Traceability of highly pathogenic avian influenza in dairy cattle production: Economic impacts on milk transportation in Southwest Kansas

by

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B.S., Kansas State University, 2018

A THESIS

Submitted in partial fulfillment of the requirements

for the degree

MASTER OF AGRIBUSINESS

Department of Agricultural Economics

College of Agriculture

KANSAS STATE UNIVERSITY

Manhattan, Kansas

2026

Approved by:

Major Professor
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ABSTRACT

This study examines the economic impact of the ongoing Highly Pathogenic Avian Influenza (HPAI) outbreak on the U.S. dairy industry, particularly in Southwest Kansas. The spread of diseases can significantly impact the economy, as demonstrated by previous pandemics, specifically COVID-19. The outbreak of the HPAI has provoked significant economic losses and increased the risk of sporadic human infections, highlighting the need for stricter monitoring and regulatory measures. The Kansas Department of Agriculture has implemented the Kansas Secure Milk Supply (KS SMS) Plan, which facilitates safe raw milk movement through enhanced surveillance, training, and biosecurity protocols. This research aims to evaluate the costs associated with traceability systems and the implementation of biosecurity measures in milk transportation. By analyzing direct government expenses and HPAI prevention initiatives, the study seeks to provide insights for stakeholders and regulatory agencies to improve traceability systems and ensure the safety of milk supply during an outbreak. The direct cost summary and scenario analysis show that although full implementation of the KS SMS Plan requires higher initial investment, it offers the greatest reduction in disease-spread risk and minimizes additional indirect costs to the government, ultimately supporting continuity of milk movement and strengthening overall emergency response capacity.

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ACKNOWLEDGMENTS

The author wishes to express sincere appreciation to the thesis committee members and major professor for their time, guidance, and dedication throughout this research process. Dr. Vicent Amanor-Boadu, Dr. Joe Parcell, Dr. Jennifer Ifft, and Dr. Dustin Pendell greatly contributed to the completion of this thesis. The author also acknowledges Janelle Perryman and Mary Emerson-Sullivan for their coordination and continued support throughout the graduate program.

Appreciation is also extended to Secretary Mike Beam and Jeff Jones, Program manager with the Kansas Department of Agriculture, for their continued support and encouragement in my educational and professional journey. I would like to make a special dedication to my grandmother, Simona Madrid, may she rest in peace. She was a constant source of motivation and inspiration throughout my life and helped shape me in the person I am today. Her love and teachings will continue to guide me throughout my life.

CHAPTER I: INTRODUCTION

A confirmed outbreak of Highly Pathogenic Avian Influenza (HPAI) in dairy cows on April 24, 2024 changed the risk profile of the U.S. dairy industry. The outbreak had affected over 186 million birds throughout the United States since its detection in February 2022. Aside from depopulating infected and exposed flocks, limited treatment options are available to control the ongoing H5N1 outbreak. The economic toll on the poultry industry has been significant, with federal response and indemnity costs exceeding $1.4 billion by late 2024 (CDC, Centers for Disease Control and Prevention 2025). In the dairy industry The Center for Strategic and International Studies (CSIS) reports a study showing the HPAI-related loss per affected dairy cow is about $950, giving a 500-herd dairy a potential loss of $475,000 (Center for Strategic and International Studies 2025). Since February 8, 2022, when HPAI was confirmed in the United States in a commercial poultry flock, production facilities, especially dairy farms, have implemented increased surveillance and biosecurity protocols in conjunction with state authorities.

Influenza viruses, as seen with the recent HPAI A (H5N1) viruses commonly found in wild birds and poultry, can evolve rapidly. Recent findings in the United States indicate an increased risk of sporadic human infections. Therefore, regular updates and preparedness efforts are essential to assess the public health risks and safeguard the dairy industry. Spackman (2024) confirmed that HPAI is inactivated through the pasteurization process outlined in the Grade "A" Pasteurized Milk Ordinance (PMO) safety program. However, the transportation of raw milk from farms to processing plants poses the highest risk for infection and contamination of both dairy cows and humans.

In response to the challenges posed by past events, effective measures have been implemented to mitigate production loss in the event of disease outbreaks. The Kansas Department of Agriculture (KDA) has developed an innovative resource specifically designed for the dairy industry within the state. This resource, the Kansas Secure Milk Supply Plan (KS SMS Plan), outlines comprehensive protocols for safe and efficient raw milk movement during an outbreak (Kansas Secure Milk Supply Plan n.d.). The primary goal of the KS SMS Plan is to ensure the economic sustainability of milk production, enabling dairy farmers to maintain their operations during challenging circumstances.

An economic analysis serves as a great tool for keeping the public informed and directing producers' attention towards adhering to Federal regulations to ensure traceability. Maintaining organized records that account for every movement of livestock, personnel, milk, and other vital supplies involved in raw milk production is critical. These records should not only track the incoming and outgoing movements but also must include comprehensive contact information for all individuals associated with milk transportation and employees at the processing plant (USDA, NAHEMS Guidelines: Surveillance, Epidemiology, and Tracing 2014). An estimated value of foodborne illnesses highlights the importance of implementing food safety policies, which includes transportation of food products. As concluded by the USDA (2025), the financial impact of foodborne illnesses totaled around $17.6 billion in 2018. This marked a rise of approximately $2 billion, or 13 percent, from the Economic Research Service's (ERS) 2013 calculation of $15.5 billion.

Collaborative efforts in virus control before interstate movement are crucial prevention measures. KDA collaborates with various agricultural production sectors and other relevant parties to respond efficiently and effectively to minimize virus spread.

Working with the Kansas Department of Transportation, Kansas Highway Patrol, and local law enforcement officials, KDA helps enforce permits to control animal movement (Kansas Secure Milk Supply Plan n.d.). Monitoring the movement of livestock to reduce virus spread is essential in the state of Kansas for the continuous supply of milk and milk products to consumers.

