A QUANTITATIVE COST MODEL OF HACCP IMPLEMENTATION

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ABSTRACT

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Foodborne illness is an important public health problem in the United States. Hazard Analysis Critical Control Point (HACCP) is widely acknowledged as an effective method to ensure product quality and control foodborne hazards. Existing literature considers the economic aspects of implementing a HACCP plan and identifies the major cost items for specific firms but stops short of providing a model to quantitatively analyze the cost of HACCP implementation over a variety of firms. This research used the case study method to refine the Prevention-Appraisal-Failure (PAF) model to identify potential costs associated with the implementation of HACCP plans and develop a cost estimation model for calculating total cost. The model was refined based on the process of applying it to two North Dakota food processing plants.

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CHAPTER 1. INTRODUCTION

Food safety has long been an important issue in the United States, and consumer awareness of food quality and safety is increasing. A contributing factor is greater public awareness of foodborne diseases caused by a variety of microbes such as bacteria, fungi, viruses, and parasites. The U.S. Centers for Disease Control and Prevention (CDC) estimated that more than 48 million cases of foodborne illness occur annually in the United States, resulting in 128,000 hospitalizations and 3,000 deaths (2010). And, the number of outbreaks reported represents just a small proportion of outbreaks that actually occur. Some outbreaks are never recognized, and those that are recognized frequently go unreported (CDC, 2006). For reducing the frequency of foodborne disease outbreaks, the U.S. federal government enacted many food laws and regulations, such as the *Federal Meat Inspection Act,* the *Food Quality Protection Act,* and the *Federal Food Drug and Cosmetic Act,* to establish inspection requirements of food products, set quality standards for food processors, and ensure food safety.

Most cases of foodborne illness are caused by consuming foods which contain pathogenic microorganisms. Arduser and Brown (2005, p.184) indicated that "meats and dairy products are most likely to be implicated in a foodborne illness outbreak". The potential for foodborne illness from consuming meats and dairy products is a concern for American consumers. A typical American consumes 195 pounds of red meat, 593 pounds of dairy product and 199.9 pounds of grain product annually (Economic Research Service, U.S. Department of Agriculture, 2000).

North Dakota processes major foods including bread, potato products, oils, dairy products, cheese, and meat products. North Dakota leads all other states in the production of barley and sunflower seed, and is among the leading states in the production wheat, oats, rye and soybeans.

Several studies have demonstrated the high cost to society of foodborne illness in developed countries, including the United States (Wittenberger and Dohlman, 2009) and Australia (Fleet et al., 2000). According to Scharff (2010), the annual cost of the health burden of foodborne illnesses in the United States is about $152 billion, which includes the costs of medical bills, lost wages and lost productivity. Clearly, there are economic benefits to be gained by improving the safety of food to reduce foodborne illness.

Some dangerous bacteria that are responsible for foodborne diseases are present in foods due to improper processing at the plant. Many food processors have implemented HACCP to control their food hazards. The National Advisory Committee on Microbiological Criteria for Foods "endorsed HACCP as an effective and rational means of assuring food safety from harvest to consumption, and provided different food industries with HACCP application guidelines and recommendations regarding the microbiological safety of foods" (U. S. Food and Drug Administration, 1997, p.1).

A HACCP system establishes process control by identifying, monitoring and controlling critical control points (CCPs) in the production process. A CCP is defined as "a point, step, or procedure where the hazard that's associated with the food can be prevented, eliminated, or reduced to acceptable levels" (U. S. Food and Drug Administration, 1997, p.4). In general, CCPs can be identified at any stage in a plant HACCP plan, such as receiving, processing, cold storing and packaging. By focusing on CCPs, adopting HACCP is effective in controlling hazards during the production process.

In a study of the effect of HACCP implementation on some restaurants in Spain, Soriano et al. (2002) compared two widely consumed meals' microbiological qualities before and after implementation of HACCP, demonstrating that HACCP application contributes to improved food safety. Cormier et al. (2007) showed the positive effectiveness and performance of HACCP implementation on reducing food safety risk by comparing the number of Ready-to-Eat seafood samples found positive for *Listeria monocytogenes* pre-HACCP and post-HACCP implementation.

The cost-effectiveness of implementing HACCP is debatable. HACCP's preventive focus is seen as more cost-effective than testing a product and then destroying or reworking it (International Commission on Microbiological Specifications for Foods, 1998). This is especially important for foodborne microbial pathogens, because their incidence is low and costs of testing and reworking are high (Unnevehr and Jensen, 1996). However, costs of HACCP implementation can be significant, especially for small companies. Taylor (2000) studied the benefit and burden of HACCP implementation on small companies. Compared with larger companies that possess more resources including money, technical expertise and management skills, small companies face a relatively harder challenge in setting up a HACCP system.

Because many factors such as type of facility and location affect cost of HACCP design and implementation, the cost effectiveness of a HACCP plan can be difficult to assess. But it is important that a firm evaluate the cost in their specific plant(s) before implementation and continue to assess cost once the plan is in place and operational. This paper identifies and summarizes the main types of costs of the HACCP systems being used by two North Dakota processors, builds a cost estimation model appropriate to estimate the costs of various HACCP systems for other firms in North Dakota, and refines this model through two case studies.

CHAPTER 2. LITERATURE REVIEW

There was little evidence to allow for developing general conclusions about the costs associated with the adoption of various HACCP systems, and apply them to a specific processing or manufacturing firm in North Dakota. However, some studies which discussed costs at the firm level or the industry level were identified in the literature. Here we focus on the categorization of HACCP costs in different food processors and the analysis of the calculated costs resulting from these studies.

