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Trade-off between cost of traceability within a small and large commercial meat plant and economic benefits of reducing the number of recalls and size of recalls

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**Trade-off between cost of traceability within a small and large commercial meat plant
and economic benefits of reducing the number of recalls and size of recalls**

by

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A thesis submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of
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ABSTRACT

Is the benefit of reducing the size or probability of a recall worth the cost of the system? Recalls have the potential to incur large cost associated with loss of product, negative publicity, and legal judgments. A model including the cost of traceability, probability that a recall occurs, costs associated with a recall, and severity of recall events is simulated using a random draw of probability and average size from a given distribution for both a 400 head per day and a 5,000 head per day beef plant. For a small plant, it was estimated that the reduction in size of recall by 77 percent is required to breakeven while a greater than 99 percent reduction in probability is required. For a large plant, the breakeven point plant is found at a 7 percent reduction in size of a recall and 15 percent reduction in the probability of a recall.

CHAPTER 1. INTRODUCTION

It has been estimated that 76 million illnesses, 325,000 hospitalizations, and 5,000 deaths occur each year in the United States due to foodborne diseases (Mead, et. al., 1999). Of these statistics, Mead and others also estimate that 14 million illnesses, 60,000 hospitalizations, and 1,800 deaths occur from known pathogens and 75% of these deaths are from *Salmonella*, *Listeria monocytogenes*, and *Toxoplasma*. However, Mead and others cite that from the Center for Disease Control in 1982 that over 200 diseases can be obtained through food. The number of known diseases that can be obtained from food has undoubtedly risen since this time.

The food industry has made vast changes in the type of products produced, especially within the last decade. These changes include greater convenience foods, more ready-to-eat foods (RTE), and foods that combine different levels of preparation in a single container. The cooking step is the final hurdle in controlling pathogens in a typical environment. This step originally took place in a consumer's home, but is now performed much earlier in the production process. This shift in processing allows for greater opportunities for contamination before the product is consumed. Food safety practices to prevent outbreaks have been the meat industries focus for investment. These safety practices continually improve and are very much advanced from the beginnings of food safety in the Food Safety and Inspection Act of 1906 sparked by Sinclair's *The Jungle*.

Even with the food industry's great investment in the prevention of contamination or adulteration, there is still failure in current prevention methods. Therefore, meat and poultry

recalls still occur. From 1997 to 2004, 549 or nearly 69 recalls per year were conducted in conjunction with the Food Safety Inspection Service (FSIS). A recall in the food industry may result in very large losses, as American Meat Institute (AMI) President Boyle stated, “Nothing is more damaging to a company’s reputation and profitability than a product recall.” Bill Marler of Marler and Clark, a law firm that has represented thousands of food illness victims in over 30 states since 1993, reports that verdicts and settlements in cases of food poisoning have totaled nearly \$200,000,000 (Marler, 2005). The settlements and verdicts are primarily after the 1993, *E. coli* outbreak from Jack in the Box restaurants.

The food industry’s potential to cause very adverse health effects to consumers due to microbial contamination or other safety risks, creates an interest to economists in the terms of potential economic loss to food producing, processing, or distribution entities (Piggott and Marsh 2002, Siaplay et al. 2005). The meat industry in particular has been the target of many negative factors due to recalls. Potential losses come in the form of cost of recovery, cost of disposal, and reimbursement for meat and poultry products, as well as negative publicity, and potential legal consequences.

Some of these costs may be reduced or eliminated by the use of a traceability system in a meat and poultry plant. The reduction of cost potentially may be due to reduced size of a recall or the decrease in chance that a recall occurs.

Traceability can help eliminate recording errors and aid in keeping records which is a major part of a successful Hazard Analysis of Critical Control Points (HACCP) plan. Reassessing HACCP plans was a major factor in reducing recalls of beef due to *Escherichia coli* (*E. coli*) (Pierson, 2005).

Furthermore, the need to quickly identify product that may be contaminated or possibly tampered with is essential in cases of emergency. Pierson 2005, points out that in a time of crisis seconds may be critical in the communication chain and having the correct information readily available and technology to pass that information along may be very beneficial.

Even though the National Animal Identification System (NAIS) has been strongly opposed in some aspects of the food animal industry, certain factors particularly in the recent past will provide the overall incentive for such a tracing system to be put in place. These factors include the increase in awareness that the U.S., the safest food supply in the world, may need additional protection from potential terror risks. 9/11 provides evidence of vulnerabilities. In addition, disease outbreaks pose threats such as Foot and Mouth Disease (FMD) which has been very detrimental to the food animal industry in Europe. In the U.S., the effects of Bovine Spongiform Encephalopathy (BSE) have been directly felt in the beef industry and the ever looming possibility of High Pathogen Avian Influenza (AI).

Specifically, will the cost of implementing a traceability system with a cut-to-carcass level of precision, be covered by the cost benefits achieved during a recall situation. The possible benefits due to a traceability system are to decrease the chance of a recall by better record keeping and not to allow product that has potential to cause a recall to escape the processor's control. Furthermore, the size of a recall may be reduced by being able to more accurately identify when and where a problem occurred and specifically which product was affected. Also, the faster the product in a recall is removed from the retail shelf, the less likely that a cost will be incurred from harm to a consumer.

In addressing the problem, the major objectives are to determine whether the cost of a traceability system in a plant can be covered by the benefits of reducing the size of a recall or the probability that a recall will occur. In achieving this objective, a model is simulated given an estimated probability of a recall, cost of a traceability system, as well as the cost of a recall. The model is simulated for both a small beef plant of 400 head per day and a large plant of 5,000 head per day.

CHAPTER 2. LITERATURE REVIEW

Background on Recalls

The Food Safety Inspection Service (FSIS) within the United States Department of Agriculture (USDA) is responsible for the inspection of all meat, poultry, and egg products that contain 3% or greater amenable product produced in federally inspected facilities (USDA₁). The FSIS inspector helps to ensure safe, wholesome, and accurately labeled products. In the event that one of these factors is not met, a recall is necessary. A recall is a voluntary action by a manufacturer or distributor to remove food from commerce in order to protect the public from products that may cause health problems (USDA₁). A recall does not include a Market Withdrawal which is the removal of product from commerce for reasons that would not require legal action by FSIS or Stock Recovery which pertains to product that has not left the direct control of the firm (FSIS Dir. 8080.1, Rev. 4).

All recalls are voluntary and done by the manufacturer or distributor and either are initiated by either the company or at the request of FSIS (USDA₁). However, FSIS only recommends a recall if they are ready to exercise their legal authority to detain and/or seize any products which are believed to be adulterated or misbranded (USDA₁). FSIS also has the option of removing inspectors from a facility, which would not allow product produced during that time to legally enter commerce. Even when a recall is initiated by the manufacturer or distributor, the firm is expected to notify the FSIS Recall Management Staff (RMS) or Office of Field Operations (OFO) (FSIS Dir. 8080.1, Rev 4). According to the FSIS Directive 8080.1 Revision 4, FSIS verifies all recall activities, coordinates recall

actions with the firm, and provides assistance or information to recalls conducted by state inspection agencies.

FSIS lists four main ways that products which may require a recall are discovered: 1) The manufacturing or distributing company informs FSIS, 2) Through regular testing practices of FSIS, 3) FSIS field or program inspectors, and 4) State or local public health departments or other federal agencies such as the Center for Disease control (CDC) or Food and Drug Administration (FDA). FSIS Directive 8080.1, Revision 4 also lists consumer complaints as a source for discovery of a potential recall situation. Once the potential for a recall is brought to the attention of FSIS, the agency follows its procedure to determine the need for a recall. The steps outlined in FSIS Directive 8080.1, Revision 4 are to conduct a preliminary inquiry, preliminary recall evaluation, and to make a recall recommendation. The preliminary inquiry step outlined is explained in further detail as collecting, documenting, and verifying information about the product of concern. This information includes establishment number, company name and address, as well as company's media and consumer contact personnel, and the reason for the potential recall. Further information concerning all brand names, package types or codes, as well as any information about where the product may have entered commerce is collected. The FSIS recall committee will then evaluate all potential health effects and a potential recall plan before making a decision as to whether a recall is deemed necessary. The recall committee bases the need for a recall on three questions: 1) is there a reason to believe a product is adulterated or misbranded, 2) is the product available to consumers, and 3) is FSIS prepared to take action if a voluntary recall is not completed. FSIS recommends a recall if these questions are answered "yes".

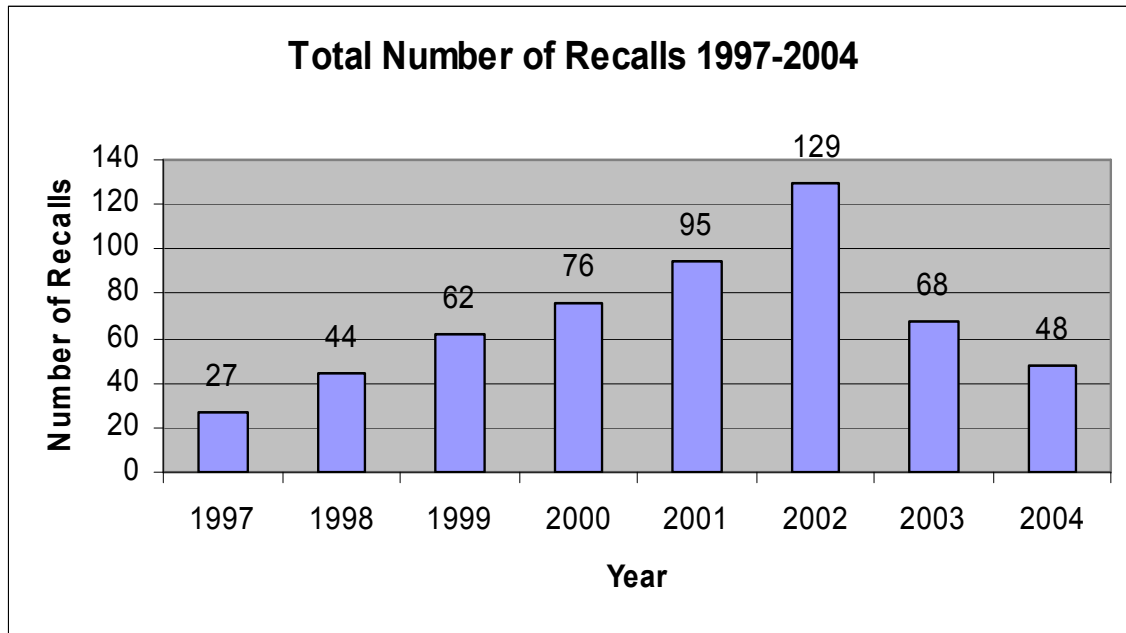
FSIS recognizes three classifications of recalls which include:

- A Class I recall is a health hazard situation where there is a reasonable probability that the use of the product will cause serious, adverse health consequences or death. Included in a Class I recall would be pathogens such as *Listeria* in ready-to-eat products or *E. coli* 0157:H7 in ground beef.
- A Class II recall is a health hazard situation where there is a remote probability of adverse health consequences from the use of the product. Class II recalls are typically cross contamination resulting in small amounts of undeclared allergens. According to the USDA the top eight food allergens: peanuts, crustaceans, fish, tree nuts, eggs, milk, soy, and wheat are the cause of 90% of all food, allergic reactions.
- A Class III is the lowest health risk recall where the use of the product will not cause adverse health consequences. Class III recalls can be due to undeclared ingredients, but generally recognized as safe (GRAS), excluding allergens and maybe due to excess water or mislabeling (USDA/FSIS News Release August 4, 2006 and FSIS Dir. 8080.1, Rev. 4).

