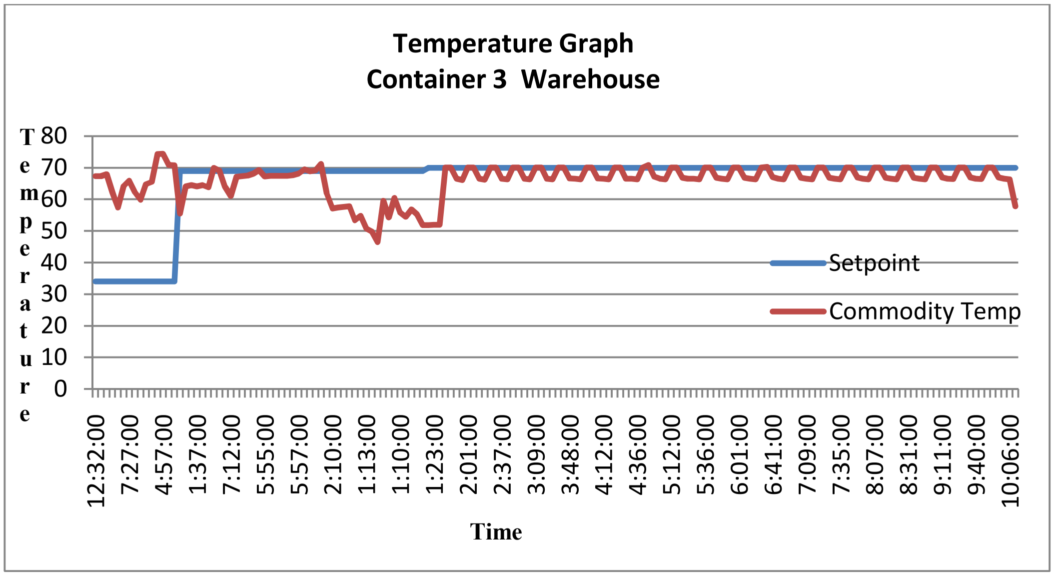

Figure 19

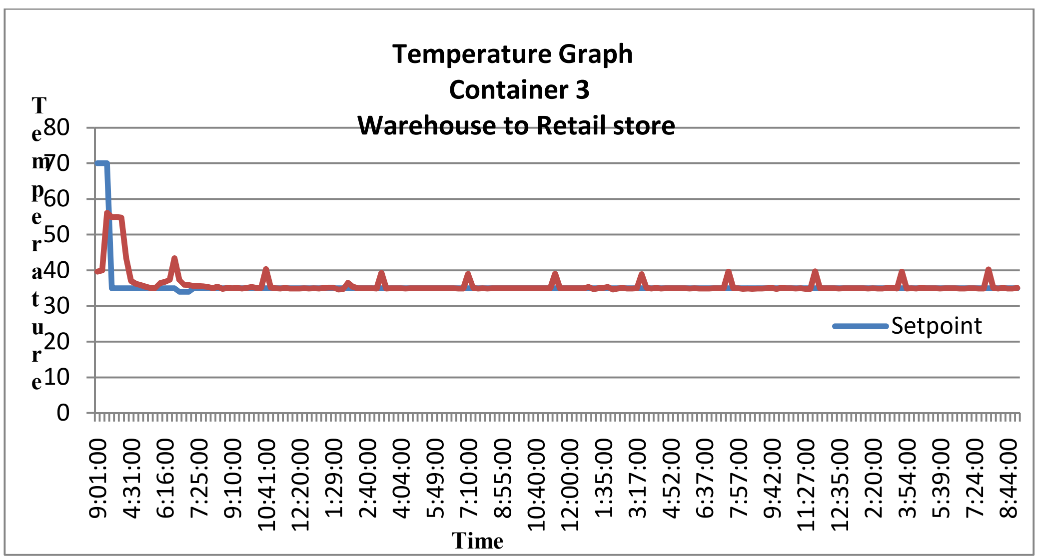

Figure 20

Figure 17-20. Container 3 temperature graphs

Figure 17, 18, 19, and 20 shows the temperature graphs for the container 3 potato produce during different stages of supply chain that is farm, farm to packing house, warehouse and warehouse to retail. The intuition behind these graphs can be summarized as follows. In the farm to packing house graphs (fig 8) the maximum spike in the temperature is 70 ° F whereas the lowest spike in temperature is 30 ° f and there are small temperature spike along the time line but they are within the threshold temperature range. In the same way, the graph (fig 9) for packing house to warehouse represents the maximum temperature of 70 °f and a minimum of 31° f. The graph for warehouse stage represents the exceptionally maintained at high temperature because the potato product is precooled. Hence, the temperature is set deliberately high to avoid freezing of the produce and the temperature graph (fig 11) at last stage of the supply chain i.e. warehouse to retail has maximum temperature of 70 °f and a minimum of 32 °f and it commodity temperature line moves parallel with temperature line. It can be said that the potato is maintained at good temperature because the produce is not subjected to abnormal temperatures and most of the spikes in the temperature are within the USDA specified range.