In a study of HACCP-regulation impacts in three Mississippi catfish processors, Herrera, et al. (1999) classified costs into those associated with training, record-keeping, receiving, metal detection, food-contact surfaces, hand sanitizing, and adulteration prevention. Three catfish firms were categorized by size (large, medium, and small). Results showed that the large processor incurred the highest total cost. By size, maximum processing capabilities were 150,000; 70,000; and 25,000 pounds per day and total costs were $413,475, $73,340, and $11,538, respectively. In this case, costs per unit of capacity also were higher for larger firms. This can be explained by the relatively greater number of CCPs used by the larger firm.

Colatore and Caswell (1998) estimated the cost of implementing a HACCP plan in eight bread-fish processors in the United States. Costs were categorized as total costs, cost of implementing minimum requirements, and incremental costs attributable to FDA regulation. Their study showed that the average first-year total cost of implementing HACCP was $113,505. In contrast, the average first-year cost in similar companies which implemented the minimum FDA's HACCP requirements was $34,323. The difference occurred because the firms generally implemented much stricter and more expensive HACCP plans than required and often had excessive numbers of CCPs within their plans.

Lupin et al. (2010) evaluated costs in three fish processing plants. The costs involved in HACCP implementation were divided into prevention, appraisal, and failure costs. The results showed that, after the proper implementation of a HACCP system and compliance with HACCP-based regulations, most fish processing plants experienced a decrease in the number of failed products and an increase in quality. The authors confirmed that, although the implementation of a HACCP system in the three plants required investments, it paid for itself in cost savings in the long term.

Several other studies surveyed food processors in different countries by questionnaires and discussed the results about the main types of costs associated with adopting HACCP systems. Romano et al. (2004) studied the costs of adopting HACCP systems for meat and dairy plants in Italy. The data were collected from four Italian meat and dairy firms of different sizes (one small, one medium and two large) via mailed questionnaires. Costs of HACCP systems were categorized as start-up costs and operation costs. The study confirmed the high effectiveness of the HACCP systems because the number of products failing their testing declined significantly after implementing HACCP systems in the four firms, but the structure of HACCP costs was different among plants.

Deodhar (2003) sent questionnaires to more than 500 food companies in India. The costs of HACCP were divided into start-up costs and operation costs. The author found that the major operating costs of HACCP were those associated with recordkeeping and product testing, and the major start-up cost was hiring an external consultant. Maldonado and Henson (2005) developed a list of six different costs of implementing HACCP and asked

160 meat processors in Mexico to rank them. They found that investment in new equipment and microbiological tests of products accounted for most of the implementation and operating costs associated with HACCP.

CHAPTER 3. METHODS

3.1. The Prevention-Appraisal-Failure Model

In 1995, the U. S. Food and Drug Administration (FDA) encouraged seafood plants to use HACCP. In 1996, the U.S. Department of Agriculture (USDA) mandated the use of HACCP in meat and poultry plants. In 2011, under the *Food Safety Modernization Act*, every food company will have to develop and implement a HACCP plan. An increasing number of companies have instituted HACCP plans. When processors decide how to apply a HACCP plan, they must take into account the costs associated with achieving the desired safety requirement. Therefore, safety and quality cost should be considered important for a company.

The concept of quality costs as described by Feigenbaum (1956) is to quantify the total costs of quality-related efforts and deficiencies. Evaluating quality costs is an important step for plants making a decision about implementing a system for controlling the quality of products. Among several methods that can be used to collect, categorize and measure quality costs such as the fixed and variable cost model and the process cost model, the Prevention-Appraisal-Failure (PAF) model developed by Feignbaum was selected for the current work. In this model, quality costs are divided into prevention, appraisal and failure costs. The main reason for the model selection is that the PAF model emphases on the relationships between major quality cost categories. However, other cost model does not discussed. The basic supposition of the PAF model is that investment in prevention and appraisal activities will reduce failure costs (Figure 1).

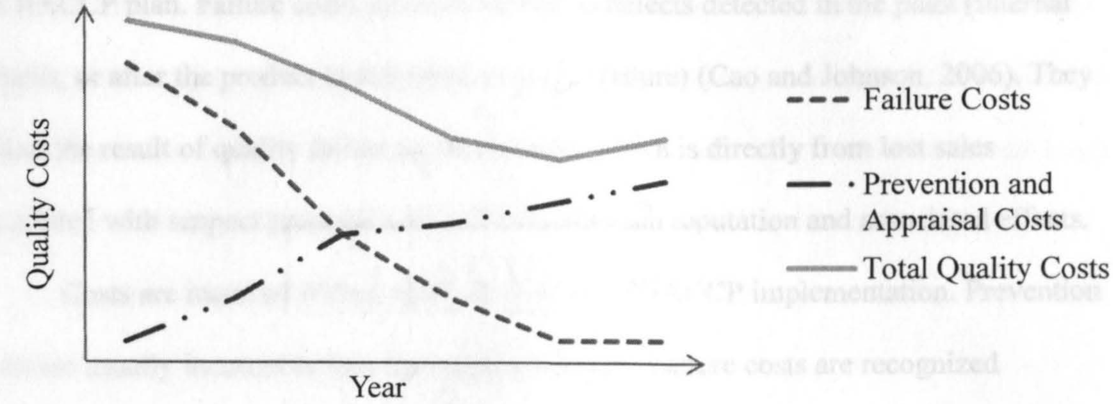

Figure 1. Relationship between Failure, Prevention and Appraisal Costs, and Total Quality Costs after HACCP Implementation