A Recall Notification Report (RNR) is generated to notify all Federal, State, and local health and food inspection agencies for all recalls. A press release is issued for Class I and Class II recalls only unless a Class III recall was conducted due to adulterating a product for economical gains. Press releases may not be issued if all product under suspicion has been recovered before a release could be issued (FSIS Dir. 8080.1, Rev. 4). A press release contains a description of the product, reason, and risk associated with the recall, as well as the intended destination of the product (FSIS Dir. 8080.1, Rev. 4).

The total number of recalls was compiled from the FSIS RNR's and Press Releases and is reported in Figure 1. The RNR's do not include recalls that occurred in State inspected facilities.

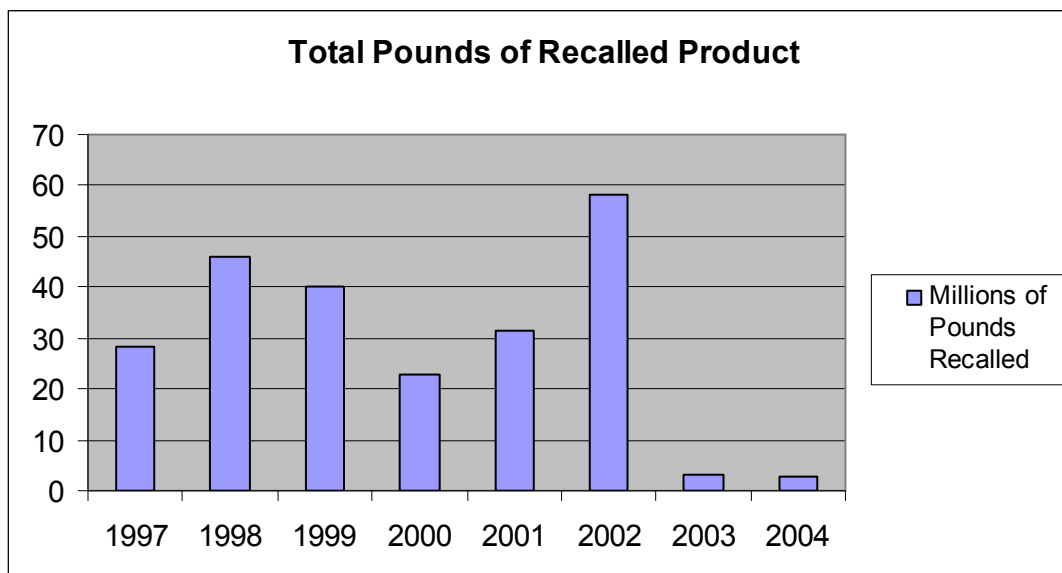
Figure 1.



The number of recalls range from a low of 27 in 1997 to a high of 129 in 2002. During this eight year period a total of 549 Recalls were conducted and an average of 69 per year.

During this same time period, the pounds of product recalled are illustrated in Figure 2. The range for the pounds of recalls per year is from 58.2 million in 2002 to 2.9 million in 2004. The average pounds recalled per year was 29.1 million pounds with an average size of 437,081 pounds per recall. The average size of recall was calculated based on 532 of the total 549 recalls, as 17 RNR did not specify the pounds of product to be recalled. The pounds recalled were much greater in 2002, which was due to a larger than normal increase in recalls due mainly to *L. monocytogenes*, allergens, and *E. coli*.

Figure 2. Total Pounds of Recalled Product by thousands



The number of Class I, II, and III recalls per year are shown in Figure 3. The total recalls over the period are: 419 Class I, 78 Class II, and 52 Class III.

Figure 3. Number of Recalls per year by Class

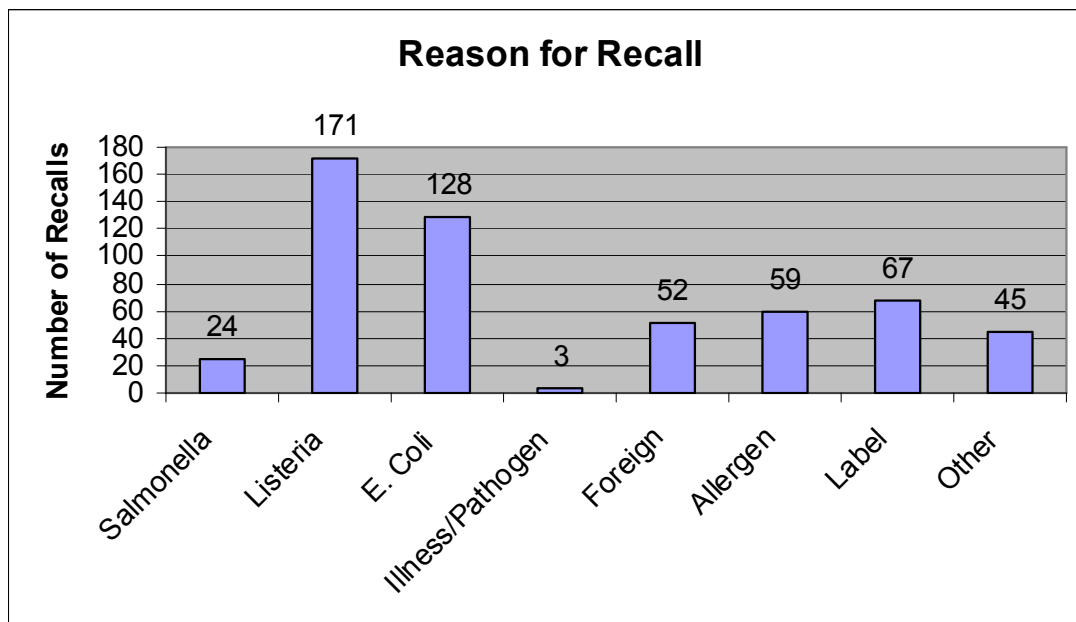
Year	Total Recalls	Class I	Class II	Class III
1997	27	16	11	0
1998	44	32	10	2
1999	62	54	7	1
2000	76	65	8	3
2001	95	69	12	14
2002	129	97	15	17
2003	68	45	12	11
2004	48	41	3	4
Total	549	419	78	52

Causes of Recalls

Listeria monocytogenes (*L. monocytogenes*), the single leading cause for a recall from the data compiled between 1997 and 2004, along with *Salmonella* were the cause of 195 recalls, which is 36% of the total 549 recalls. An additional pathogen, *Escherichia coli* (*E. coli*) 0157:H7, was also a major reason for meat and poultry recalls during this time

period. The total recalls for *L. monocytogenes*, *E. coli*, and *Salmonella* account for 323 recalls or 59% of the recalls over the years 1997-2004. The numbers of total recalls for each cause over the time period are illustrated in Figure 4 and the number of recalls per year by cause is in Appendix A. The illness/pathogen category includes pathogens besides *L. monocytogenes*, *E. coli*, and *Salmonella* or an illness caused by an unidentified pathogen. Foreign material would include any glass, plastic, metal, oil, drug, or chemical. Common allergens in meat and poultry recalls include soy, dairy, peanuts, fish, or shell fish. The labeling category includes mislabeling, undeclared ingredients, and misbranding. Other reasons consist of undercooking, illegal entry into the United States, improper cooling, Bovine Spongiform Encephalopathy (BSE), not properly USDA inspected, undocumented formulation, spoilage, and held or produced under unsanitary conditions.

Figure 4. Reason for Recall



Listeria monocytogenes

Listeria monocytogenes, the single greatest cause of meat and poultry recalls from 1997-2004, accounted for 31% of the total. *L. monocytogenes*, is considered an adulterant¹ in RTE meat and poultry products and would be a cause for a Class I recall, as it is a pathogenic bacterium. Meat and Poultry products containing *L. monocytogenes* are prohibited from entering any form of commerce by the Federal Meat Inspection Act (FMIA) and the Poultry Products Inspection Act (PPIA). *L. monocytogenes* is commonly found within the environment including soil, water, and vegetation. The CDC reports a 20% fatality rate for *L. monocytogenes* and is of particular concern to the elderly and infants since the fatality rate increases with the age extremes (Federal Register, 2003). Furthermore, 28% of food-related deaths have been estimated to be caused by *L. monocytogenes* (Mead, et. al., 1999). Listeriosis can cause still births in pregnant women. Immunocompromised persons are at greater risk including cancer patients undergoing Chemotherapy or Human Immunodeficiency Virus (HIV). The USDA requires one of three options for additional control of *L. monocytogenes* in ready-to-eat products. The first is by sanitation alone, which includes additional testing of the product and contact surfaces. Second would be reformulation of the product to include antimicrobial agents² such as lactates or diacetates to control *L. monocytogenes*.

¹ A meat or poultry product is adulterated if it contains any poisonous or deleterious substance that may render it injurious to health (21 U.S.C 601 (m) (1), 453 (g) (1)). Also, if it has been prepared, packed, or held under unsanitary conditions whereby it may have been rendered injurious to health (21 U.S.C 601 (m) (1), 453 (g) (1)).

² An Antimicrobial Agent is defined by FSIS in 9 CFR 430.1 as a substance in or added to an RTE product that has the effect of reducing or eliminating a microorganism or of suppressing or limiting its growth throughout the shelf life of the product.

Lastly, a post-lethality¹ process² of the product is an option, which may include an in package method (Federal Register, 2003). The number of positive samples in *L. monocytogenes* testing of ready-to-eat meat products has declined from 1995 to 2003 from a high of 3.02% in 1995 to a low of 0.75% in 2003 (Murano, 2004). However, from the data compiled during this research 171 recalls were due to *L. monocytogenes* or 31% of the total 549 recalls between 1997 and 2004, and 41% of the 419 Class I recalls. The trend of the food industry toward more convenience type products including fully cooked meat or poultry make *L. monocytogenes* into a primary concern due to the nature of the organism. It is psychrotrophic meaning it can live and reproduce at refrigerated temperatures and as stated by Samelis and Metaxopoulos (1999) at temperatures around 0°C. *L. monocytogenes* is typically more heat resistant than other non-spore forming pathogens and has been shown to have a D value³ at 70C of 0.14 to 0.27, and would require two minutes at 70C to achieve a 6 Log reduction (Gaze et. al., 1989). However, Lin et. al. (2006) states that when comparing isolates the raw product is rarely the source of contamination in the final product. This is in agreement with other studies as the processing environment including equipment and personnel have been suggested as of a greater source of *L. monocytogenes* in product (Nesbakken, et. al., 1996, Lin et. al. 2006, Rørik, et. al., 1995).

¹ The processing environment in which a product may be exposed which has gone through an initial lethality process. FSIS 9 CFR 430

² A post-lethality treatment is applied to the final product or sealed package after post-lethality exposure to reduce or eliminate pathogens. FSIS 9 CFR 430

³ The D value is defined as the time required to reduce the number of organisms by 1 log or 90% at a given temperature.