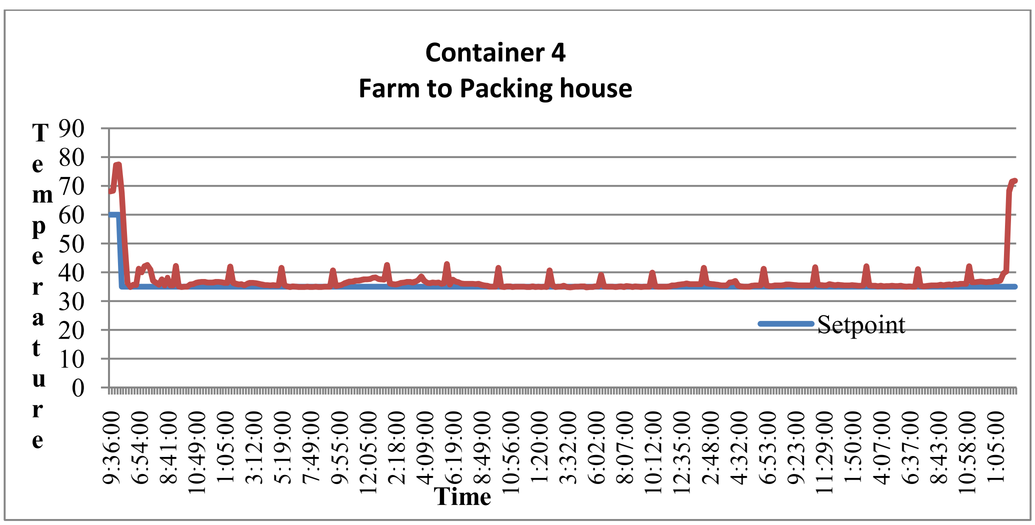

Figure 21

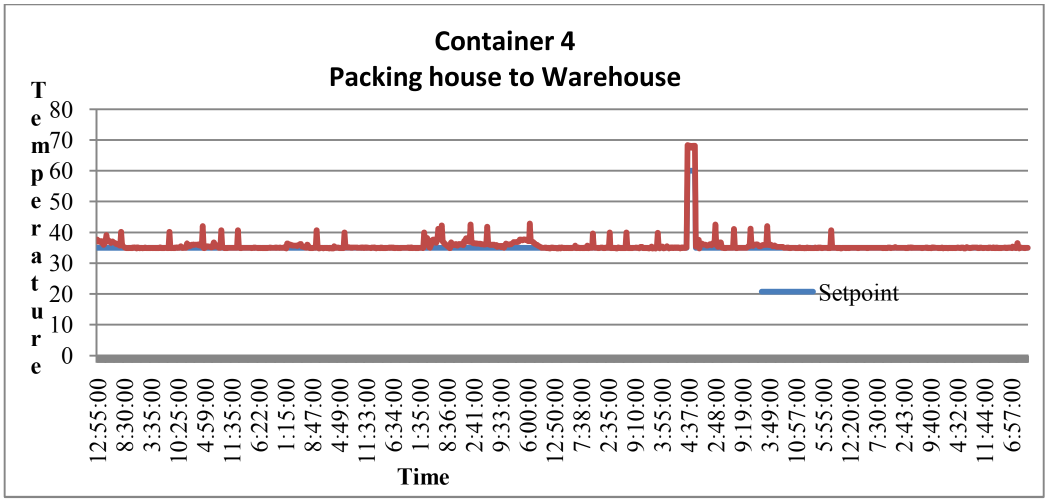

Figure 22

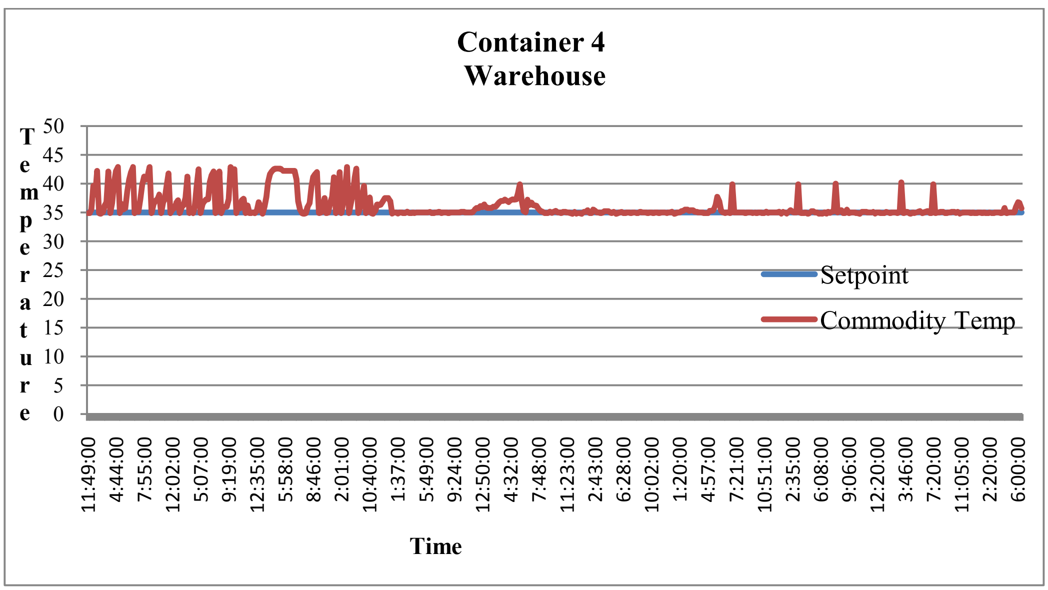

Figure 23

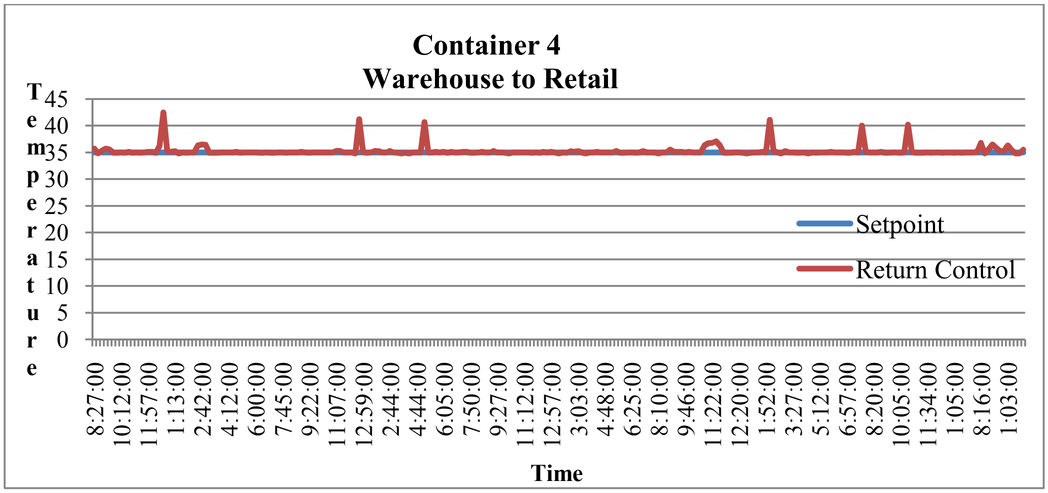

Figure 24

Figure 21-24 Container 4 temperature graphs.

The Figure 21, 22, 23 and 24 shows the temperature graphs for the container 4 of the potato produce during different stages of supply chain, that is farm, farm to packing house, warehouse and warehouse to retail. The intuition behind these graphs can be summarized as follows. In the farm to packing house graphs (fig 12) the maximum spike in the temperature is at 75 ° F whereas the lowest spike in temperature is 34 ° f and there are small temperature spike along the time line but they are within the threshold temperature