By analyzing and observing the changes in quality costs before and after the implementation of HACCP, a manager can gauge the cost effectiveness of the HACCP program. Lupin et al. (2010) applied the PAF model to quantify the economic impacts of HACCP systems in fish processing plants. In their study, cost information was based on the total quality costs (TQC) model (Feigenbaum, 1974), shown here as:

$$TQC = \sum C_P + \sum C_A + \sum C_F \qquad (1)$$

Where:

TQC = total quality costs of products per year

C_P = prevention costs per year

C_A = appraisal costs per year

C_F = failure costs per year

Prevention costs arise from training, and from designing and maintaining the HACCP system. They are those costs associated with keeping safety issues from occurring. Appraisal costs arise from detecting and checking for defects via inspections, tests, audits and records. They are associated with collecting information about whether the quality of raw materials, and intermediate and final products conforms with the standards identified in the HACCP plan. Failure costs are costs related to defects detected in the plant (internal failure), or after the product is delivered (external failure) (Cao and Johnson, 2006). They reflect the result of quality failure as lost income, which is directly from lost sales associated with suspect products and indirectly through reputation and associated effects.

Costs are incurred during different periods of HACCP implementation. Prevention costs are usually incurred before the actual operation. Failure costs are recognized before/after ownership transfer of products between entities in the marketing channel. Most other costs are appraisal costs which are incurred during the operation and maintenance of the monitoring and control systems for all CCPs (Lupin et al., 2010).

3.2. Firm Descriptions

Target firms of this study were selected that had existing HACCP plans and performed several functions including receiving and storage of raw materials, cleaning, processing, and packing product for market, storage of packed product, and shipment with all steps prior to shipment taking place at one facility. NDSU faculty involved in the Food Safety program were asked via list-serve to submit suggested firms for consideration. Ten firms were suggested, and two of the firms that met the research criteria were selected.

Firm A has over thirty years of history in meat processing and has two plants. Both plants are located in eastern North Dakota. The firm sells a wide variety of products, such as smoked sausages, smoked hams, ground beef and chicken. It serves the North Dakota, South Dakota, and Northwest Minnesota markets.

The business strategy of Firm A focuses heavily on product safety. This firm controls food hazards beginning with the ordering and receipt of raw materials. Raw materials are ordered from a list of suppliers who have certificates guaranteeing their materials' quality and each box loading raw materials identifies the source (supplier and specific plant origin). The HACCP plan is perceived by managers as one of the main tools to assure product safety. Firm A has seven HACCP plans for different production processes. Two HACCP plans are performed at the main plant, where ground beef, beef patty mix, ground chuck and beef patties are produced, and five plans are implemented at another plant.

During two plant visits, the costs associated with HACCP implementation for ground beef in the main plant were elicited. This HACCP plan has been in effect since 1999 and is adapted as new products are developed, or USDA regulations change. As part of its HACCP plan, this firm renovated a microbiology laboratory for sampling raw materials and finished products, added an alarm in the cold storage room to warn of temperatures outside the acceptable range, and documents the HACCP system on a daily basis.

Firm B, which is located in the Red River Valley in the upper Midwest, is one of the largest suppliers of custom-milled and whole grain blends in North America. The quality of raw materials is a high priority for this company. Due to its location, the plant can immediately access premium raw materials, and it has had a strong, cooperative relationship with the farming community for over 20 years. Moreover, suppliers have certificates that guarantee the quality and safety of their raw materials. Firm B's produces specialty mixes, grain blends, and toasted products. The total output in 2010 was approximately 75 million pounds of product and output continues to grow. Firm B supplies the wholesale bread baking industry, and its products have been exported to 13 other countries.

For pursuing the highest level of product quality and sanitation standards, Firm B created a HACCP program in 2005 based on the guidelines of the American Institute of Baking. This HACCP plan was applied in six different production lines. The major hazard during the processing is physical hazards, because its products are processed and moved directly by many pieces of equipment that could lead to metal contamination. For reducing physical hazards, this firm uses several magnets and sieves throughout processing, and metal detectors prior to product packaging in whole process lines. This is the CCP in the HACCP system and the recordkeeping of this CCP is maintained for three years. In contrast, the risk from microbiological hazards is quite low because of steaming and toasting steps during the product processing. Most microorganisms can be killed by high enough temperatures in these two steps.

3.3. Data Collection

PAF model refinement was based on face-to-face interviews carried out at the two firms. The goal was to create a more comprehensive PAF model to allow quantitative estimation of costs of various HACCP systems, and collect realistic costs related to the HACCP implementation in the two firms to test the quantitative cost model.

Case study is a research method to enables investigation to be conducted directly with individuals or organizations. It often use questionnaires or informal query for investigation. There are disadvantages associated with the use of a questionnaire for this particular project. First, the in-depth nature of the questions may result in a low response rate which cannot be afforded given the limited number of local firms. Second, quality of information from a questionnaire cannot be guaranteed. Third, a questionnaire constitutes one-way communication and does not accommodate immediate follow-up or clarification.

Further, the general questions may not reflect the realities of HACCP implementation for different firms; realities that are likely to be important due to variability in firm size, organization, product handled, process, and the design and implementation of their HACCP plans.

Interviews were based on a structured questionnaire and were conducted with Quality Assurance managers and staff involved in the HACCP systems. A structured questionnaire was developed based on costs identified from the literature review and the initial PAF model. These interviews were recorded by hand-written notes. Information about the plants' HACCP implementation and operation were collected, including cost data.

CHAPTER 4. MODEL DEVELOPMENT

Three steps were taken to develop the quantitative model. First, the initial PAF model was built based on the literature review. Next, based on the refined PAF model, the cost estimation model was developed. Finally, it was applied to the two food processors in North Dakota.