Due to the nature of production of certain products that require contact of equipment or personnel especially slicers, after cooking, FSIS has classified deli meats and frankfurters as a high risk to *L. monocytogenes* (Federal Register, 2003).

Escherichia coli 0157:H7

Escherichia coli 0157:H7 the second most frequent cause of meat and poultry recalls from 1997-2004 accounted for 128 of 549 or 23% of the total. Furthermore, 3% of food-related deaths have been estimated to be caused by *E. coli* (Mead, et. al., 1999).

Cattle are the primary source of *E. coli*, as they are carriers of the organism in their intestine, which may be transferred to the carcass; consequently, undercooked ground beef is of primary concern with the contraction of the infection. The onset of the disease is typically 3-4 days after ingestion of the live organism (CDC, 2006). Clinical symptoms associated with *E. coli* include bloody diarrhea and abdominal cramps, as well as hemolytic uremic syndrome (HUS) a condition causing kidney failure and destruction of red blood cells. (CDC, 2006) Most symptoms are reduced after 5-10 days; yet, the development of HUS can have permanent health consequences such as blindness, paralysis, kidney failure or abnormalities in later years, or bowel removal (CDC, 2006). An *E. coli* infection can be prevented by cooking food to the proper temperature as the organism is killed if the temperature reaches 160F (USDA).

Non-intact beef as defined by FSIS is adulterated if found to contain *E. coli* or product intended to be processed into non-intact product that will not go through further processing sufficient to kill the pathogen. Trimmings are considered intact beef and non-intact product is any beef that has gone through a mechanized process such as grinding, cubing, injection or tenderization.

Salmonella

According to the USDA *Salmonellosis* is the second most reported foodborne illness and is estimated to cause 1.4 million sicknesses, 16,000 cases causing hospitalization, and 600 deaths by the CDC. However, *Salmonella* was only responsible for 24 or the 549 recalls which is 4% of the total meat and poultry recalls reported from 1997-2004.

Salmonellosis is caused by *Salmonella* and has reported symptoms of diarrhea, fever, or abdominal cramps with a typical cycle lasting 4-7 days (ERS, 2003). The organism lives in the intestinal tracts of animals. As with other illnesses infants and the elderly are the most adversely affected, particularly the elderly as the majority of the deaths occur in persons older than 65 (ERS, 2003). *Salmonella* has been shown to survive at high temperatures if it can shed some of its own water during low humidity of the early cooking process (ProMED-mail, 2003). This means that heat must be applied in combination with humidity as the organism is capable of surviving a dry heat. It has been reported that the lethality wet-bulb temperature to kill *Salmonella* is 130F for two hours, 140F for 12 minutes, or 160F for 8 seconds (ProMED-mail, 2003). This organism may be of particular concern to products that are dried during processing, such as jerky, semi-dry sausages, and dry sausages, in which higher humidity would be undesirable as it would lengthen the thermal treatment. Furthermore, 31% of food-related deaths have been estimated to be caused by *Salmonella* (Mead, et. al., 1999).

Traceability

Traceability is defined by Golan et al. (2004) and Souza-Monterio and Caswell (2004) as the ability to follow the history, application, or location, of that which is under consideration, particularly food through the production processes. As described by Caporale

et al. (2001) the United States Environmental Protection Agency (EPA) further adds to the definition as the ability to document all relevant movements, processes, and controls needed to define an animal/animal product's life or history. It is understood that the system must be able to document these activities in a timely manner to be effective.

Traceability can be measured in three ways breadth, depth, and precision. Golan et al. (2004) and Smith (2005) Breadth is the total amount of information collected to define an animal product through the production process. Depth is how far forward or backward in a production process that a product's history can be traced. Precision is the degree of assurance that a system can pinpoint movement (Golan et al. 2004 and Smith 2005). Identity preservation is also referred to as traceability and is suggested to include inputs in the food marketing chain (Liddell and Bailey 2001). Transparency is a term used to describe the information that is available to outside sources such as the rules, procedures, and practices along a food chain (Baines and Davies 1998 and Liddell and Bailey 2001).

The recent outbreaks of Foot and Mouth disease in Europe, high pathogenic avian influenza abroad, and particularly BSE in the United States beef industry in December of 2003 have provided the incentive for APHIS to start planning an animal identification system. The United States Animal Identification Plan (October 2003) was developed by government officials as a basis for a system that allows for complete tracing of an individual animal's premise history within 48 hours. From the USAIP the National Animal Identification System (NAIS) was announced in April of 2004, which was developed by a team of 100 people representing 70 groups involved in the animal food industry. This team built on the USAIP and focused on the beef industry as the starting point for traceability.

The National Animal Identification System is referred to as the “Live Animal System.” NAIS is designed to trace an animal’s entire history within 48 hours of an infectious disease outbreak. The history includes each premise the animal was ever at, as well as other animals that it came into contact with throughout its lifetime. A premise is defined by USDA as a unique and describable geographic location where activity affecting the health and/or traceability of animals may occur. Furthermore, a premise is further defined as any place that animals commingle and a spread of disease may occur, which include but are not limited to sale barns, farms, shows, feedlots, and packing plants. In NAIS, Premises must be registered by a seven digit code and attributes of premise recorded with the USDA. These attributes include contact name, type of premise, and location. As of March 9, 2007, 374,289 or 26% of the total 1,438,280 premises have been registered in all 50 states including 2 territories, and 5 tribes. Currently, Wisconsin is the only state that has required premise registration. States such as Texas has postponed premise registration due to the strong opposition by producers. Vermont has also postponed premise registration until USDA has a detailed plan of action. The USDA timeline for a trace system was to start identification of individual animals in March of 2006, by June 2006 have a cooperative agreement with private or State held tracking databases, and by 2007 the databases were to be operational (Adams and Wilson, 2004). Currently, the USDA is issuing animal identification numbers and storing information in USDA held databases. Although originally proposed as a mandatory program, participation in the program remains voluntary.

Mandatory animal identification is opposed by some producers as they believe this infringes on their personal freedom. Producers also are aware that an added cost is associated with the ability to track an animal. The tracking of an animal to the final

inspection station alone may not provide enough economic incentive for producers to support such a program. Still other producers prefer a vertical traceability system to allow for adequate branding of their product (Mennecke and Townsend 2005). About 53% of food processors feel the cost outweigh the benefits, while an even larger percentage of producers believe this (Crews, J. 2004). Many individuals along the food chain are concerned with an added liability, but as in the case of the BSE animals in the U.S., the origin of the animals was still discovered, but it took a longer time period. A traceability system does not change the laws of who is liable in food safety litigation, but if the source of hazards are positively identified it is easier to hold the guilty agents responsible (Souza-Monterio and Caswell 2004). This may also be an incentive for food processors to take pro-active measures to reduce any food safety concerns (Souza-Monteiro and Caswell 2004).

In contrast to opposition, an accurate record of traceability may provide proof that all measures were taken to ensure that food safety concerns were met; therefore, reducing the risk of being wrongfully held liable. This has been evidenced by HACCP records, which only pertain to food safety issues not quality. The basis of most recalls is a clear food safety issue as most Recall Notification Reports are class I recalls, the most likely to cause severe health effects. HACCP records can provide assistance in determining lot codes and materials or ingredients that may be included in a product during the event of a recall (Scott 2006). HACCP records must be kept for at least one year relative to slaughter processes or non-shelf stable refrigerated products, while frozen or shelf stable product records must be kept for two years (Scott 2006 and USDA/FSIS).

However, the debatable topic of traceability not only raises questions about the benefits of knowing information versus the cost of giving up privacy, but also the cost of

implementing a system versus the benefits that the system provides. If the animal identification system becomes mandatory, it is determined to end in the food chain when the animal is declared wholesome and safe to enter the food supply by a USDA inspector (USDA₂). USDA is currently making no plans for a mandatory system (USDA₂). The USDA and States would only collect and retain necessary identification data in the preharvest production chain and through final inspection at slaughter establishments (USDA₂).

Linking the information from producers of the live animal to the food product may prove valuable for harvesting facilities to continue the tracing of each carcass. Once a live animal trace back system is in place the necessary infrastructure is in place to allow information to be tied to an animal with little cost or effort. This may allow for the identification of credence attributes through the food chain to the final product. These attributes may be of added value, but are not readily identifiable in the finished product. Credence attributes may include product from animals with certain handling practices prior to harvest or the type of feed such as organic or grass fed.

Many facilities already track a group of carcasses rather than individual carcasses to be able to pay the producer on a grid based on USDA quality and yield grades, carcass weight, and premiums or discounts. Tracking may be taken a step further to identify individual carcass traits which may be relayed to the producer to make decisions such as genetics, feed rations, marketing weight, or handling methods. This valuable information to the producer may support some of the cost of an ID system.

Traceability can provide a premium or value for information to not only cover the cost of a tracing system, but may provide a profit. It is well researched that consumers are

willing to pay a premium for certain attributes for their food supply (Dickinson and Bailey, 2001). If international consumers are willing to pay more for traceability attributes of a product, the United States producers that do not have traceability may not receive the same premium as producers in other countries whom have traceability systems in place. In the United Kingdom, traceability actually ranked ahead of price when supermarkets purchased meat (Dickinson and Bailey, 2001). Traceability premiums for a \$3.00 roast beef sandwich were estimated to be \$0.23 for basic traceability, \$0.50 for animal treatment, and \$0.63 for guaranteed food safety, and \$1.06 for all the attributes combined (Dickinson and Bailey, 2001). Consumers in Canada have also shown a willingness to pay less than a 10% premium on a \$2.50 roast beef sandwich for traceability (Hobbs, 2003). The United States may lose a portion of its market share if prices are similar and the product has less attributes. Many of the U.S.'s export markets are requesting traceability including Japan the largest importer of US beef prior to 2004 (Vanderveer, 2007).

When trade is open to Japan only carcasses from beef animals 20 months of age or less are permitted. To ensure that no carcasses of animals older than 20 months have been allowed a USDA grader assigns a maturity score based on physiological maturity. To allow for error between physiological and chronological age, a maturity score of A 40 approximately 15.8 months was determined acceptable for Japanese export. This reduced the error of including a carcasses of an animal greater than 20 months to less than 0.01% (Ransom, 2005). Carcasses in this maturity range represent about 8% of the beef harvested in the United States (Ransom, 2005). If the age could be verified by previous tracing of an animal, a larger portion of the beef supply would be eligible for export to Japan which would lead to a wider market base.

Domestic markets are beginning to require higher levels of traceability. McDonald's the world's largest food service company and buyer of beef, including over 1 billion pounds per year in the U.S. alone is paying a premium for the ability to trace the beef it purchases to a particular lot (Ishmael, 2005). In some areas where traceability is more difficult to achieve, it is reported that McDonald's is offering a premium of up to \$30 per head for traceability (Ishmael, 2005). The world's largest retailer of meat is Wal-Mart which has issued mandates that its top 100 suppliers use RFID tags on pallets and cases (Arnold, 2005). Traceability only allows for the identification of attributes and does not create any specific quality attributes for a product along the supply chain. Although traceability itself may become a quality or brand attribute (Mennecke and Townsend, 2005).