1.1 Research Problem, Questions and Objectives

From the foregoing, it is evident that the problem this research seeks to address is the economics of traceability during disease events. It uses the Kansas dairy industry and HPAIv as a case study because of their currency and relevance as well as challenges. The research question is this: How economical is the implementation of a traceability system in managing the spread of a disease outbreak in the dairy industry?

The overall objective of the research is to evaluate the economics of traceability systems in response to the ongoing Highly Pathogenic Avian Influenza (HPAI) outbreak. It focuses on milk supply and dairy herds in Southwest Kansas, the region with the largest number of processing plants. Specifically, this study estimates the direct costs of traceability measures and increased biosecurity protocols when transporting milk from the farm to the processing plants.

Increased biosecurity protocols can help agricultural producers comprehend the economic consequences of implementing or not implementing a traceability system. This preparation will specifically consider how the health of the dairy herds in Kansas directly influences the broader food supply chain by having a constant flow of raw milk entering the processing section. The analysis will focus on the logistics of raw milk movement, linking directly to dairy premises and examining how adopting a traceability system could affect both the economic welfare of producers' and consumers' safety. This involves evaluating the costs and benefits of monitoring the flow of raw milk through the supply chain, specifically from the farm to the processing plant, to ensure that any virus outbreaks can be quickly contained and addressed.

The main goal of these prevention measures is to prevent an outbreak, which could have devastating economic impacts on producers and consumers. It also aims to set clear guidelines for safely handling and transporting raw milk to reduce contamination risks. By improving producers' skills in preparation and response, this initiative wants to build a stronger agricultural sector that can effectively deal with health risks while protecting economic stability.

1.2 Significance of the Study

Following the identification and confirmation of the HPAI H5N1 virus in a U.S. commercial poultry flock on February 8, 2022, concerns related to food safety and traceability have increased among producers and regulatory officials. In 2025, as we continue to address the spread of avian influenza, these concerns are especially relevant.

HPAI is a contagious viral disease that affects a wide range of domestic and wild mammals, including domestic poultry and wild birds. In the United States, HPAI infection has also been detected and confirmed in dairy cattle, leading to decreased milk production and other health issues that impact animal welfare and productivity.

An updated report of HPAI's known cases has included all known feral and domestic cats and other scavenging or carnivorous species. Domestic cats are often found at dairy farms and near the milking parlors. Typically, cases of transmission among these animals are rare exceptions, usually occurring within family groups or areas where they congregate (USDA 2025). As a result, they do not play a significant role in the spread or transmission of the virus. Nevertheless, cats have been linked to the spread of HPAI on dairy farms. Therefore, the USDA has included all known cases of Influenza A H5N1 in domestic cats that were detected before March 1, 2024 (USDA 2025).

Human infections with the HPAI A (H5N1) virus are currently rare, but they can occur when individuals directly touch or have close contact with infected animals or contaminated environments without using respiratory or eye protection (CDC, Centers for Disease Control and Prevention 2025). This lack of protection increases the risk of infection. Since 1997, sporadic human infections have been reported in 23 countries, with a case fatality rate exceeding 50% (CDC, Centers for Disease Control and Prevention 2025).

On January 6, 2025, the state of Louisiana announced that an individual who was previously hospitalized due to severe illness from HPAI A(H5N1) had died. This marked the first reported death in the United States resulting from an H5 infection. Globally, the World Health Organization (WHO) has recorded over 950 human cases of H5N1 bird flu, with approximately half of those resulting in fatalities. According to the CDC, 66 confirmed human cases of H5N1 bird flu have been in the United States since 2024 and 67 since 2022. Addressing the emergence of zoonotic diseases is a crucial component of developing a food safety plan, which should include measures for traceability.

On April 24, 2024, USDA confirmed HPAI H5N1 virus detections on 33 dairy cattle premises in eight states, including Kansas. According to the USDA, based on specific phylogenetic evidence and epidemiological information, eight poultry premises in five states (Kansas, Michigan, Minnesota, New Mexico, and Texas) have also been infected with the same HPAI H5N1virus genotype detected in dairy cattle (APHIS and USDA 2025). A federal order, effective April 29, 2024, requires testing and reporting of HPAI for interstate movement of dairy cattle to monitor the virus's impact and reduce further spread.

On December 6, 2024, the USDA issued a Federal Order requiring additional testing for and reporting of HPAI in livestock and milk. HPAI poses significant threats to the poultry industry, animal health, human health, trade, and the global economy.

Kansas is home to 175,000 dairy cows raised on a mixture of more than 209 large and small dairy farms (Kansas Livestock Association 2024). With the completion in 2017 Dairy Farmers of America milk powder plant in Garden City, Kansas, about 75% of the milk produced in Kansas is processed within the state. A new cheese plant, Hilmar, began processing in October 2024 in Dodge City, Kansas. It was reported that the plant would receive, on average, 260 tanker trucks of milk per day once in full production. Flora Food Group announced, in late September 2024, the purchase of a previously closed plant in Hugoton, Kansas, which adds another manufacturing milk plant to the southwest Kansas area. In addition, McCarty Family Farms' processing plant, located in Rexford, Kansas, began processing milk in 2012 and continues to grow.