4.1. The Refined PAF Categorization Model

After a preliminary PAF model analysis and the plant visits, the cost items of HACCP implementation were grouped, and the number of the cost items was reduced. For instance, for both firms the "shipping" step is not dependent on the HACCP system, and the "shipping" cost is the same regardless of the implementation of a HACCP plan. Thus, shipping cost was not considered as a part of the costs of HACCP for these two firms. Moreover, some cost items had minor contributions to the total quality costs and thus were not considered. Table 1 lists the resulting types of prevention, appraisal and failure costs and sources for each type identified.

4.1.1. Prevention Costs

The most common prevention costs incurred in HACCP systems are the following:

Designing and developing a HACCP plan. Before introducing the HACCP plan, firms are required to establish prerequisite programs (FDA, 1997). In Firms A and B, Good Manufacturing Practices (GMPs) and Sanitation Standard Operating Procedures (SSOPs) act as the HACCP prerequisite programs. After that, if a HACCP system will be introduced into a food processing plant, the first step should be to design and develop a HACCP plan. Because effective HACCP program design will help ensure that the program is successful and cost effective (Newslow, 2002), hiring HACCP experts can assist the firm to follow the prerequisite programs, identify the CCPs and determine critical limits for each CCP that are adequate to control the food safety hazards. The cost of hiring HACCP experts is the main cost for designing and developing HACCP plans.

Table 1. Types and Sources of Possible Prevention, Appraisal, and Failure Costs of HACCP

Cost categories in PAF model	**Source of costs**
Prevention costs (C_P)	
1. Designing and developing a HACCP plan	HACCP experts (internal or external)
2. Staff training and follow-on formal training	HACCP experts (internal or external)
3. Cleaning and sanitation of equipment and facility	Detergents, disinfectants, labor cost or cleaning service contract
4. Antimicrobial system	Labor cost, testing chemicals and storage tanks
Appraisal costs (C_A)	
1. Guaranteeing quality of incoming raw materials	Labor cost
2. Sampling raw materials and final products	Labor cost, materials used for sampling (e.g., test kits) or external contract testing fees
3. Calibrating and maintaining equipment used for HACCP systems	Labor cost, service contract for calibration and maintenance
4. Inspecting and verifying CCPs during processing	Labor cost
5. Record keeping	Labor cost
6. Costs of equipment and building improvements used for HACCP systems	Depreciation
Failure costs (C_F)	
1. Internal failure costs (scraps, reprocessing, retest or spoilage)	Labor and facilities costs, wastage (raw materials)
2. External failure costs (rejected and/or returned products, reputation effect)	Lost income on product, other potential loss in income (e.g., reputation effect), cost implementing, additional prevention steps

Staff training and follow-on formal training. "Education and training are important elements in developing and implementing a HACCP program" (Surak and Wilson, 2007, p.8). Because short and long term training programs can provide the foundational knowledge and methodology of HACCP systems, they help employees understand the importance of the HACCP plan and their role in this system. The main cost of training programs arises from hiring employees who are knowledgeable about HACCP or outside HACCP experts. In Firms A and B, their personnel involved in the HACCP system were trained in-house by internal HACCP supervisors in most cases.

Cleaning and sanitation of equipment and facility. In prevention activities, sanitation of equipment and facilities is important because maintaining sanitary processing conditions can ensure the quality of products. In the FDA's HACCP Guidelines (1997), cleaning and sanitation are considered to be one of the prerequisite programs of HACCP plans. This cleaning and sanitation cost includes detergents, disinfectants and labor costs, and any used cleaning service fees. Firm A had a service contract with a cleaning crew for the routine cleaning of the facility. In Firm B, one employee was responsible for the daily cleaning.

Antimicrobial system. The microorganisms found on or in meat and poultry may contribute to meat spoilage, reduce shelf-life of meat and cause foodborne diseases (Aberle et al., 2001). Therefore, most of the meat processors' emphasis is on microbial hazards associated with meat and poultry. Firm A used an antimicrobial treatment (spray chemicals on the surface of meat) to control microbial growth. The costs of labor, chemicals and storage tanks used for this system are the main cost items. Because of the different types of product and the low microbiological hazard in processing, Firm B did not apply an antimicrobial system.

4.1.2. Appraisal Costs

Appraisal costs are associated with ensuring the products meet the quality standard and processing conforms to the HACCP plan.

Guaranteeing quality of incoming raw materials. In general, receiving the incoming raw materials is the first step in the process flow. If incoming raw materials contain biological, chemical, or physical hazards, the materials may affect the final products directly. Therefore, sampling raw materials or checking certificates at receiving is necessary. Both Firms A and B check certificates of the raw materials. The cost of this step includes labor cost.

Sampling raw materials and final products. Sampling raw materials is one method to detect food safety hazards. Sampling final products is a method to check for microbiological hazards and verify the proficiency of the HACCP system. Sampling cost includes the costs associated with the labor, materials, and external testing fees needed to evaluate the quality of raw materials and final products. Firm A had one microbiology laboratory in the main plant and sampled the raw materials twice and the final products four times per year. USDA also provides the meat inspection service and covers the cost of the service. Firm B had two microbiology laboratories and only sampled the final products daily.

Calibrating and maintaining equipment used for HACCP systems. Any equipment used to demonstrate compliance to a specified requirement must be calibrated and maintained (Newslow, 2002). Calibration confirms the accuracy of the equipment and regular maintenance helps ensure equipment used in HACCP system works consistently. Conversely, lack of proper calibration and maintenance of equipment may result in potential food safety hazards. For instance, an uncalibrated metal detector can miss detecting the physical (metal) hazards and an inaccurate thermometer cannot measure the true temperature of meat products. Also, equipment used in HACCP systems must be operated, resulting in labor costs or service contract costs for calibration and maintenance.