An important question that was raised by Golan et al. (2004) is what level of traceability is economically efficient. Mennecke and Townsend (2005) added identification of food products from individual animals through the entire food chain may not be efficient and a production lot may be optimal. The optimum amount of traceability may be a difficult question to access. When determining the cost of a traceability system it becomes more expensive and complicated as the precision becomes greater; therefore, an efficient level to ensure a profit must be determined. Reduced recall expense due to smaller lot size may play a role in determining a level of equilibrium. In future marketing of a product, the question of the optimal amount of traceability may be outweighed by the question of whether a product can be marketed at all without traceability (Beil 2005).

A certain level of traceability must exist within a plant for food safety including HACCP records, as well as allowing payment to be made to producers based on merit of carcasses. In a processing facility, additional traceability may offer greater food safety and

reduced size of recalls or the number of recalls. Is the benefit of reduce costs from recalls large enough to offset costs from additional tracing of products.

CHAPTER 3. METHODS AND MATERIALS

Objectives

The objective is to determine the cost and benefit trade off between the cost of traceability and benefits in both a large and small scale animal harvesting/processing facility. A large facility is defined as 5,000 head of beef per day and a small facility is defined as 400 head of beef per day. Specifically, will the cost of implementing a traceability system with a cut-to-carcass level of precision, be covered by the benefits achieved during a recall situation. The possible benefits associated with improved traceability are to decrease the probability of a recall by better record keeping and not allowing product that has potential to cause a recall to escape the processor's control. Furthermore, the size of a recall may be reduced by being able to more accurately identify when and where a problem occurred and specifically which product was affected. Also, the faster the product in a recall is removed from the retail shelf, the less likely that cost will be incurred from harm to a consumer. In achieving the objectives, an economic model was used taking into consideration pre-event actions; i.e., investment in a traceability system. Post-event actions or the direct costs of a recall will be considered, as well as a loss function to account for economic loss to a consumer due to negative adverse effects from consuming a product included in a recall. The hypothesis is that the benefits of reduced cost associated with recall will be of value, but may not entirely cover the cost of such a precise traceability system.

Model

Elbakidze and McCarl (2006) developed a model that can be used in a number of events that have a low probability of occurrence but with very large losses, and that the

effects may be reduced by taking actions before such events occur. In this particular model animal disease preparedness or pre-event factors were economically weighed against the probability of an outbreak occurring and post-event factors. The animal disease in consideration was Foot and Mouth, which included an estimate of the low probability of occurrence, cost of factors that would help to control an outbreak, and the cost of post-outbreak factors.

We used the model in equation (i) by Elbakidze and McCarl (2006) to determine the cost effectiveness of using a traceability system to reduce the cost of a recall.

Equation (i). $C = P[L(s, r, \partial) + w_s s + w_r r] + (1 - P)w_s s$

The model was applied in a micro manner to a specific plant rather to the industry as a whole. The focus of the model is (C) or the average cost of a recall considering ingoing factors. We have considered pre-event factors (s) or pounds of product to be traced, probability of event (P), and post-event factors (r), as well as the severity of events (∂) stemming from a recall situation. Where (w) is the unit cost of s or r respectively. An estimation of the value for each factor is plugged into the model, then simulated 1.5 million times with Crystal Ball software 7.2.2. It is simulated using two random variables; probability of a recall and average recall size. The software takes the average for all the simulations having a random draw for both probability and average size of a recall.

Pre-Event Factors

Traceability is the only factor that is chosen to be analyzed as a pre-event factor in this model. Other pre-event factors include, but are not limited to PR/HACCP implementation of more stringent SOP's, GMP's, and SSOP's. Also recall insurance may help to cover some of the costs associated with a recall which may included direct recall

expenses, such as recovering and disposal of the product, as well as any additional product testing to aid in the recall process. Other expenses that may also be included are public relations expenses both during and for a time period after a recall occurs to aid in rehabilitation of the consumer's perception (www.meatami.com accessed 10/24/06).

The pre-event factors include both (w_s) the unit cost of traceability and s the pounds of product being traced through the plant. (W_s) has been estimated from private sources to be from \$0.03 to \$0.07 per carcass or \$0.00009537 and \$0.00004087 per pound respectively for a large plant and for a small plant up to \$9.54 per carcass or \$0.013 per pound. The differences in the cost of traceability for a small versus a large plant are partially due to economies of scale. The same technology cost spread over 400 head would be larger per unit than the cost spread over 5,000 head. Additionally, the estimates from private sources may be for traceability systems of varying precision. The large plants cost may be underestimated by private sources whom market this type of technology. To compensate for cost variations, a sensitivity analysis was performed for varying cost levels of traceability.

In determining the pounds of product traced within a plant, an estimate of the number of head per day was multiplied by the number of days worked per week and by the number of weeks worked per year. The result is the number of head harvested per year. The number per year is multiplied by an average carcass weight, resulting in the pounds produced per year in a commercial plant. The number of pounds produced per year are displayed in Figure 5. The average hot carcass weight was determined from USDA's Red Meat Yearbook. The total estimated head harvested between 1997 and 2004 was 283.5 million and the total production of commercial meat was 208.2 billion pounds. Therefore, the weighted average for carcass weight was 734lbs; the simple average over each year was also 734lbs.

Figure 5.

Head per day	400	5,000
Days per week	5	5
Weeks per year	51	51
Total Head per year	102,000	1,275,000
Average HCWT	734	734
Total lbs. per year	74,868,000	935,850,000
Total bnls. lbs per year	37,434,000	467,925,000

Probability

Determining the probability of a recall in the meats industry provides many challenges. These challenges occur because of the large number of transactions between production, wholesale, distribution, and retail, which all have potential to cause a recall. This is also a very large industry as the total meat and poultry consumption in the U.S. between 1997 and 2004 totaled 477.6 billion pounds with an average of 59.7 billion pounds per year. Consumption totals were estimated from per capita consumption of beef, veal, pork, lamb, chicken, and turkey, multiplied by U.S. population per year reported by the Economic Research Service (ERS). Consumption of all species were totaled using a retail cut equivalent except turkey which was based on a boneless, trimmed equivalent as a retail cut basis was not available. The eight year span of data was chosen to provide a good estimate of the consumption while providing the ability to accurately forecast future events, as this will include the most common practices currently effecting variables in the model. The main industry practice is the Pathogen Reduction/Hazard Analysis and Critical Control Points (PR/HACCP) that was introduced as legislation in February 1995 and passed in July of 1996.

This required establishments in the food industry to have written standards in place by

January of 1997. Therefore, the data analyzed began in 1997 and continued through year 2004 which was the most current data available from ERS.

The total pounds of all meat and poultry recalled for the same time period 1997-2004 was taken from Recall Notification Reports (RNR) in FSIS Recall Case Archives. The total pounds recalled were 232.5 million with 549 recalls averaging 423,547 pounds per recall over the eight years. The probability of a recall per pound is calculated as pounds recalled (232.5 million) divided by total consumption (477.6 billion), for a probability of 0.00049 per pound. This probability per pound can then be multiplied by the total pounds produced in a plant, which has been converted to a boneless, closely trimmed basis. The boneless closely trimmed percentage is based on a Yield Grade 3 carcass, which USDA predicts to be between 47.7% and 50.0%. Therefore, the average hot carcass weight is multiplied by the estimated percent of boneless, closely trimmed retail cuts. This is divided by the average recall size to give the probability of having an average sized recall. It is relevant to note that these recalls only included FSIS or federal recalls and do not include the recalls conducted in conjunction with the 28 state inspection services. Also, 17 federal recalls were not included in the total pounds during this time as the amount to be recalled was not reported. For both of these situations, state conducted recalls and recalls without pounds reported, the total amount of recalls and quantity would increase. Two factors that would decrease the number and amount of recalls are reports of recalls included that at least a portion was exported outside the U.S. and recalls that were of product that included foods other than meat and poultry, such as chicken salads or chili.

Furthermore, the probability of a significant recall was calculated in the same manner, defined as a recall of 5,000 pounds or greater. For this the number of recalls of 5,000 pounds

or greater was 279 for a total of 232.2 million pounds with an average size of 832,429. Therefore, the total pounds recalled in recalls of 5,000 pounds and greater is divided by the total consumption (232,247,656 lbs / 477,589,913,700 lbs). This gives the probability of a recall per pound. This is multiplied by the total pounds produced on a boneless weight. The boneless weight is determined by multiplying the total pounds produced per year by an average percent of boneless closely trimmed retail cuts for both a small and large plant and represented in Figure 5. This is then divided by the average recall size to get the probability that will be used in the model which is the probability of having an average size recall in both a small and large plant. The probability of having an average sized recall during the year for a small plant is 0.02189 and 0.27268 for a large plant.

Post-Event Factors

Recalls have many factors that incur cost associated with post-event factors. These events include the physical recall of product in question, cost of replacing product or refunding the value of product, and disposal of product. Other costs may come in the form of governmental fines and/or legal actions by entities that were harmed. Indirect cost may also result from recall in the form of negative publicity and decreased consumer demand for products. AMI which offers insurance on recalls list possible costs that are included in the coverage plan as recall expenses of actual product, storage or moving of product, and further testing of product, lost profit up to one year, customer's expenses, rehabilitation expenses to restore market share and public relations, and crisis management related managing a recall.

In our estimation of recall post-event costs, the unit cost (w_r) and pounds of product recalled (r) are considered. The unit cost is based on an average retail price of beef from the ERS/Bureau of Labor and Statistics (BLS) (www.lmic.info) based on a Choice, Yield Grade

3 carcass, which is \$3.25. In addition, to the average retail price 40 percent over the retail product cost was added to cover other recall expenses that give a total of \$4.55. These expenses include but are not limited to physical recovery of product, disposal, and decreased consumer demand. The pounds of product are the total boneless pounds per year for both a small and large plant, also listed in Figure 5.

Severity of Recall Events

The potential severity of a recall situation was based on the ERS cost estimates of the foodborne disease *Salmonella* (ERS, 2007). These estimates were compiled from various sources including: Medical costs from the MarketScan database of MEDSTAT Group and lost productivity from the National Health Interview Survey.

The costs are a subdivided into four categories; a full recovery without a physician, full recovery with physician, full recovery with hospitalization, and hospitalization along with death. The costs are the total economic effect including medical expenses, lost productivity, and premature death. Based on the total economic effect of all the categories and the number of cases for each an average economic impact of \$2,126 is determined. The total economic impact reported by ERS for each category is in Figure 6. The total cases reported is divided by the total pounds of consumption for the number of cases per pound of product consumed. Then the number of cases per pound (0.000002958) is multiplied by the weighted average per case (\$2,126) for a cost per pound of product (\$0.00629). The cost per pound is then multiplied by the pounds produced on a boneless basis within a plant for the total cost to the plant, which is \$235,386.14 for a small plant and \$2,942,326.73 for a large plant.