Kansas has five dairy state inspectors for farms and processing plants that cover 105 counties, 130 grade “A” dairy producers, 13 manufacturing plants, six active dairy associations (cooperatives), 69 active dairy distributors, six single service (dairy container) manufacturers, 11 tank washing facilities, 191 milk haulers, one active transfer station, and hundreds of tankers requiring state inspections (Jones 2025). A map of the dairy inspection areas is organized by county (Figure 1.1). The stars represent large processing plants in each county. Each color corresponds to a specific inspection area covered by inspectors monitoring the dairy farms. Approximately, 80 percent of the cows are located in western Kansas (Jones 2025). The number of farms is indicted by the numbers in each of the counties on the map. A graph of grade “A” dairy farms shows the percentage of producers by region (Figure 1.2). These figures help regulatory agencies and producers understand several important aspects, like planning, outbreak response, and regional resource allocation. The dairy industry in Kansas is growing, particularly in Southwest Kansas, which has been recognized as a promising state due to its dry climate and accessible feed supply. Data for 2024 show that Kansas produced 4.24 billion pounds of raw milk, and 1.70 billion pounds of raw milk was processed in Kansas plants (Jones 2025).

Figure 1.1 Dairy Inspection Area Map

(As of 01-03-2025)

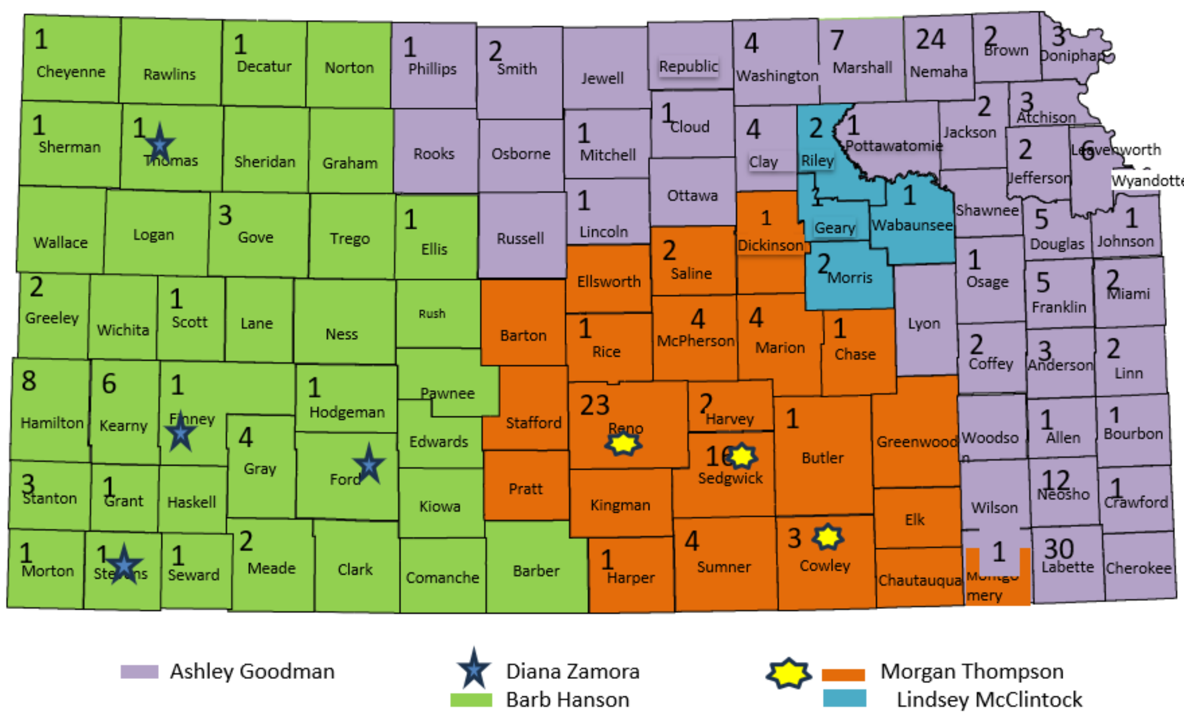
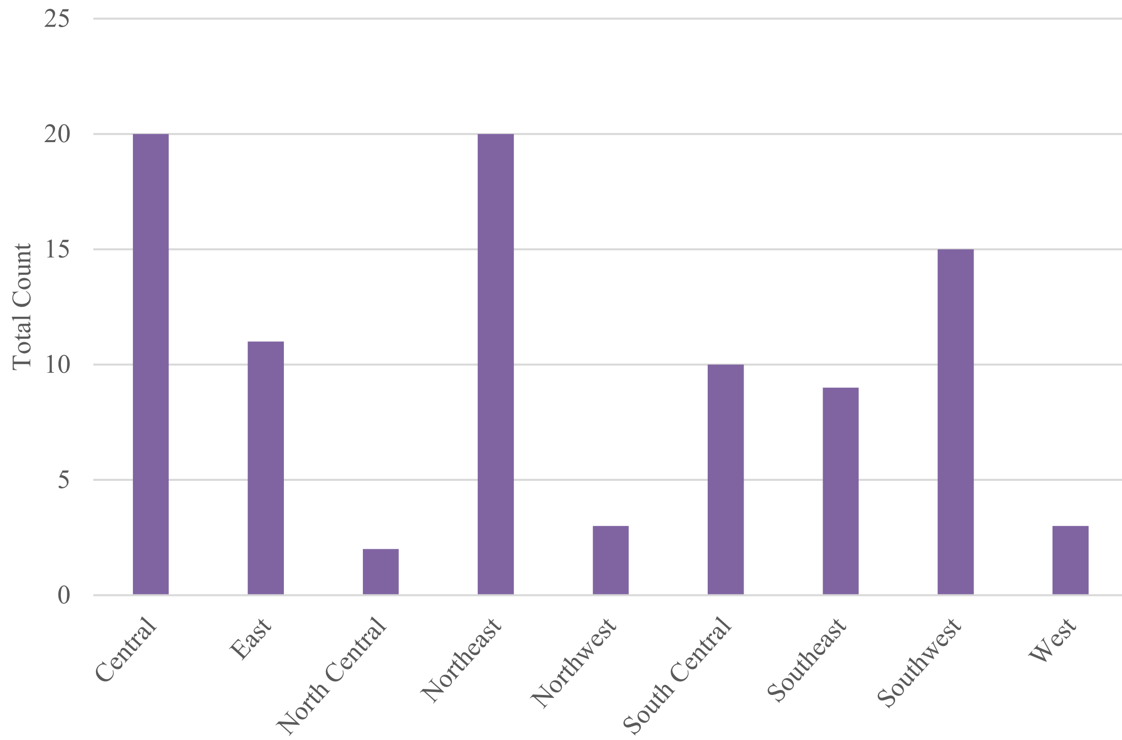