range. In the same way, the graph (fig 13) for packing house to warehouse represents the maximum temperature of 65 °f and a minimum of 34° f. The graph for warehouse stage and warehouse to retail stage (fig 14 & 15) also within USDA specified range i.e. 35-55 without much variation. The commodity temperature line moves parallel with temperature line. It can be said that the potato is maintained at good temperature because the produce is not subjected to excessive hours of abnormal temperatures and most of the spikes in the temperature are within the USDA specified range.

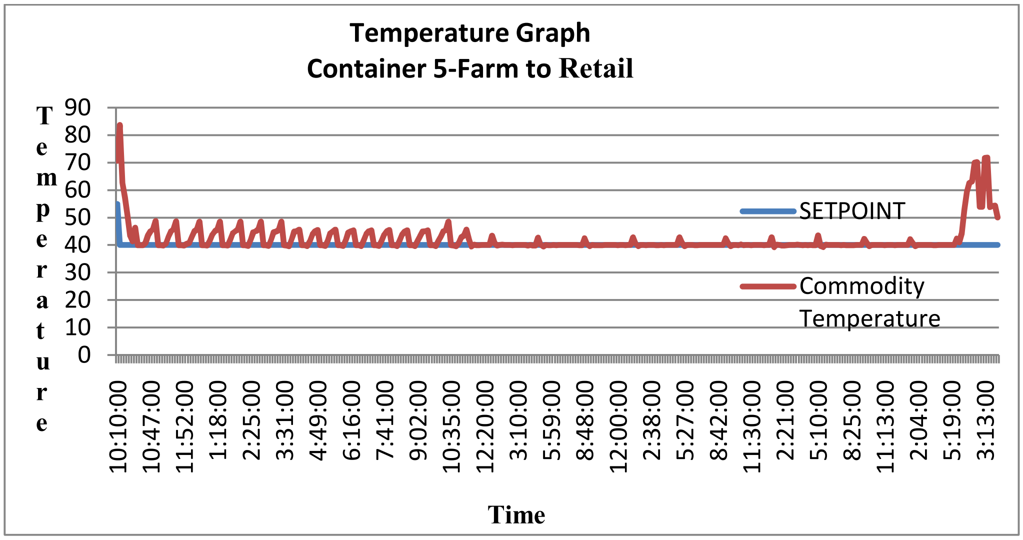

Figure 25. Container 5 temperature graph

The Figure 25 shows the temperature graphs for the container 5 potato produce during different stages of supply chain that is farm, farm to packing house, warehouse, and warehouse to retail. From the graph, it can be said that initial temperature of the produce went up to 80 °f but only lasted for few hours and temperature of produce is almost consistent with set point temperature during its entire supply chain process. Again the high temperature spikes are observed for 4 hours (approximately) during final stage of supply chain. If we recall from the table 4 probability statistics results, the possible reason for the high variance in the probability statistics can be related to the high temperature spikes in the temperature during supply chain. Though, the produce subjected to abnormal temperatures, the produce is considered to be safe because it has subjected to high temperature only for few hours.