Figure 6. Total economic impact of Salmonella. Source ERS

Severity of Case	Number of Cases	Total Economic Impact (Million dollars)
No physician; recover fully	1,294, 107	55.6
Visit physician; recover fully	101,903	40.9
Hospitalized; recover fully	15,906	208.6
Hospitalized; die	582	2,698.0
Total	1,412,498	3,003.1
Weighted Average		\$2,216.00

In support of possible costs if the product in a recall causes injury to the consumer, Marler Clark Attorneys at Law a well known as a leader in food borne illness litigation lists settlements and verdicts due to food borne illness such as a \$15.6 million settlement for the most seriously injured person in the 1993, E. coli outbreak at Jack in the Box. Marler and Clark also list a \$4.6 million verdict for eleven children who were sickened by E. coli due to hamburger in school lunches at Finley, Washington in 1998.

Comparative Static Analysis

Equation 1 is the base model and contains all the variables under consideration. P is the probability or the likelihood that an event would occur and in our particular case a recall of meat or poultry. (L) is a function of variables that would represent to the economic loss if a recall occurs. The variables in the loss function are the (s) the pre-event factors, which in this case the event is a recall of meat or poultry and the pre-event factor is the investment in a traceability network. While (r) is the post-event or recall factors which would include any cost associated with the occurrence of a recall. The remaining variable (θ) is a measure of

the severity of the recall and any adverse effects from such an event. Furthermore, w_s represents the per unit cost of traceability prior to a recall occurring, while w_r is the unit cost of post recall factors. Additionally, the P is also included on the right hand side of the equation as $1-P$ multiplied by the traceability or pre-event factors as the cost of traceability will still be incurred regardless of the chance of a recall. However, the post recall expenses will only be expressed if a recall occurs and is directly reflected by the estimate of P .

$$\text{Equation 1. } C = P[L(s, r, \partial) + w_s s + w_r r] + (1 - P)w_s s$$

The first order conditions are derived by taking the derivative of Equation 1 with respect to both traceability (s) and (r) adverse effects of a recall and are represented in Equation 2 and 3 respectively.

First order conditions

$$\text{Equation 2. } PL_s(s, r, \partial) + w_s = 0$$

$$\text{Equation 3. } L_r(s, r, \partial) + w_r = 0$$

The model is then represented in a matrix form as in Equation 4 from which Cramer's rule is applied to be used in a comparative static analysis. Equations 5-12 are the results of derivatives of both pre-event actions (s) and post-event consequences (r) with respect to each of the fixed variables: cost of traceability (w_s), cost of a recall (w_r), severity of recall events (∂), and the probability of a recall (P).

Equation 4.

$$\begin{pmatrix} PL_{ss} & PL_{sr} \\ L_{rs} & L_{rr} \end{pmatrix} \begin{pmatrix} ds \\ dr \end{pmatrix} \Rightarrow \begin{pmatrix} -dw_s - L_s dP - PL_{s\partial} d\partial \\ -dw_r - L_r d\partial \end{pmatrix}$$

Equation 5.

$$\frac{-L_{rr}}{P(L_{ss}L_{rr} - L_{sr}^2)} = \frac{ds}{dw_s}$$

Equation 6.

$$\frac{L_{rs}}{P(L_{ss}L_{rr} - L_{sr}^2)} = \frac{dr}{dw_s}$$

Equation 7.

$$\frac{L_{sr}}{L_{ss}L_{rr} - L_{sr}^2} = \frac{ds}{dw_r}$$

Equation 8.

$$\frac{-L_{ss}}{L_{ss}L_{rr} - L_{sr}^2} = \frac{dr}{dw_r}$$

Equation 9.

$$\frac{-L_{s\hat{\partial}}L_{rr} + L_{r\hat{\partial}}PL_{sr}}{L_{ss}L_{rr} - L_{sr}^2} = \frac{ds}{d\hat{\partial}}$$

Equation 10.

$$\frac{-L_{ss}L_{r\hat{\partial}} + L_{s\hat{\partial}}L_{rs}}{L_{ss}L_{rr} - L_{sr}^2} = \frac{dr}{d\hat{\partial}}$$

Equation 11.

$$\frac{-L_sL_{rr}}{P(L_{ss}L_{rr} - L_{sr}^2)} = \frac{ds}{dP}$$

Equation 12.

$$\frac{L_sL_{rs}}{P(L_{ss}L_{rr} - L_{sr}^2)} = \frac{dr}{dP}$$

A comparison of pre-event, post-event, severity, and probability was done by a comparative static analysis. From Equation 1, first order conditions were determined by taking the derivative of both cost of pre-event and cost of post-event factors and set equal to 0. Using Cramer's rule the comparative analysis by Elbakidze and McCarl 2006 was verified and the detailed formulas are in appendix A. After verifying that the previous analysis was correct, it was applied to a meat and poultry recall scenario. In the case of Equation 5, a downward sloping demand curve is shown by the negative sign; therefore, a higher unit cost of the pre-event action of traceability the less of that factor would be demanded. This supports common expectations that the more costly a traceability system is then the less likely a meat processor will invest in this particular technology.

Equation 8 can readily be signed as negative, which in our model is determined by deriving with respect to cost of post event factors. The negative sign also shows a downward sloping demand curve or simply the higher the cost of post event actions or expenses associated with a recall indicates less recalls are more desirable. This is also as expected.

The signs of both Equation 9 and 10 are dependent on the sign and magnitude of L_{sr} , $L_{s\delta}$, and $L_{r\delta}$ as stated by Elbakidze and McCarl, which are respectively; the loss due to traceability with respect to a recall, the loss due to traceability with respect to the severity of the recall, and loss due to a recall with respect to severity of a recall. However, in Equation 9 it would be expected that an increase in the severity of factors associated with a recall would have a positive sign or more pre-event security.

Yet, with Equation 10 a negative sign is expected as an increase in the severity of a recall would lead you to expect a decreasing demand curve for any post-event recall factors.

The sign for Equation 11 follows the presumed pattern of having a positive or increasing demand curve. This indicates an increase of the probability of the occurrence of a recall, and will also result in the increase in the demand for pre-event actions or traceability.

Equation 12 is essentially meaningless except for supporting the model in that it has a positive sign, which means that as the probability of a recall increases so does the post-event recall factors.

Computer Simulation

The model was simulated using Crystal Ball 7.2.2 an add-in for Excel. The model simulated the average cost for a recall. The fixed variables included the cost of traceability per pound, pounds produced per year for the plant, cost of recovering recalled product, as well as cost of negative consequences based on the severity of the case. The probability was a random variable simulated by a triangular distribution with a maximum of 1 and minimum of 0 and the mean estimated from data as the likeliest value. The likeliest value for a small plant was 0.02189 and 0.27268 for a large plant. Average recall size was the second random variable simulated with a lognormal distribution using the mean and standard deviation from the recall notification reports of pounds of product recalled. The mean recall size is 832,429 with a standard deviation of 4,061,619 pounds. The distribution of pounds recalled is illustrated in Figure 7, which is most accurately represented as lognormal. In the simulation the distribution is based on recalls of 5000 pounds and greater. This included 279 recalls with a total of 232,247,656 pounds and an average size of 832,429 pounds. The model was then simulated 1.5 million times the largest number possible with the available equipment. This simulation was run for both a small 400 head per day plant and a large 5000 head per day plant. The fixed variable of traceability for each plant used a traceability cost of \$0.013

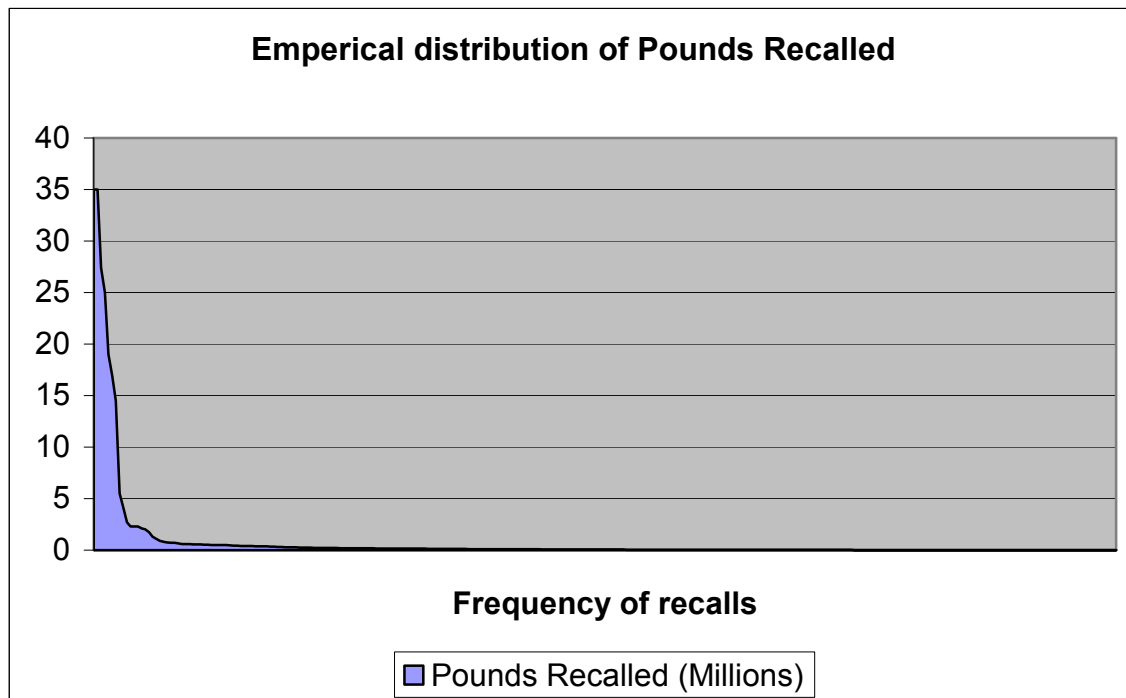
per pound in a small plant and \$0.07 per head in a large plant. The model for a 400 head a day plant is below with the average plugged in for the simulated variables probability and average size of a recall.

$$C = 0.02189[\$235,386.14 + (\$0.013 * 74,868,000) + (\$4.55 * 37,434,000)] + (1 - 0.02189)(\$0.013 * 74,868,000)$$

The same model for a 5,000 head per day is listed below.

$$C = 0.27268[\$2,942,326.73 + (\$0.00009537 * 935,850,000) + (\$4.55 * 467,925,000)] + (1 - 0.27268)(\$0.00009537 * 935,850,000)$$

Figure 7. Distribution of recalled pounds



CHAPTER 4. RESULTS

The results of the simulation or recall cost per year for a plant harvesting 400 head per day are in Figure 8. A small plant of 400 head per day is shown with an expected cost per year of recalls; without traceability, with traceability and no change to the recall costs, as well as a decrease of 50% to the average size of a recall, standard deviation of recall size, and the probability that a recall will occur. Also, the cost per head and cost per pound on a boneless retail basis are included.

Figure 8. Average simulated recall cost of a 400 head per day plant.