Figure 1.2 Active KDA Dairy Producers by Kansas Region



In 2024, Kansas shipped more than $4.75 billion worth of agricultural goods to 94 different countries, securing the 8th position in the United States for agricultural exports (KDA 2025). The primary markets for Kansas dairy exports include Mexico, Japan, China, Canada, and South Korea (KDA 2025). Alongside the increasing number of large dairy farms, there is also a rise in the number of smaller milk producers. The goal of the KDA's Dairy Inspection program is to promote quality dairy products by educating producers and maintaining strong relationships with them. Quality and safety are ensured by adhering to Kansas dairy and milk regulations, which are based on the U.S. Food and Drug Administration's Grade A Pasteurized Milk Ordinance (KDA, Dairy Industry n.d.).

1.3 Organization of Thesis

Chapter 2 provides a literature review, starting with a historical overview of the economic implications of the confirmed HPAI virus on the movement of raw milk from farms to processing plants, including transmission. As well as drawing on previous and current research. Chapter 3 discusses the transportation of milk with current biosecurity measures to provide an overview of the Kansas Secure Milk Supply Plan (KS SMS Plan) and analyzes its traceability and safety protocols framework. Chapter 4 focuses on methods and models for estimating direct government costs associated with the HPAI outbreak for dairy haulers in southwest Kansas. Chapter 5 discusses the results of the analysis. Finally, Chapter 6 presents the conclusions and recommendations emanating from the study.

CHAPTER II: LITERATURE REVIEW

2.1 Literature Introduction

The literature review is organized into ten sections examining previous and current food safety and traceability research. The first section provides a review of the history of HPAI in the United States and the risks it poses to the dairy industry. The second section will also discuss the transmission methods for the virus, as discussed in the literature. The economic and health risks of HPAI infections provides the rationale for reviewing the KS SMS Plan initiative. The third section describes the modern milk processing method called the Pasteurized Milk Ordinance (PMO). The fourth section reviews safety measures outlined in the KS SMS Plan, specifically during transportation. The fifth section presents recent findings on the inactivation of the HPAI virus in raw milk when processed into pasteurized milk. Section 6 and Section 7 will focus on earlier food safety and traceability research, respectively. Sections 8 and 9, we explore the implementation and significance of animal identification programs concerning traceability. Finally, Section 10 discusses the direct costs, including the impact of implementing preventative measures. The chapter will conclude with information on how this research contributes to existing literature and supports further implementation of biosecurity measures.

2.2 History of Transmission - Highlighting Transportation

Avian influenza was first identified in poultry, with the earliest documented case of HPAI virus reported in Italy during the late 1870s (Spackman 2020). Historical infections have been associated with decreased production, increased mortality, vaccination costs, and trade restrictions if the virus enters a commercial poultry facility. The H5N1 strain of HPAI was detected in wild birds across North and South Carolina in the United States in January 2022, spreading shortly thereafter, to commercial poultry farms. Since then, the virus has resulted in the culling of more than 186 and 18 million birds in all 50 states and one territory by January 16, 2026 (USDA n.d.)

The primary identified host is poultry, specifically aquatic birds like ducks and geese. However, recent genome sequencing from affected farms has revealed the presence of the virus in dairy cows, domestic cats, and a raccoon, indicating interspecies transmission (Caserta, Frye and Butt 2024). Epidemiological and genomic studies have shown that cows can quickly spread the disease to one another. This occurrence was seen after healthy cows from an affected farm were transported to a different farm in another state. These findings demonstrate that the HPAI virus can be transmitted in unseen environments, highlighting its ability to cross species barriers, specifically during transportation.

2.3 Transmission

It is crucial to increase bio-security measures, particularly for lactating dairy cows during transportation. Caserta, Frye, and Butt (2024) provide evidence that the mammary gland is the primary site of virus replication, leading to significant virus shedding in raw milk. They also emphasize that raw milk with significant infectious viral loads of HPAI is common when cows are infected. Signs of influenza in dairy cows include low appetite, decreased milk production, lethargy, and irregular milk appearance, which may resemble mastitis and mislead diagnosis. The decrease in milk supply can raise concerns for the dairy industry, particularly regarding reduced milk flow into production facilities. For the influenza virus to infect a new host, a strong interaction between the virus and the host is necessary, which typically requires close contact (Spackman, A Brief Introduction to Avian Influenza Virus 2020). Once a herd has become infected, this occurrence limits transportation of raw milk from the farm to the processing plant, including limitations for specific routes if neighboring farms are present and appear positive. Indirect contact with the virus can occur through contaminated equipment, surfaces, shoes, clothing, and hands. Equipment such as milk trucks used to transport milk can be a potential way for the virus to be transmitted. Direct contact can occur through virus shedding from milk, nasal secretions, urine, and feces (L. C. Caserta 2024). Areas without strict biosecurity measures are more vulnerable to outbreaks. Biosecurity measures such as proper sanitation or disposal of waste (contaminated milk, used gloves, contaminated equipment) are necessary to follow. An important consideration as the dairy industry moves forward is the environment and its influence on the spread of the virus, alongside the implementation of increased biosecurity protocols.