Stochastic optimization results

Table 8

Comparison for RFID and Barcode traceability system for potato cost model

Variables	Potato Cost Model	
	Barcode	RFID
Utility	1.1462	1.1462
% Sample (trucks)	1%	1%
Buyer risk	0.0921	0.0524
Seller risk	0	0
Volume Diversted (lbs)	0	0
Cost of testing ($/lb)	0.00062	0.00063
Cost of traceability system ($/lb)	0.024	0.042
Medical Cost ($/lb)	0.077	0
Cost of quality loss ($/lb)	0.0116	0.0092
Total cost ($/lb)	0.1147	0.0616
Certainty Equivalent	0.1147	0.0616
Risk Premium	0.0531	

Table 8 indicates the results of comparisons between RFID technology traceability system and barcode traceability system variables for potato stochastic optimization model.

In the potato cost model (see table8), the estimated buyer risk for Barcode traceability system is 0.00921 while for RFID traceability system is 0.0524 while seller risk for Barcode as well as RFID traceability system is 0. The cost of implementation of Barcode, medical costs and quality costs are $0.024/lb, 0.077, and 0.0116, respectively, resulting in a total cost of $0.1147/lb. The certainty equivalent is 0.1147, when the company implements barcode system in their supply chain. Whereas, the cost of implementation of RFID, medical costs and quality costs are $0.042/lb, 0, and 0.0092, respectively, resulting in a total cost of $0.0616/lb and the certainity equivalent is 0.0616.

Further, the intuition behind results can be drawn as follows, even though, the cost of implementation of RFID system is higher compared to Barcode system. The risk premium of 0.0531 is obtained by investing in RFID traceability system over the barcode traceability system. The risk premium is due to reduction in medical costs, buyer risk and quality costs by implementing RFID over traceability system.

Chapter 5

SUMMARY

In these days, the food recalls in the fruit and vegetable business sector appear to be a frequent phenomenon. In spite of the several efforts to reduce recall rate by the firms in international and domestic food business, they still fail to mitigate the food safety risk in the supply chain. The risk in food trade business is high because of the perishable nature of fruits and vegetables, and other issues related to food terrorism. This risk is expected to increase in the upcoming years if the firms continue to lack behind in taking preventive measures to avoid market failure risk.

In an effort to reduce the recall rate and to supply safe food to U.S. food consumers, the FDA has revised their food recall policies. In recent past, the Law called Food Safety Modernization Act was introduced which gives improved authority to FDA to recall the food products of industry. These government measures mainly imply the food businesses to have efficient traceability systems in their supply chain in order to avoid food safety risk.

Out of many reasons, the prominent reason for the food safety risk is due to inefficient traceability system in the food supply chain system. In order to prevent food safety risk and increase the traceability of the food during its supply chain. The modern traceability systems equipped with good tracking systems and which could provide increased visibility into food supply chain could be helpful to mitigate the food safety risk. Of such traceability systems, the RFID technology equipped traceability system would be efficient one to prevent recalls and increase faster recall rates. The large scale industries in food retail businesses like Wal-mart have already taken measures to adopted RFID technology. Whereas, it is difficult for the medium scale food industries to implement this type of technology because of low margins on fruit and vegetables products and its high implementation costs. In order for them to implement RFID technology traceability system, the evidence of risk reduction plus costs and benefits occurred due to the implementation of RFID traceability in the food supply chain is needed.

The procedures adopted in the research helps medium scale food business and inspection services to effectively measure the buyer and seller risk in food supply chain. This probability distribution fitting and mahalonibis model approach helps in estimating the nearest possible values of contamination probability of commodity which in turn helps in buyer and seller risk estimation.