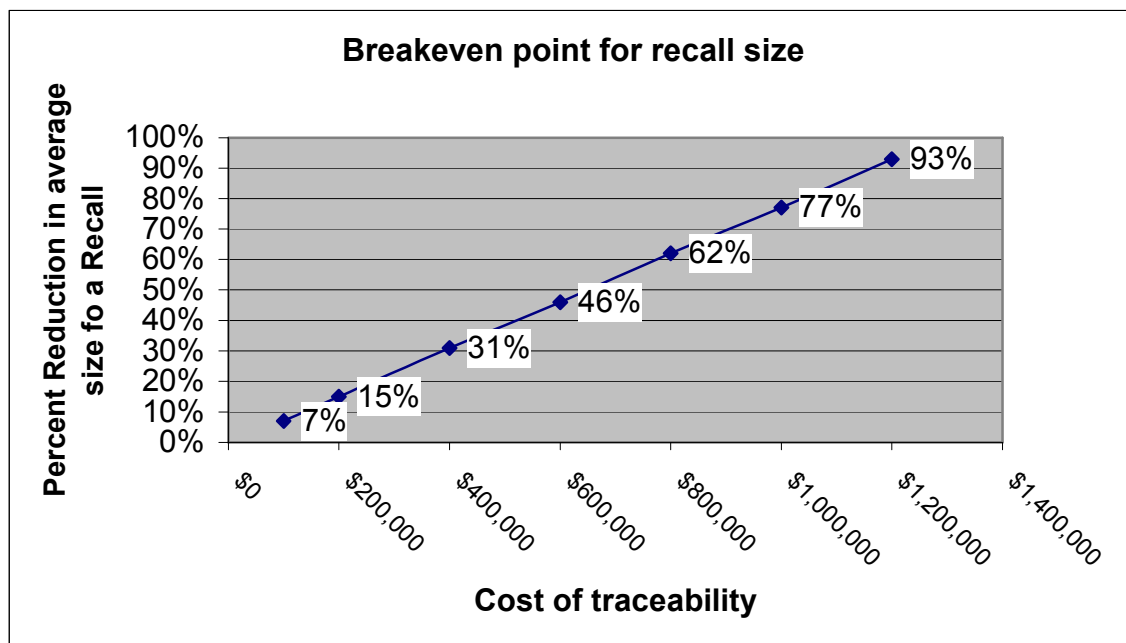
	Average Cost	Cost per head	Cost per pound
No Traceability	\$1,372,009	\$13.45	\$0.04
Traceability without benefits	\$2,343,751	\$22.98	\$0.06
Traceability reduced recall size by 50%	\$1,703,386	\$16.70	\$0.05
Traceability reduced standard deviation of recall size by 50%	\$2,340,529	\$22.95	\$0.06
Traceability reduced probability by 50%	\$2,331,636	\$22.86	\$0.06

The difference in the No Traceability and the Traceability without benefits would also be the cost of the system on a yearly basis. In this case, that cost is nearly \$1 million, \$9.54 per head or \$0.02 per boneless retail pound. If the cost when reducing the probability of a recall, size of a recall, or standard deviation of recall size is smaller than the No Traceability cost, then the system has value. In a small plant, none of these variables

reduced by up to 50% would be worth the investment. If the average size of a recall is reduced by 50% the average cost is \$640,000 over a no reduction in recall size, compared to the \$1 million cost of traceability.

Furthermore, an analysis was conducted to find the breakeven point where the cost of adding traceability was equal to the cost of recalls with No Traceability (\$1,372,009). The results are displayed in Figure 9.

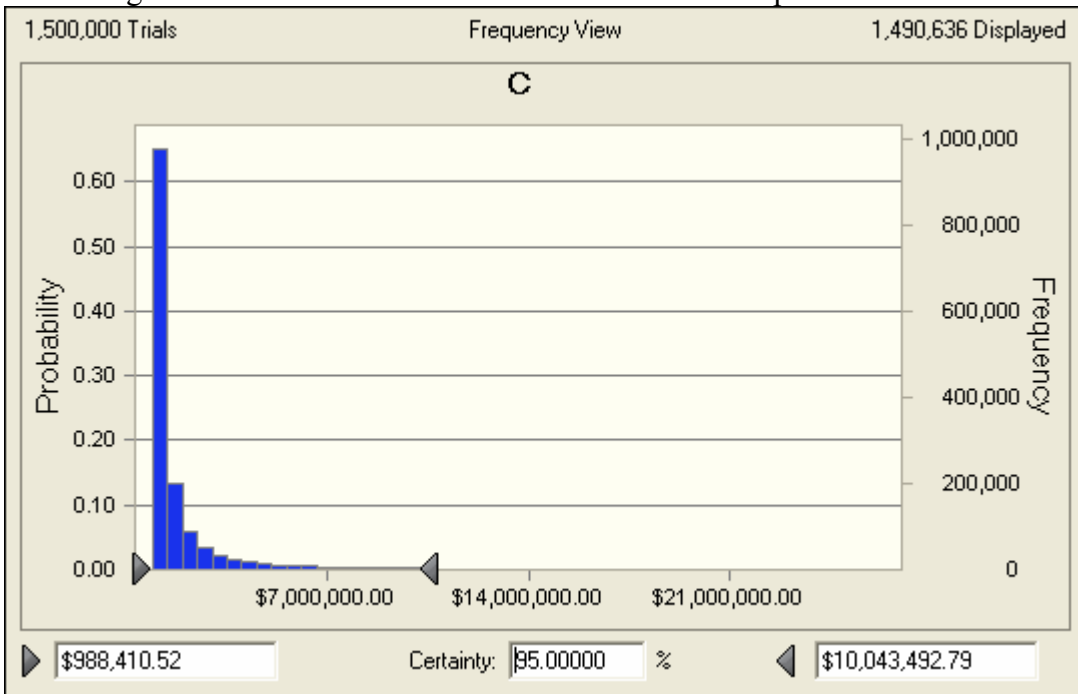
Figure 9.



For the originally estimated cost of \$1,000,000 for a traceability system in a small plant, a decrease of 77% of the average size of a recall is necessary to breakeven. The costs are evaluated on \$200,000 dollar increments and have a linear graph with an average of 16 percentage points reduction needed for every \$200,000 of cost. The same analysis was completed for the reduction in probability, but even at a cost of only \$100,000 and a reduction in the probability of 99% the breakeven cost could not be achieved. This is linked

to the probability calculation as it is on a per pound basis and a small plant would produce fewer pounds than a large plant. Additionally, a figure of the distribution of the average cost for a small plant is shown in Figure 10. It is important to note that in most cases the cost is very small and only when a recall occurs, based on the random draw of probability and random size, will large expenses be incurred. Thus, a small plant facing these investment cost, probability of a recall, and cost of a recall would not likely choose to adopt a traceability system.

Figure 10. Distribution for cost of recalls in a small plant



A large plant was defined as harvesting 5000 head per day. The results for the simulation of average cost per year of recalls are in Figure 11. The average cost, cost per head, and cost per pound are included for recalls without traceability, with traceability and no benefits, traceability and the reduce average size of a recall by 50%, the reduce standard deviation of pounds recalled, and the reduced probability of a recall by 50%. The estimated

cost for traceability is \$100,000 per year, \$0.08 per head, or \$.0002 per pound on a boneless basis, which is the difference in No Traceability and Traceability without benefits. It is important to note that in the case of a large plant both a reduction of 50% in average recall size and probability of a recall have a net gain in value of \$700,000 and \$200,000 respectively. This is determined by comparing the average cost to the cost without traceability.

Figure 11. Average simulated recall cost of a 5000 head per day plant.

	Average Cost	Cost per head	Cost per pound
No Traceability	\$2,848,196	\$2.23	\$0.0061
Traceability without benefits	\$2,948,864	\$2.31	\$0.0063
Traceability reduced recall size by 50%	\$2,144,073	\$1.68	\$0.0046
Traceability reduced standard deviation of recall size by 50%	\$2,940,247	\$2.30	\$0.0063
Traceability reduced probability by 50%	\$2,640,630	\$2.07	\$0.0056

The estimated breakeven point in which the average cost with benefits is equal to the average cost with out traceability would occur with a reduction in the average recall size of 7%. The breakeven point of \$2,844,196 can also be reached with a reduction in the probability that a recall would occur by 15%. This analysis was also evaluated at different levels of cost for both average recall size and probability. The breakeven points are represented in Figures 12 and 13. For both cases, the results are linear and have an average reduction needed of 6 percentage points for the average size and 15 percentage points for the probability of a recall

per \$100,000 of cost. Some variation occurs in the figure, in that the curve is not exactly linear which is due to the model being a simulation based on the average of a random draw for probability and size of a recall. This variation for a large plant is greater than for a small plant and as the probability is larger due to more pounds being produced; therefore, a recall occurs more often. Figure 14 represents the distribution of average cost of a recall in a large plant.

Figure 12.

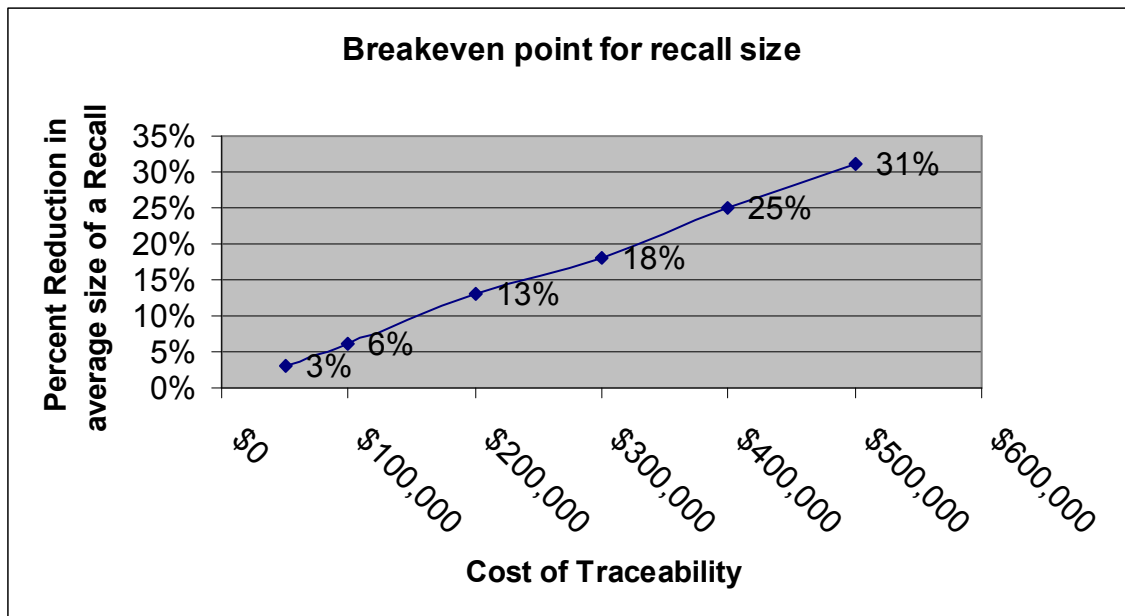


Figure 13.