2.4 Pasteurized Milk Ordinance Safeguard for milk

For over 100 years now, the Grade "A" PMO has guided and provided producers and the public with an effective way to consume milk with low levels of harmful bacteria and viruses using temperature and time standards, more specifically and emphasized in this thesis, High-Temperature Short Time pasteurization. First introduced and established in 1942, the Standard Milk Ordinance ensured safe products for consumers. According to the U.S. Food and Drug Administration, "Pasteurization and diversion or destruction of milk from sick cows are two important measures that are part of the federal-state milk safety system" (FDA 2025). In conjunction with state regulatory agencies and the FDA, the PMO is used to implement and enforce regulations regarding the production and distribution of Grade "A" milk and milk products intended for human consumption. A key task in minimizing the risk of spread and contamination is by proactively linking food safety and traceability.

2.5 KS SMS Plan Introduction

A plan was developed to ensure the secure movement of raw milk during a virus outbreak. This plan was designed for producers to voluntarily collaborate with the KDA's Division of Animal Health (DAH) and the Dairy and Feed Safety program (Kansas Secure Milk Supply Plan n.d.). Adhering to the guidelines can assist in stopping the transmission of viruses via milk trucks, tankers, haulers, and drivers. This will also ensure that raw milk from unaffected dairy farms can be processed promptly, with support from regulatory officials if necessary. The current KS SMS Plan specifically addresses foot and mouth disease (FMD) outbreaks with corresponding biosecurity recommendations. Although the plan primarily focuses on FMD, the written guidelines can also be adapted to address other outbreaks, such as the ongoing HPAIv.

The Kansas Secure Milk Supply (KS SMS) plan comprises two key components aimed at managing the movement of raw milk and supporting the economic stability of the dairy industry by focusing on prevention and response. One of these components, and the focus of this thesis, is movement permitting, which requires advanced notification to facilitate a steady flow of raw milk. Permitting involves obtaining a Secure Milk Supply certification, maintaining fourteen days' worth of movement records, and providing a statement from a veterinarian to support the plan.

2.6 Inactivation using HTST

The proposed study highlights important factors related to traceability and food safety during the processes of pumping milk into bulk tanks, transporting it, and storing it before processing. Spackman (2024) also emphasizes the importance of traceability during the transportation stages, specifically when the raw milk is picked up at the farm and received at the processing plants. Raw milk can be stored in bulk tanks, which are used to cool and hold the milk brought in from dairy farms until it is ready to be pasteurized and processed into the final product. Large dairy farms have the capability to pump the milk directly into tanker trucks for transportation to processing plants. These tanks and tanker trucks can hold raw milk from approximately 600 to 700 cows (Spackman 2024).

High Temperature Short Time (HTST) pasteurization is an effective method for heating milk to a specific temperature for a short duration, which rapidly inactivates microorganisms and enzymes (Spackman, 2024). Standard U.S. continuous flow HTST pasteurization effectively kills HPAIv. This method reduces the viral load significantly higher than the average amount of infectious virus found in raw milk from bulk storage tanks (Spackman 2024). These findings indicate that pasteurized milk in the United States is safe to drink. Testing raw milk silos is a priority for detecting HPAIv, as visual inspections on farms are sometimes ineffective; infected cows that appear healthy have been identified. It is crucial to understand how prevalent infectious viruses can be and to estimate their potential presence at each stage of the milk supply chain.

2.7 Dairy Product Traceability

Food safety and traceability practices in the dairy industry are becoming more complex as dairy farms grow larger. Charlebois and Haratifar (2015) explain that the rapid transportation and mobility of raw food ingredients and products around the world raise concerns about potential hazards. This has led to a greater risk of spreading food safety-related incidents than in previous years, which could potentially impact millions of consumers (Charlebois and Haratifar 2015).

Challenges related to food traceability are the need to rely on information between the different processing stages effectively. A more cost-effective way to track products is by using paper, especially for smaller businesses. However, certain circumstances can produce problems when recording data accurately, storing it, and searching for products. Incorrect or lost data can disrupt proper traceability when transporting milk, as discussed throughout this study. Digital databases are seen as more costly to set up and run as they require hardware, software, skilled labor, training, and certification. Among industries, a combination of paper and digital databases is seen, but production facilities are slowly transitioning to digital databases. As discussed in this study and seen in the industry, some companies avoid implementing digital systems due to costs. Charlebois and Haratifar (2015) conclude that the costs of implementing digital databases help restore consumer confidence in food safety and quality and the willingness to pay a higher premium for such dairy products.

2.8 Food Safety

Food safety is an ongoing process that involves identifying all potential hazards at different levels within industry. Inspections and audits enforced by the Food and Drug Administration (FDA) or U.S. Department of Agriculture (USDA), are essential in preventing foodborne illnesses involving the food industry's quality control processes. Regulations provide guidance to help companies manage and reduce risks involved in the production and distribution of animal food or associated human food products. Advancements in technology have begun to shape traceability to further safeguard the food supply chain from the farm to the table (Abbott 2024).

2.9 Developing Animal Identification and Traceability Systems

Global leaders in animal, trade, and food safety organizations have emphasized the priority of developing animal ID along with a traceability system. Schroeder and Tonsor (2012) compare and analyze a strategic assessment to ensure effective policy, planning, and program development regarding traceability.

Control of management when dealing with food safety commingles with animal and human health, emphasizing the importance of animal ID and traceability. Globally identified as crucial, the guidelines of the World Organization for Animal Health, the World Trade Organization, the Food and Agriculture Organization of the United Nations, and Codex Alimentarius (Schroeder and Tonsor 2012) are acknowledged and supported. Schroeder and Tonsor (2012) highlighted how the United States lags a crucial component compared to significant exporting and importing countries in adopting and developing cattle identification and traceability.