Inspecting and verifying CCPs during processing. The goal of inspection and verification of CCPs is to help firms determine whether the system is working as written in the HACCP plan. In Firms A and B, the Quality Assurance (QA) managers were responsible for inspecting and verifying CCPs. The in-progress inspection and verification cost arises from hiring well-trained employees and outside HACCP consultants engaged in the evaluation of the conformance of CCPs.

Record keeping. In the FDA's HACCP Guidelines, Principle Seven is "Establish record-keeping and documentation procedures ". In the HACCP plan, records should include information on the ingredients (suppliers, storage, parameters, etc.), product safety, processing (monitored CCPs), packaging, storage and distribution, deviation and corrective actions, validation records, HACCP plan modifications and employee training records (FDA, 1997). Hiring a knowledgeable HACCP expert to record the HACCP system is the main cost.

Costs of equipment and building improvements used for HACCP systems. For complying with the HACCP plan, the plant may need to purchase equipment or establish a laboratory used to evaluate the quality of chemicals or other materials used during processing or products. In this study, the straight-line method was selected to estimate the depreciation costs of associated equipment. When the straight-line method is used to calculate depreciation, the equipment's depreciable cost is spread evenly over the estimated useful life of the equipment (Needles and Powers, 2007).

4.1.3. Failure Costs

Failure costs mainly result from non-conforming products. They are divided into internal and external failure costs. The external failure costs include reject, returned, and recall costs, and the cost of lost sales. Due to difficulty in estimating, the external failure costs were not considered in this study. Internal failure costs are direct losses and include scrap, re-work, retest, and wastage costs. Firm A did not retest and rework the positive products but sent them to a cooking company directly. Firm B had both wastage and re-work costs.

4.2. The Cost Estimation Model

The purpose of this study is to design a practical cost model for North Dakota firms to make initial cost estimates of implementing HACCP plans. During the first step of this study, the cost items were determined by the refined PAF model. However, the PAF model is only a basic concept, and the cost items categorized by the PAF model are sometimes not straightforward to identify and estimate by individual firms. For this reason, a cost estimation model was transformed from the refined PAF categorization model and all of quality costs were reclassified into 4 groups: labor, equipment, material and failure costs. The parameters used in the cost model are defined in Table 2.

Table 2. Labor, Equipment, Material and Failure Costs, and Parameters

Costs items	Cost categories in PAF model	Parameters
Labor costs (C_L)		N_o= number of employees or HACCP experts
Designing and developing HACCP plans	C_P	N_h= number of working hours per day
		N_d= number of working days per year
Staff training	C_P	R= labor rate per unit time (hour, day)
Follow-on formal training	C_P	C= cost of service contracts for cleaning the plant, or calibration and maintenance of equipment, testing or other activities per year ($)
Cleaning and sanitation of equipment and facility	C_P	

Table 2. Labor, Equipment, Material and Failure Costs, and Parameters (Continued)

Costs items	Cost categories in PAF model	Parameters
Antimicrobial system	C_P	
Calibrating and maintaining the equipment used for HACCP systems	C_A	
Inspecting and verifying CCPs during the processing	C_A	
Sampling the raw materials and final products	C_A	
Record keeping	C_A	
Equipment costs (C_E)		P_e=purchase price of equipment ($)
Depreciation costs of equipment	C_A	L=equipment's useful life (yr)
Material costs (C_M)		P_w=purchase price of testing chemicals, testing kits, detergents and disinfectants, or raw materials, and selling price of final product($/lb, $/kit, $/unit)
Testing chemicals and testing kits for sampling	C_A	
Raw materials and final products for sampling	C_A	U_w= testing chemicals, testing kits, detergents and disinfectants, raw materials, and final products used per year (lb, kit, unit)
Chemicals for antimicrobial system	C_P	
Detergents and disinfectants for cleaning the plant	C_P	
Failure costs (C_F)		
Waste (products cannot be re-worked)	C_F	
Re-work product (including retesting)	C_F	

The resulting cost model has two assumptions. First, the total quality cost of implementing a HACCP plan can be calculated from the twelve cost items of the refined PAF model. Second, the productivities of staff and equipment associated with the HACCP system remain constant. In this model, the quality-related costs, which were transformed from the refine PAF categorization model, were reclassified into labor, equipment, material and failure costs.

To calculate the TQC associated with the HACCP implementation, the labor, equipment, material and failure costs are studied separately. In a food processing plant, many staff involved in the implementation of HACCP system, such as operators, cleaners, inspectors, microbiologists, and HACCP experts, are needed. Equation (2) calculates total labor cost.

$$\sum C_{\mathrm{L}} = \sum_{i=1}^{n}(N_{oi}N_{hi}N_{di}R_i + C_i) \qquad (2)$$

Where:

N = Number of different labor categories (based on wage rate)

C_L = Labor costs per year ($)

N_o = Number of employees or HACCP experts

N_h = Number of working hours per day

N_d = Number of working days per year

R = Labor rate per unit time per year (hour)

C = Cost of service contracts for cleaning the plant, or calibration and maintenance of equipment, testing or other activities per year ($)

Some necessary equipment, such as testing and measuring instruments, were purchased by the case firms to evaluate the quality of products. The straight-line method was used to estimate the total depreciation cost of all equipment as follows:

$$\sum C_{\mathrm{E}} = \sum_{i=1}^{n}(P_{ei}/L_i) \qquad (3)$$

Where:

N = Number of pieces of equipment

C_E = Equipment costs per year ($)

P_e = Purchase price of equipment ($)

L = Equipment's useful life (yr)

Material costs include the costs related to the sampling and testing, antimicrobial system, and cleaning and sanitizing materials. Total material cost is established by equation (4).

$$\sum C_{\mathrm{M}} = \sum_{i=1}^{n}(P_{wi}U_{wi}) \qquad (4)$$

Where:

N = Number of different material costs

C_M = Material costs per year ($)

P_w = Purchase price of testing chemicals, testing kits, detergents and disinfectants, or raw materials, and selling price of final product($/lb, $/kit, $/unit)

U_w = Testing chemicals, testing kits, detergents and disinfectants, raw materials, and final products used per year (lb, kit, unit)

For failure costs, the costs of product wastage and re-work are listed because they are direct company losses and may be related to the selling price of the product. However, the computation of them depends on the different methods used in various firms to deal with the failure products.

As above mentioned, each of the annual prevention costs (C_P), appraisal costs (C_A) and failure costs (C_F) can be represented separately by the summation of corresponding types of costs listed in Table 2. Then, based on equation (1), the annual TQC can be calculated.

$$\mathrm{TQC} = \sum C_P + \sum C_A + \sum C_F \qquad (1)$$

In theory, an increase of investment in the prevention and appraisal costs should lead to a decrease in failure costs after completion of the HACCP implementation, and there should be a point which represents the lowest value of total quality costs (TQC). For an individual firm, the effectiveness of the HACCP plan implementation can be evaluated through observing and analyzing the trend of each quality cost during the post-HACCP period.

4.3. Results of Case Studies

To validate the cost estimation model, each cost item listed in Table 2 was collected from two food processing plants. Based on the cost model, the estimated prevention costs, appraisal costs and failure costs were calculated and expressed as percentages of TQC (Figure 2). This figure shows the individual contribution of the three quality costs to the TQC.

The structure of TQC of HACCP implementation in the two firms seems quite different. In Firm A, investments in prevention actions are six times larger than in appraisal actions and this high investment demonstrates that the prevention actions are the most costly part of the HACCP system (84.7%). For this firm, the total costs of prevention cost and appraisal costs account for more than 99% of the TQC of the HACCP system. Conversely, the appraisal costs in Firm B account for a significant share of TQC (83.6%). In other words, Firm A (the meat processing firm) focuses more on prevention costs, while Firm B (the grain processing firm) devotes a significant effort to appraisal costs (e.g., sampling and metal detecting).

Figure 3 shows how much the various actions contribute to total prevention costs and compares the prevention costs of the HACCP systems between Firms A and B. Types of products processed in the plants determine investments in prevention actions. In this study, investment in an antimicrobial system was necessary for Firm A, but not for Firm B. Moreover, designing a HACCP plan and staff training were not performed every day, while cleaning and sanitizing the equipment and facility were. Therefore both Firms A and B present significant daily cleaning and sanitation costs comprising overall prevention costs (74.10% and 76.20%, respectively).

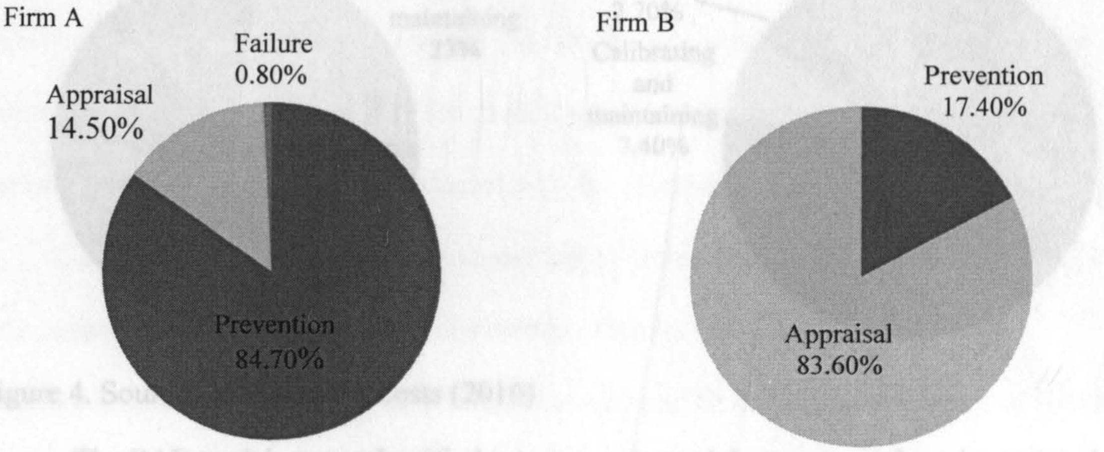

Figure 2. Estimated Prevention, Appraisal, and Failure Costs of TQC in Firms A and B (2010)

No regular data from Firm B supports an estimate of failure costs. Its value depends on the working situation of the metal detectors. If there was a metal detector malfunction, the malfunction would result in failure costs (wastage and re-work). The failure cost of Firm A in this study only includes the cost of cooking the products not meeting quality standards.