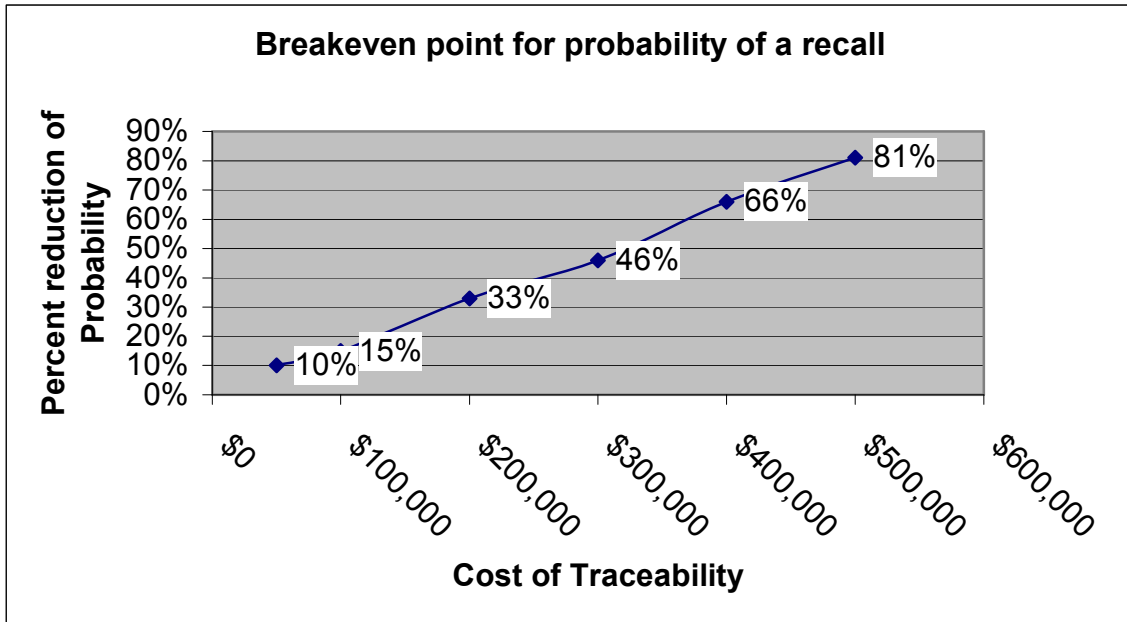
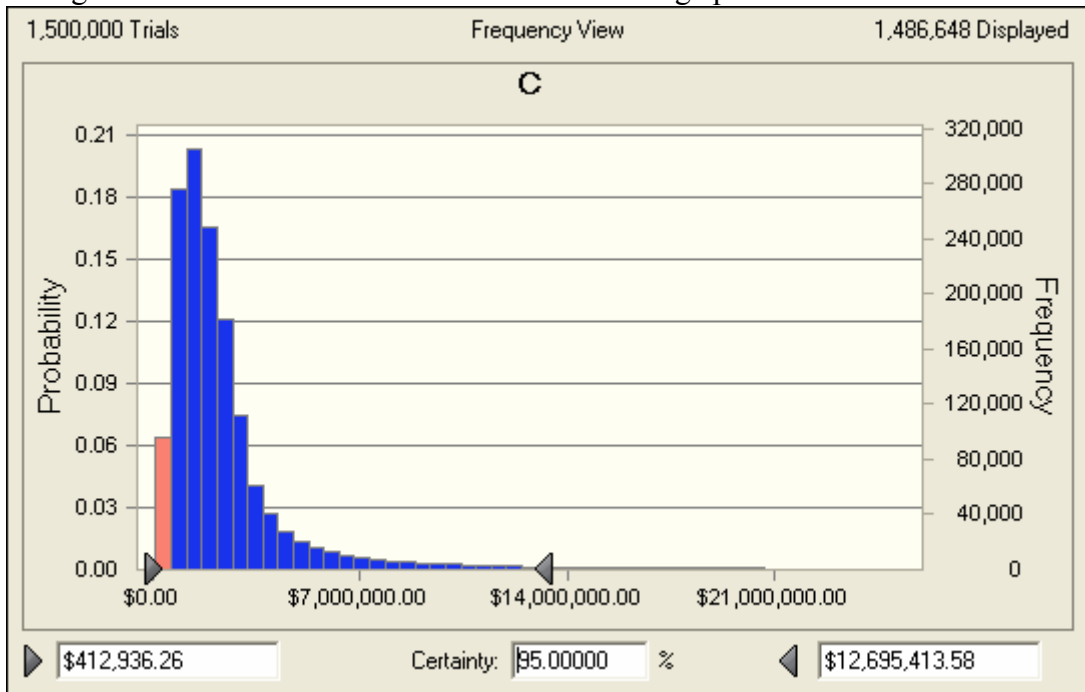


Figure 14. Distribution for cost of recalls in a large plant



A sensitivity analysis was conducted for both a small and large plant for varying levels of probability. This was completed as the most likely value for the probability may have been under estimated in a small plant and over estimated in a large plant. This would be because the probability simply increased as the number of pounds produced increased between a small and large plant. This would not consider the fact that a large plant, which may have more to lose in the event of a recall, may have more prevention steps in place. These may include more specialized personnel to perform duties in the plant and to handle a recall situation. The results are shown in Figure 15 graphically and in table form in Figure 16 with costs rounded to the nearest thousand dollars.

Figure 15.

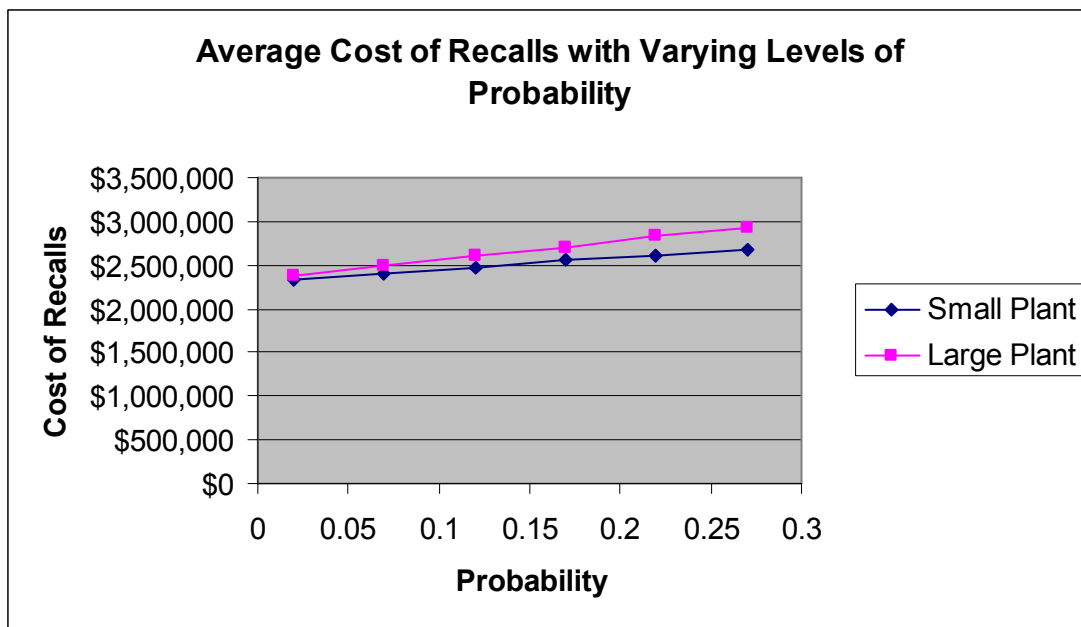


Figure 16. Average cost of recalls with Varying Levels of Probability

Probability	Small Plant	Large Plant
0.02	\$2,343,000	\$2,382,000
0.07	\$2,409,000	\$2,494,000
0.12	\$2,470,000	\$2,598,000
0.17	\$2,553,000	\$2,710,000
0.22	\$2,608,000	\$2,835,000
0.27	\$2,684,000	\$2,938,000

The sensitivity analysis represented in Figure 15 and in Figure 16 shows a higher cost for a large plant at all probabilities and a steeper slope. The average cost increase for an increase in probability of 0.05 is \$68,000 in a small plant and \$111,000 for a large plant. Both sized plants would be more likely to adopt a traceability system as the probability of a recall increases, this is particularly true for a large plant.

CHAPTER 5. CONCLUSION

In a small plant the use of traceability to reduce the cost of a recall by reducing the average size of a recall or probability that a recall will occur is not economically feasible. The cost of the tracing system out weighs any reduced cost from logical reductions in size and chance of recalls. This does not mean that the overall benefits of traceability are negative. Increases in efficiency may cover any additional costs. In addition, the ability to pass data to both producers and customer about the meat source may provide value by effectively branding the product. As prices of technology continue to drop and it becomes more common place, a small plant may be able to capture benefits by adopting the technology.

In a large plant, the costs are much lower per pound due to the economies of scale by volume; therefore, the breakeven point of reducing a recall size by 7% or reducing the probability of a recall by 15% seems to be within reason. This would be a logical investment if the reduction in cost of recalls alone covered the cost of traceability, as other benefits such as an increase in efficiency, consumer confidence, or increased market share would be of profit. These may include increased efficiency, opportunities for export markets, an attribute of a branded product, and ability to pass market signals forward to consumers or backward in the food chain to producers.

It is important to recap additional pre-event factors such as HACCP plans, recall insurance, sanitation, or testing procedures were not included. Additional costs that may be incurred for a period after a recall include a decrease in market share or negative brand recognition.

This only brings up additional gaps in research that could be answered. For example are the estimated costs of a traceability system with cut-to-carcass precision accurate? Furthermore, after the industry's intensive concentration of preventing recalls including testing of product, cleaning methods, and recall awareness from mock recalls, is there error that could be improved with the use of traceability. Lastly, what level of precision in traceability is required to benefit in a recall situation?

GLOSSARY OF ACRONYMS

AMI – America Meat Institute

AI – Avian Influenza

BLS – Bureau of Labor and Statistics

BSE – Bovine Spongiform Encephalopathy

CDC – Center for Disease Control

E. coli – *Escherichia coli* 0157:H7

ERS – Economic Research Service

EPA – Environmental Protection Agency

FDA – Food and Drug Administration

FMD – Foot and Mouth Disease

FMIA – Federal Meat Inspection Act

FSIS – Food Safety Inspection Service

GMP – Good Manufacturing Practice

GRAS – Generally Recognized As Safe

HACCP – Hazard Analysis of Critical Control Points

HIV – Human Immunodeficiency Virus

HUS – Hemolytic Uremic Syndrome

L. monocytogenes – *Listeria monocytogenes*

NAIS – National Animal Identification Plan

OFO – Office of Field Operations

PPIA – Poultry Products Inspection Act

PR – Pathogen Reduction

RNR – Recall Notification Report

RMS – Recall Management Staff

RTE – Ready-to-eat

SSOP – Sanitation Standard Operating Procedure

SOP – Standard Operating Procedure

USAIP – United States Animal Identification Plan

USDA – United States Department of Agriculture

APPENDIX A

Number of recalls conducted through FSIS per cause between 1997 and 2004.