2.10 National Animal Identification and Traceability Program

Due to several animal disease outbreaks, livestock traceability has become a significant concern in the United States. Industry stakeholders are worried about the potential high costs and long-term impacts of applying and administering a national animal ID and traceability program. Shear and Pendell (2020) assess the reactions of a beef cattle animal ID and traceability system in the United States. Through the use of an economic model, they show a comparison of how different sectors in the beef industry must adapt to counterbalance costs related to a national animal ID and traceability program. The study also calculates direct costs of implementing such programs, using CattleTrace to include the different production sectors in the U.S. beef industry.

Four scenarios are described using a technology-based approach, CattleTrace, to show the economic influence of such a program. The initial two scenarios examined differ in the producer's expenditure on costs. The last two scenarios concentrate on the fluctuations in U.S. beef demand for both domestic and international consumers. Shear and Pendell (2020) propose that the typical changes in beef demand, both domestically and internationally, could offset the immediate expenses for producers and industry.

2.11 Direct Costs of Animal Health Events

Many studies that evaluate economic impacts of animal health events primarily focus on market effects. For instance, Paarlberg et al. (2008) analyze disease control strategies to reduce outbreaks' duration. The study emphasizes that understanding the duration of an outbreak is crucial for assessing the producer and consumer welfare effects along with trade disruptions (Paarlberg, et al. 2008).

Schroeder et al. (2015) study focuses on the regional economic impacts, expecting government costs to exceed $11 billion, likely without an emergency FMD vaccination strategy. The study compares adding preventative programs to reduce government costs. The costs of $1 billion are estimated when adding prevention programs compared to $11 billion when no prevention program is added. Government direct costs include the euthanasia and disposal of infected animals, compensation payments to producers, vaccination expenses, and the cleaning and disinfection of premises.

Few studies report direct costs. Kim et al. (2017) simulate outbreak effects, focusing on the direct costs of infected livestock and the immediate production losses. The study concludes that increasing levels of animal traceability significantly reduces direct economic costs by limiting the spread of disease and allowing producers to respond more quickly. Direct economic costs are tied directly to lower government costs when the culling of infected and exposed animals is reduced due to improved traceability. When traceability is improved, estimates of depopulation rates are lower.

2.12 Contributions

Valuable contributions to the existing literature will highlight the direct costs associated with government expenses, specifically within the dairy industry, focusing on the transportation of raw milk. These direct costs are often overlooked, yet essential for analysis. Preventative programs, such as the KS SMS Plan, can be economically justified by the potential reduction in producer losses and significant savings in direct government costs related to outbreak responses.

CHAPTER III: TRANSPORTATION AND KS SMS PLAN

Dairy industry safety activities in Kansas are organized into general subprograms, each with designated inspectors. These programs cover farm production, transportation of raw milk, milk processing, and distribution of packaged products. The role of milk haulers in the supply chain is crucial for ensuring the timely delivery of raw milk to the processing facility and assessing the milk's quality to ensure it meets high standards before departing from the farm (KDA, Dairy Industry n.d.). This chapter will focus on raw milk transportation biosecurity measures, and how strengthening these measures can serve as a preventative strategy during a viral outbreak.

Collaboration among industry, state, and federal representatives enables the effective use of premises identification for animals, physical locations, milk products, and individual farms. This is achieved through the use of a National Premises Identification Number (PIN), a Location Identifier (LID), a Bulk Tank Unit (BTU) number, and a permit number (Secure Milk Supply 2025). Each identifier serves a distinct and important purpose within the dairy industry. A PIN is a unique code used nationwide for tracking during an outbreak of foreign animal diseases (FAD). This code provides information about the producer's name, phone number, and the type of livestock located at specific geographic coordinates using latitude and longitude. The PIN can be used and managed under federal regulations by USDA’s Animal and Plant Health Inspection Service (APHIS) assigned by State Animal Health Officials (SAHOs). A LID, on the other hand, is a distinct numeric state code permanently linked to a specific physical location; however, not all states issue LIDs, and this code is not utilized for issuing movement permits during FAD outbreaks, nor can it be used by USDA-APHIS. Permit numbers are provided by state regulatory agencies to individual farms for monitoring milk samples and inspections; similar to LIDs, these numbers are also not used for movement permits. BTUs are assigned by the state to milk plants, groups of farms, or individual farms that market milk. To ensure traceability in the movement of raw milk from farms to processing plants, the BTU number is the primary method used, particularly for tracking concerns related to the AI virus. Currently, the USDA is tracing raw milk and collecting samples from silo tanks, as this stage of processing poses the highest risk for the shedding of the virus. In Kansas, licensed milk haulers are trained and evaluated by the KDA, as they transport raw milk from farms to processing plants using bulk tank trucks (KDA, Dairy Industry n.d.). Samples are taken by the milk haulers and are also taken at the processing plants. This process ensures the quality of the milk and proper sampling.

3.1 SMS Plan

In 2011, the Kansas Division of Animal Health (DAH) joined the KDA, currently with three programs: Animal Disease Control, Animal Facilities Inspection, and Brands Program (KDA 2025). The program includes 44 licensed dairies; all facilities must register with DAH, and any facility with 1,000 heads or more is required to register (DAH 2025). The 44 licensed dairy farms are large operations with over 1,000 milking cows. Farms with less than 1,000 head of cows are not required to register. Kansas has 16 dairies with a recognized KS SMS Plan registered with the Kansas Division of Animal Health (DAH). Currently, the KS SMS Plan is only voluntary for producers. A registered KS SMS Plan is one of the requirements to obtain a movement permit for dairy producers to transport raw milk in and out of the farm in the event of a FAD outbreak and only required during an outbreak.

This study aims to provide evidence of the economic benefits gained from improving biosecurity. It begins with the implementation of a KS SMS Plan. Additionally, it highlights the importance of dairy facilities registering their farms with an established KS SMS Plan, focusing on the transportation of raw milk as we continue to tackle the spread of the AI virus.