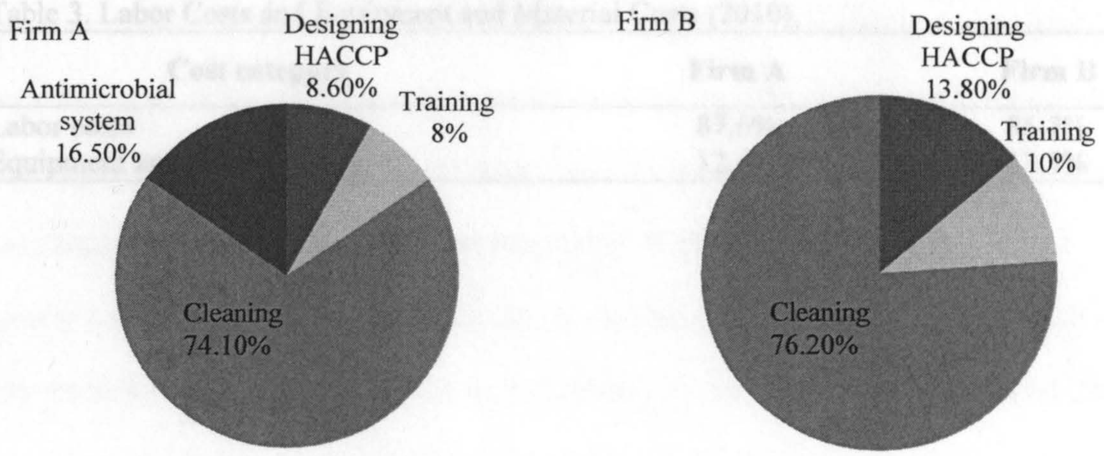

Figure 3. Sources of Prevention Costs (2010)

In Figure 4, the appraisal costs are broken down into five cost items. It shows that record keeping is a slight majority of the appraisal costs for Firm A (37%). For Firm B, the main item of appraisal costs is sampling the final products (78.2%), because the firm had a relatively large product output and daily sampling of final products is necessary.

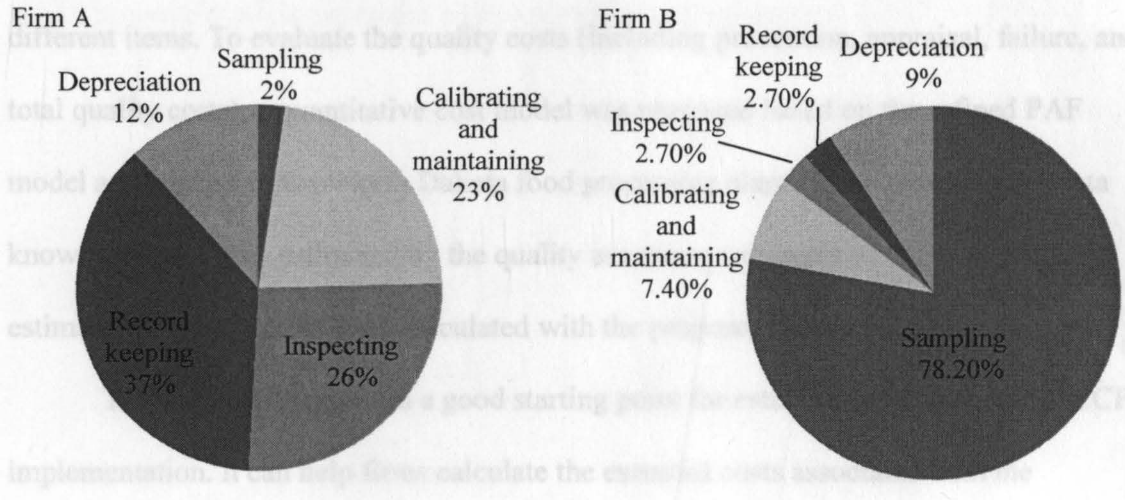

Figure 4. Sources of Appraisal Costs (2010)

The PAF model was reclassified into two groups: labor costs, and equipment and material costs (Table 3). The failure costs for both firms are not included. Table 3 shows that the majority of costs associated with the HACCP systems for both Firms A and B is from labor (more than 85% of all costs).

Table 3. Labor Costs and Equipment and Material Costs (2010)

Cost category	**Firm A**	**Firm B**
Labor costs	87.6%	86.7%
Equipment and material costs	12.4%	13.3%

CHAPTER 5. CONCLUSIONS

The PAF model is one tool to classify and calculate quality costs associated with the implementation and use of a HACCP plan. In this study, the structure of the PAF model was refined based on plant visits. In the refined model, total quality costs consist of twelve different items. To evaluate the quality costs (including prevention, appraisal, failure, and total quality costs), a quantitative cost model was proposed based on the refined PAF model and applied to two North Dakota food processing plants. Through using the data known or reasonably estimated by the quality assurance managers of the two plants, the estimates of quality costs were calculated with the proposed model.

The cost model provides a good starting point for estimating the costs of HACCP implementation. It can help firms calculate the essential costs associated with the implementation of HACCP and allow firms to evaluate the long term efficiency of HACCP plans by comparing the quality costs over time. But, the cost model still has limitations. First, the TQC was calculated by the direct costs of the implementation of a HACCP system. In equation (1), total prevention, appraisal and failure costs are variables. However, other potential variables that can increase the indirect costs and lead to a higher TQC are not considered in this model because most of them cannot be estimated with reasonable accuracy, such as the cost of rejected products and food recalls. Analysis of these variables can help to develop a more complete model. Second, the cost model was applied to only two firms. In a future study, other food processing firms should be surveyed and their quality costs calculated by this cost model. An increase in the number of firms considered can result in an increase in the number of cost items and variables of this cost model. Third, we did not obtain the trends of each quality cost of the HACCP implementation in the two firms over time. Looking at the trend of quality costs associated with HACCP implementation can help firms test whether the HACCP system is cost effective in improving the product quality over time. Although the results may not be accurate due to these limitations, the methods used in this study can be followed and the quantitative cost model presented in this paper can be developed to further models.