Year	Total Recalls	E. Coli	Listeria	Salmonella	Illness/ pathogen	Foreign	Allergen	Label	Other
1997	27	6	3	1	0	8	2	2	5
1998	44	13	6	3	2	10	0	4	6
1999	62	10	31	6	0	3	0	6	6
2000	76	21	35	4	0	5	0	9	2
2001	95	26	25	2	1	10	11	15	5
2002	129	35	42	4	0	5	22	15	6
2003	68	11	15	2	0	4	12	15	9
2004	48	6	14	2	0	7	12	1	6
Total	549	128	171	24	3	52	59	67	45

APPENDIX B

Equation 1.

$$C = P[L(s, r, \partial) + w_s s + w_r r] + (1 - P)w_s s$$

$$\Rightarrow PL(s, r, \partial) + Pw_s s + Pw_r r + w_s s - Pw_s s$$

$$C = PL(s, r, \partial) + Pw_r r + w_s s$$

First order conditions

Equation 2.

$$\frac{dc}{ds} = PL(s, r, \partial) + w_s = 0$$

Equation 3.

$$\frac{dc}{dr} = PL(s, r, \partial) + Pw_r = 0$$

$$\Rightarrow P[L(s, r, \partial) + w_r] = 0$$

$$\Rightarrow L(s, r, \partial) + w_r = 0$$

Equation 4.

$$\begin{pmatrix} PL_{ss} & PL_{sr} \\ L_{rs} & L_{rr} \end{pmatrix} \begin{pmatrix} ds \\ dr \end{pmatrix} \Rightarrow \begin{pmatrix} -dw_s - L_s dP - PL_{s\partial} d\partial \\ -dw_r - L_{r\partial} d\partial \end{pmatrix}$$

Equation 5.

Set all to 0 except dw_s

$$\begin{pmatrix} PL_{ss} & PL_{sr} \\ L_{rs} & L_{rr} \end{pmatrix} \begin{pmatrix} ds \\ dr \end{pmatrix} = \begin{pmatrix} -dw_s \\ 0 \end{pmatrix}$$

Divide by both sides dw_s

$$\begin{pmatrix} PL_{ss} & PL_{sr} \\ L_{rs} & L_{rr} \end{pmatrix} \begin{pmatrix} \frac{ds}{dw_s} \\ \frac{dr}{dw_s} \end{pmatrix} = \begin{pmatrix} -1 \\ 0 \end{pmatrix}$$

Apply Cramer's Rule

$$\theta = \begin{pmatrix} PL_{ss} & PL_{sr} \\ L_{rs} & L_{rr} \end{pmatrix} \quad A = \begin{pmatrix} -1 & PL_{sr} \\ 0 & L_{rr} \end{pmatrix} \quad \frac{\det A}{\det \theta} = \frac{ds}{dw_s}$$

$$\Rightarrow \frac{-L_{rr}}{PL_{ss}L_{rr} - PL_{sr}L_{rs}} \Rightarrow \frac{-L_{rr}}{P(L_{ss}L_{rr} - L_{sr}L_{rs})}$$

$$\Rightarrow \frac{-L_{rr}}{P(L_{ss}L_{rr} - L_{sr}^2)} = \frac{ds}{dw_s}$$

Equation 6.

Set all to 0 except dw_s

$$\begin{pmatrix} PL_{ss} & PL_{sr} \\ L_{rs} & L_{rr} \end{pmatrix} \begin{pmatrix} ds \\ dr \end{pmatrix} = \begin{pmatrix} -dw_s \\ 0 \end{pmatrix}$$

Divide by both sides dw_s

$$\begin{pmatrix} PL_{ss} & PL_{sr} \\ L_{rs} & L_{rr} \end{pmatrix} \begin{pmatrix} \frac{ds}{dw_s} \\ \frac{dr}{dw_s} \end{pmatrix} = \begin{pmatrix} -1 \\ 0 \end{pmatrix}$$

Apply Cramer's Rule

$$B = \begin{pmatrix} PL_{ss} & -1 \\ L_{rs} & 0 \end{pmatrix} \quad \frac{\det B}{\det \theta} = \frac{dr}{dw_s}$$

$$\Rightarrow \frac{-L_{rs}}{P(L_{ss}L_{rr} - L_{sr}^2)} \Rightarrow \frac{L_{rs}}{P(L_{ss}L_{rr} - L_{sr}^2)} = \frac{dr}{dw_s}$$

Equation 7.

Set all to 0 except dw_r ,

$$\begin{pmatrix} PL_{ss} & PL_{sr} \\ L_{rs} & L_{rr} \end{pmatrix} \begin{pmatrix} ds \\ dr \end{pmatrix} = \begin{pmatrix} 0 \\ -dw_r \end{pmatrix}$$

Divide both sides by dw_r ,

$$\begin{pmatrix} PL_{ss} & PL_{sr} \\ L_{rs} & L_{rr} \end{pmatrix} \begin{pmatrix} \frac{ds}{dw_r} \\ \frac{dr}{dw_r} \end{pmatrix} = \begin{pmatrix} 0 \\ -1 \end{pmatrix}$$

Apply Cramer's Rule

$$C = \begin{pmatrix} 0 & PL_{sr} \\ -1 & L_{rr} \end{pmatrix} \quad \frac{\det C}{\det \theta} = \frac{ds}{dw_r}$$

$$\Rightarrow \frac{PL_{sr}}{PL_{ss}L_{rr} - PL_{sr}^2} \Rightarrow \frac{L_{sr}}{L_{ss}L_{rr} - L_{sr}^2} = \frac{ds}{dw_r}$$

Equation 8.

Set all to 0 except dw_r ,

$$\begin{pmatrix} PL_{ss} & PL_{sr} \\ L_{rs} & L_{rr} \end{pmatrix} \begin{pmatrix} ds \\ dr \end{pmatrix} = \begin{pmatrix} 0 \\ -dw_r \end{pmatrix}$$

Divide both sides by dw_r ,

$$\begin{pmatrix} PL_{ss} & PL_{sr} \\ L_{rs} & L_{rr} \end{pmatrix} \begin{pmatrix} \frac{ds}{dw_r} \\ \frac{dr}{dw_r} \end{pmatrix} = \begin{pmatrix} 0 \\ -1 \end{pmatrix}$$

Apply Cramer's Rule

$$D = \begin{pmatrix} PL_{ss} & 0 \\ L_{rs} & -1 \end{pmatrix} \quad \frac{\det D}{\det \theta} = \frac{dr}{dw_r}$$

$$\Rightarrow \frac{-PL_{ss}}{PL_{ss}L_{rr} - PL_{sr}^2} \Rightarrow \frac{-L_{ss}}{L_{ss}L_{rr} - L_{sr}^2} = \frac{dr}{dw_r}$$

Equation 9.

$$\begin{pmatrix} PL_{ss} & PL_{sr} \\ L_{rs} & L_{rr} \end{pmatrix} \begin{pmatrix} ds \\ dr \end{pmatrix} = \begin{pmatrix} -PL_{s\partial}d\partial \\ -L_{r\partial}d\partial \end{pmatrix}$$

Divide both sides by $d\partial$

$$\begin{pmatrix} PL_{ss} & PL_{sr} \\ L_{rs} & L_{rr} \end{pmatrix} \begin{pmatrix} \frac{ds}{d\partial} \\ \frac{dr}{d\partial} \end{pmatrix} = \begin{pmatrix} -PL_{s\partial} \\ -L_{r\partial} \end{pmatrix}$$

$$E = \begin{pmatrix} -PL_{s\partial} & PL_{sr} \\ -L_{r\partial} & L_{rr} \end{pmatrix} \quad \frac{\det E}{\det \theta} = \frac{ds}{d\partial}$$

$$\Rightarrow \frac{-PL_{s\partial}L_{rr} - (-L_{r\partial}PL_{sr})}{PL_{ss}L_{rr} - PL_{sr}^2} \Rightarrow \frac{-L_{s\partial}L_{rr} + L_{r\partial}PL_{sr}}{L_{ss}L_{rr} - L_{sr}^2} = \frac{ds}{d\partial}$$

Equation 10.

$$\begin{pmatrix} PL_{ss} & PL_{sr} \\ L_{rs} & L_{rr} \end{pmatrix} \begin{pmatrix} ds \\ dr \end{pmatrix} = \begin{pmatrix} -PL_{s\partial}d\partial \\ -L_{r\partial}d\partial \end{pmatrix}$$

Divide both sides by $d\partial$

$$\begin{pmatrix} PL_{ss} & PL_{sr} \\ L_{rs} & L_{rr} \end{pmatrix} \begin{pmatrix} \frac{ds}{d\partial} \\ \frac{dr}{d\partial} \end{pmatrix} = \begin{pmatrix} -PL_{s\partial} \\ -L_{r\partial} \end{pmatrix}$$

$$F = \begin{pmatrix} PL_{ss} & -PL_{s\hat{\theta}} \\ L_{rs} & -L_{r\hat{\theta}} \end{pmatrix} \quad \frac{\det F}{\det \theta} = \frac{dr}{d\theta}$$

$$\Rightarrow \frac{-PL_{ss}L_{r\hat{\theta}} - (-PL_{s\hat{\theta}}L_{rs})}{PL_{ss}L_{rr} - PL_{sr}^2} \Rightarrow \frac{-L_{ss}L_{r\hat{\theta}} + L_{s\hat{\theta}}L_{rs}}{L_{ss}L_{rr} - L_{sr}^2} = \frac{dr}{d\hat{\theta}}$$

Equation 11.

Solve for $\frac{ds}{dP}$ set other variables to 0

$$\begin{pmatrix} PL_{ss} & PL_{sr} \\ L_{rs} & L_{rr} \end{pmatrix} \begin{pmatrix} ds \\ dr \end{pmatrix} = \begin{pmatrix} -L_s dP \\ 0 \end{pmatrix}$$

Divide both sides by dP

$$\begin{pmatrix} PL_{ss} & PL_{sr} \\ L_{rs} & L_{rr} \end{pmatrix} \begin{pmatrix} \frac{ds}{dP} \\ \frac{dr}{dP} \end{pmatrix} = \begin{pmatrix} -L_s \\ 0 \end{pmatrix}$$

Apply Cramer's Rule

$$G = \begin{pmatrix} -L_s & PL_{sr} \\ 0 & L_{rr} \end{pmatrix} \quad \frac{\det G}{\det \theta} = \frac{ds}{dP}$$

$$\Rightarrow \frac{-L_s L_{rr}}{P(L_{ss}L_{rr} - L_{sr}^2)} = \frac{ds}{dP}$$

Equation 12.

$$\begin{pmatrix} PL_{ss} & PL_{sr} \\ L_{rs} & L_{rr} \end{pmatrix} \begin{pmatrix} ds \\ dr \end{pmatrix} = \begin{pmatrix} -L_s dP \\ 0 \end{pmatrix}$$

Divide both sides by dP

$$\begin{pmatrix} PL_{ss} & PL_{sr} \\ L_{rs} & L_{rr} \end{pmatrix} \begin{pmatrix} \frac{ds}{dP} \\ \frac{dr}{dP} \end{pmatrix} = \begin{pmatrix} -L_s \\ 0 \end{pmatrix}$$

$$H = \begin{pmatrix} PL_{ss} & -L_s \\ L_{rs} & 0 \end{pmatrix} \quad \frac{\det H}{\det \theta} = \frac{dr}{dP}$$

$$\Rightarrow \frac{L_s L_{rs}}{P(L_{ss} L_{rr} - L_{sr}^2)} = \frac{dr}{dP}$$

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