Regulatory officials can designate locations as infected, suspect, or contact sites to assess whether animal products, such as raw milk, can be moved before issuing a permit in the event of a FAD outbreak (CFSPH 2017). Each situation is unique and will be evaluated based on the specifics of the outbreak. Officials may or may not require various actions, such as obtaining a PIN, improving biosecurity measures at the location, and ensuring safety protocols for the truck and driver. In some cases, a stop movement order for milk may be necessary, and the location might be classified as a Monitored Premises. This classification requires a valid PIN and an inspection to verify proper safety measures and surveillance, aligning with an established KS SMS Plan. A permit will be needed to transport raw milk to processing facilities in the event of a virus outbreak. Once a farm has the required documentation guided under the KS SMS Plan, the farm will be granted a movement permit.

This situation could lead many dairy farms to start dumping milk, which would further spread the virus and raise environmental concerns if a facility is unprepared to obtain a movement permit. Disposing of large quantities of milk may result in consumer shortages during a major outbreak and put upward pressure on the prices of dairy products. During such outbreaks, regulatory officials focus on key activities to contain the spread of the virus. These activities include tracing the movement of animals from infected farms, investigating suspected and contact farms, and quarantining affected areas to prevent further spread (CFSPH 2017). Officials may or may not carry out necessary actions for the disposal of raw milk, virus elimination, monitor surrounding control zones, and allow essential operations, such as the movement of feed and equipment, to continue.

3.2 Biosecurity

Biosecurity encompasses all the measures taken to prevent or reduce the introduction and spread of pathogens and other harmful organisms. It generally includes physical barriers to disease and pathogen introductions and process measures to identify, arrest, and prevent infection and contamination. Successful implementation of biosecurity, therefore, involves all the major actors in the supply chain, from input suppliers to consumers.

Traceability is the ability to trace an object of interest throughout its life cycle. It includes the ability to identify a pathogen’s origin, spread pathways, and infection targets. Establishing effective biosecurity measures begins with a form of traceability, which is essential for tracking the health status and treatments of live animals to further evaluate the quality of raw milk. This chapter primarily focuses on the use of a PIN to assess the impact of traceability responses in the handling of raw milk. This unique alphanumeric identifier enables officials to locate the precise physical location of the animals. If a virus is introduced, maintaining accurate records of animal movements would facilitate the identification of the source and enable informed management decisions. Additionally, when applying for a movement permit through the state, proper record-keeping can demonstrate that there has been no contact with the virus, allowing for the continuous flow of milk to processing plants (Federation 2025).

Personnel play a crucial role in enhancing biosecurity measures, especially for milk haulers. They are classified as individuals who do not have contact with animals on the premises during transportation. Milk haulers must have a designated area where they avoid contact with animals, feed, and manure (Federation 2025). It is essential for them to wear personal protective equipment (PPE) as needed, particularly when handling raw milk. Proper record keeping can significantly benefit facilities by tracking visitors, which allows for traceability if necessary. It is important to document the date, contact information, reason for entry, interaction with livestock, and the last location visited.

One of the most frequently overlooked aspects of biosecurity is training, especially documentation and record keeping. Regular employee training is necessary for establishing clear communication and/or expectations across everyone involved in milk production, transportation, handling, processing, and shipping of final products. The effectiveness of training depends on factors such as individual roles, the type of facility, and management styles. To ensure a secure and efficient training environment, it is essential to also implement appropriate measures that include identifying the specific types of separations needed to safeguard the facility. USDA offers multiple training programs available for producers.

A Line of Separation (LOS) is an established outer control boundary around or within the premises, designed to limit the movement of the virus into areas where susceptible animals may be exposed (Federation 2025). The LOS should be clearly defined and marked on the premises. Vehicles are only authorized to cross the LOS at clearly marked and controlled access points. It is important to define these access points to restrict entry to a specific, limited number of controlled areas. Vehicles passing through an LOS access point must be cleaned and disinfected. All movements should be documented and made easily available for review. More specifically, regarding the thesis, it is essential to determine the flow of raw milk by controlling traceability measures. Milk haulers and drivers should adhere to a farm-specific standard operating procedure that meets or exceeds the standards for a KS SMS Plan. The driving path to the milk house must be established and communicated clearly.

Biosecurity measures should ensure that raw milk from other operations does not leak into areas that cannot be adequately disinfected. Milk samples should be transported in containers that can be disinfected to remove any visible contamination on the exterior. Additionally, a milk disposal plan should be evaluated in case raw milk cannot be transported for processing off the farm.

Enhancing biosecurity starts with the implementation of a KS SMS Plan. KDA offers multiple training documents and material such as templates and check lists. This chapter emphasizes the significance of dairy facilities registering their farms with an established KS SMS Plan. By adopting improved biosecurity measures with the plan's guidance, these facilities can ensure the uninterrupted flow of raw milk during a virus outbreak.

CHAPTER IV: MODEL AND METHODS

The purpose of the model is to facilitate estimating direct costs affecting production and processing in the dairy industry and explore the effects of alternative scenarios. The analysis allows the use of an economic trade-off by adding prevention programs (KS SMS Plan) and increased biosecurity measures. Specifically, the government and industry costs associated with the HPAI outbreak for dairy haulers in southwest Kansas will be analyzed. An analysis would benefit state and federal agencies and, ultimately, producers. The study measures biosecurity costs to further help manage direct costs to be used in conjunction with market-level impacts and regional impacts to estimate the total economic impact.

4.1 Cost Analysis: Government and Industry

The evaluation will consider the following factors related to the KS SMS Plan specific to the transportation process:

- *Personnel Training*
    - Biosecurity Training includes a one-time session for haulers on the HPAI protocol using a base salary rate specifically for haulers only as an industry cost. The training includes watching a video, hands-on training, and taking a short quiz for accountability. State training or direct government costs associated with personnel training provided by state inspectors are included as government costs and are calculated using base salary rates to reflect required annual training.
- *Personnel biosecurity labor*
    - Daily biosecurity tasks are calculated as labor hours using a base salary rate at the farm level for cleaning appropriate work areas and equipment. A

separate daily biosecurity labor component is also calculated for milk receivers at the processing plant when the raw milk is received. Proper PPE use, including gloves, masks, and protective eyewear, to protect workers while reducing the risk of virus transmission.