The stochastic optimization model helps in calculation of the uncertain costs and benefits associated with implementation of different traceability systems. The Stochastic optimization model evaluates risk premium for implementing RFID traceability system over barcodes traceability system. From the Table 7 results, it is evident that the certainty equivalent by implementing RFID traceability system is less than the Barcode traceability system. Therefore, there is a positive risk premium in investing RFID traceability over other Barcode traceability system.

As a recommendation to firms in food industry, the probability based models and the stochastic optimization model for cost benefit analysis could be adopted to estimate the market failure risks (buyer or seller) and risk premium of their investment in electronic traceability system. This research helps policy makers and food safety government agencies by encouraging the firms in food business to implement RFID technology. Hence, the research provides complete frame of work models for medium scale firms to better understand various types of risk, and measures to mitigate food safety risk.

Research Implications

As mentioned in the introduction, the models developed in this research are useful in estimating the market failure risk (type I & type II error) using the time, temperature and location data. Reducing the Type I and Type II error simultaneously using the models developed in the research could improve food supply chain market efficiencies.

To further improve the accuracy in market failure risk estimations, the information about other commodity quality parameters of the product like relative humidity, microbial content, moisture content etc could be added to these probability models. The probability models (to estimate the market failure risks) discussed in the chapter 3 are also applicable for other quality parameters data like relative humidity, moisture content etc.

Further, the research can be extended in the three areas of study. They are, the inspection resource allocation, commodity shelf life improvement, and introducing the Bayesian conditional probability concepts for risk estimation. As mentioned in the chapter 3, the zonal classifications methods (classification of commodity into three zones based on their safe probability) could be used to allocate the limited inspection resources efficiently. The combination of current research models and Bayesian probability methods could help in improving the reliability of market failure risk estimation.

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APPENDIX A

SIGNIFICANT FRUIT AND VEGETABLES PRODUCTS RECALLS

Table A1

Fruit and Vegetables product recalls

Significant Fruit and Vegetable Outbreaks in Recent Years		
Year	Product	Pathogen
2011	Turkish Pine Nuts	Salmonella Enteriditis
	Jensen Farms Cantalopes	Listeria monocytogenes
	Whole, Fresh Imported Papayas	Salmonella Agona
	Alfalfa and spicy sprouts	Salmonella Enteriditis
	Del Monte Cantoloupe	Salmonella Panama
	Hazelnuts	Eschericha coli O157:H7
2010	Alfalfa sprouts	Salmonella
	Frozen Mamey Fruit Pulp	Salmonella Chester
	Shredded Romaine Lettuce from a single Processing Facility	Eschericha coli O145
2009	Alfalfa sprouts	Salmonella Saintpaul
	Peanut Butter	Salmonella Typhimurium
	Pistachios	Salmonella
2008	Raw Produce	Salmonella Saintpaul
	Malt-O-Meal Rice/ Wheat Cereals	Salmonella Agona
	Cantaloupes	Salmonella
2007	Veggie Booty	Salmonella Wandsworth
	Peanut Butter	Salmonella
2006	Tomatoes	Salmonella Typhimurium
	Fresh spinach	Escherichia coli O157:H7

APPENDIX B

MAHALANOBIS DISTANCE CALCULATION RESULTS

Mahal Probabilities	
Safe	Unsafe
0.92	0.08
0.86	0.0226
0.91	0.04
0.92	0.0208

BIOGRAPHICAL SKETCH

Deepak Kumar Janke is an international student from India. He received his Bacherlor`s degree in Agriculture from Acharya N.G.Ranga Agricultural University, Hyderabad in 2004. In Fall 2009, he entered the Morrison School of Agribusiness and Resource Management to pursue his Master`s in Agribusiness. He worked as a Graduate Research Assistant and professional assistant during Master`s program. He has helped in development of annual reports for various projects like NFAPP, Ag Mediation Program etc. He is a certified Ag mediation trainer in Arizona.