REFERENCES

Aberle, Elton D., John C. Forrest, David E. Gerrard, Edward W. Mills, Harold B. Hedrick, Max D. Judge and Robert A. Merkel. *Principles of Meat Science.* Dubuque: Kendall Hunt Publishing. 2001.

Arduser, Lora and Douglas Robert Brown. *HACCP and Sanitation in Restaurants and Food Service Operations: A Practical Guide Based on the FDA Food Code.* Ocala: Atlantic Publishing Group. 2005.

Cao, K and R Johnson. "The Costs and Benefits of Introducing Mandatory Hygiene Regulations." New Zealand Agricultural and Resource Economics Society Conference. 2006. http://ageconsearch.umn.edu/bitstream/31976/1/cp06ca01.pdf(accessed 25 Apr. 2011).

Centers for Disease Control and Prevention. "Surveillance for Foodborne-disease Outbreaks -- United States." Nov. 2006. http://www.cdc.gov/mmwr/preview/mmwrhtml/ss5510a1.htm (accessed 25 Apr. 2011).

Centers for Disease Control and Prevention. "CDC 2011 Estimates: Findings". Dec. 2010. http://www.cdc.gov/foodborneburden/PDFs/FACTSHEET_A_FINDINGS.pdf (accessed 25 Apr. 2011).

Colatore, Corinna and Julie A. Caswell. "The Cost of HACCP Implementation in the Seafood Industry: A Case Study of Breaded Fish." *The Economics of HACCP: Costs and Benefits.* St. Paul, MN: Eagan Press. 1998.

Cormier, R.J., M. Mallet, S.Chiasson, H. Magnusson, and G. Valdimarsson. "Effectiveness and Performance of HACCP-based Programs." *Food Control,* 18 (2007): 665-671.

Deodhar, S.Y. "Motivation For and Cost of HACCP in Indian Food Processing Industry." Dec. 2003. http://www.ijeb.com/Issues/data/Dec03_5_mfchifpi.pdf (accessed 25 Apr. 2011).

Feigenbaum, Armand V. *Total Quality Control.* New York: McGraw-Hill, 1974.

Fleet, G.H., P. Heiskanen, I. Reid, K.A. Buckle. "Foodborne Viral Illness–status in Australia." *International Journal of Food Microbiology*, 59 (2000):127-136.

Herrera, J. J., C. W. Herndon, Jr., and L. House. "The Impact of Safety Regulations on Three Catfish Processors: A Case Study." *Journal of Agricultural and Applied Economics.* 31(1999): 395-396.

International Commission on Microbiological Specifications for Foods. "Application of the Hazard Analysis Critical Control Point System to Ensure Microbiological Safety and Quality." *Microorganisms in Food 4*. Oxford: Blackwell Scientific Publications, 1998.

Lupin, H.M., M.A. Parin, A. Zugarramurdi. "HACCP Economics in Fish Processing Plants." *Food Control*, 21 (2010): 1143-1149.

Maldonado, E.S. and S.J. Henson. "Cost–benefit Analysis of HACCP Implementation in the Mexican Meat Industry." *Food control,* 16 (2005): 375-381.

Needles, Belverd E. and Marian Powers. *Financial Accounting*. Florence: South Western Educational Publishing. 2007.

Newslow, Debbie L. "HACCP Prerequisites". *Food Quality*, May/June(2002):28-37.

Romano, D., A. Cavicchi, B. Rocchi, G. Stefani. "Costs and Benefits of Compliance for HACCP Regulation in the Italian Meat and Dairy Sector." Report prepared for presentation at the 84th European Association of Agricultural Economists Seminar.

Feb. 2004. http://ageconsearch.umn.edu/bitstream/24983/1/sp04ro02.pdf (accessed 25 Apr. 2011).

Scharff, L. R. "Health-related Costs from Foodborne Illness in the United States." Mar. 2010. http://www.producesafetyproject.org/admin/assets/files/Health-Related-Foodborne-Illness-Costs-Report.pdf-1.pdf. (accessed 25 Apr. 2011).

Soriano, J.M., H. Rico, J.C. Molto, and J. Manes. "Effect of Introduction of HACCP on the Microbiological Quality of Some Restaurant Meals." *Food Control*, 13 (2002): 253-261.

Surak, John G. and Steven Wilson. *The Certified HACCP Auditor Handbook.* Milwaukee: ASQ Quality Press. 2007.

Taylor, E. "HACCP in Small Companies: Benefit or Burden." *Food Control*, 12 (2010): 217-222.

Unnevehr, L.J. and H.H. Jensen. "HACCP as a Regulatory Innovation to Improve Food Safety in the Meat Industry." *American Journal of Agricultural Economics*, 78 (1996): 764-769.

U.S. Department of Agriculture's Economic Research Service. "Agriculture Fact Book ". Nov. 2000. http://www.usda.gov/factbook/chapter2.pdf (accessed 25 Apr. 2011).

U. S. Food and Drug Administration. "Hazard Analysis and Critical Control Point Principles and Application Guidelines". Aug. 1997. http://www.fda.gov/food/foodsafety/HazardAnalysisCriticalControlPointsHACCP/ucm114868.htm (accessed 25 Apr. 2011).

Wittenberger, K. and E. Dohlman. "Impacts of the 2008-09 Foodborne Illness Outbreak Linked to Salmonella in Peanuts." Feb. 2010.

http://usda.mannlib.cornell.edu/usda/ers/OCS//2010s/2010/OCS-02-01-2010_Special_Report.pdf (accessed 25 Apr. 2011).