- *Personal Protective Equipment (PPE)*
  - PPE supplies are assumed to be single-use and required for each hauler per visit. Daily PPE usage is estimated on a per-person basis, reflecting one work shift to account for multiple contacts within a workday. PPE use is classified as an industry cost and reflects standard biosecurity practices.
- *Cleaning/Disinfection*
  - Disinfectant (per application): Disinfectant use is calculated on a per-vehicle, per-application basis to allow treatment of all tires. Application time is assumed to range from 5 to 10 minutes per vehicle. This cost is classified as an industry cost at the farm level.
  - Equipment (sprayers): Equipment costs include sprayers required for disinfectant application. These costs are treated as a one-time expense and classified as an industry cost at the farm level.
  - Tire Disinfection (wheel bath): Tire disinfection bath costs include the installation of a basic wheel bath at each site to be installed at a controlled access point. Costs are treated as a one-time industry investment per site at the farm level.
- *Record Keeping and Compliance*

    - Administrative labor is estimated for maintaining compliance logs and digital or paper-based traceability records, including documentation of sanitation and milk movement events. Labor hours are calculated using a base salary rate, assuming a 5-day work week per person. Costs are classified as industry costs at the farm level.

- *Additional costs*
    - Additional expenses include an annual state licensing fee for hauler permits, classified as a required industry cost. Government costs include additional laboratory testing fees in the event of a positive sample, including associated shipping costs.

This chapter will calculate the cost by incorporating the direct costs associated with implementing the KS SMS Plan focusing on the increase of biosecurity during the transportation of raw milk. All labor costs used in the analysis are calculated using base salary rates only, excluding fringe benefits, taxes, and overhead rates. Costs in this analysis represent aggregated response expenses rather than per-farm or per-animal values. Estimates are based on a set of assumptions to account for the unpredictable nature of disease outbreaks in terms of timing, duration, and severity. The data will prepare and educate policymakers to implement informed and effective management strategies.

4.2 Direct and Indirect Costs

A one-time training course will be implemented for each hauler to ensure that all drivers understand the protocols for Highly Pathogenic Avian Influenza HPAI. The costs of training will cover topics such as the proper use and removal of PPE, disinfection procedures, and reporting requirements. Each hauler will receive PPE, including disposable gloves, N95 masks, and boot covers, to protect personnel and farms from potential virus transmission. Additionally, costs will be incurred for labor associated with enhanced cleaning and disinfection activities. This measure aims to prevent the spread of the virus during transport. Costs will also include chemical disinfectants for vehicles and equipment washes during each farm visit and the purchase of sprayers needed for applying these chemicals. Furthermore, installation will include a tire bath on the farm to mitigate the spread of HPAI, which is known to be a vector for on-farm transmission. Lastly, administrative labor costs will be included to log movement and test results, ensuring traceability and compliance with regulatory reporting requirements.

Additional or indirect costs associated with a viral detection occur when a sample tests positive for HPAIv. Such a result will trigger further testing, and an epidemiological investigation to determine how the farm became infected, along with any other interconnected farms. Therefore, when a raw milk sample tests positive in a holding raw milk silo, additional herd-level testing is required to determine herd status. According to the USDA (2024), a situation where a sample test positive would require the implementation of increased biosecurity and rapid response measures.

4.3 Scenarios

Cost estimations are completed by calculating daily costs by multiplying unit costs, such as the price per hauler, the fee for daily farm visits, or the cost of personal protective equipment (PPE) kits, by the corresponding quantities needed each day. The costs for all relevant categories, including labor, equipment, supplies, and incidentals, are summed to arrive at the total daily costs. Combining these daily costs can effectively determine the cumulative expenses and the impact of resource allocation.

The Scenario-Based What-if Analysis examines three distinct scenarios to evaluate potential outcomes of implementing a KS SMS Plan. A baseline scenario or no action represents a situation where no KS SMS Plan is in place and enhanced biosecurity measures are absent, serving as a control group for comparison related to direct costs. In a moderate response scenario or partial implementation, the adoption of a basic KS SMS Plan is established without comprehensive training. While this approach may provide a limited level of protection, it lacks the depth of understanding required for the thorough implementation of biosecurity protocols and may result in reduced disinfectant use, lower compliance, and higher employee turnover. In contrast, the full implementation scenario reflects a complete adoption of the KS SMS Plan, incorporating extensive biosecurity protocols and employee training. This scenario represents the most proactive and well-prepared response, designed to minimize disease spread and significantly reduce direct government costs associated with further testing, epidemiological investigations, or, in the worst-case situation, depopulation.

CHAPTER V: RESULTS

A direct cost summary was developed to outline expenditures related to personnel, supplies, equipment, recordkeeping, and additional related costs. A scenario analysis was conducted, and the results are presented across three categories: 1) no actions (representing the current situation), 2) partial implementation, and 3) full implementation of the KS SMS Plan (see 4.2 Scenarios Implementation). The analysis focuses on direct government cost associated with implementation of biosecurity and traceability protocols aligned with producers current production practices.

Personnel components are divided into four categories, reflecting the additional training required from raw milk collection through transport and delivery, as well as the inclusion of direct government-led training (Table 4.2)

- Trucking company or (transport): One-time hauler training for 10 drivers, valued at $240.00 total ($24/hour), representing industry time investment.
- State training (government cost): Inspector or regulatory staff training valued at $234.00 total, based on a GS-8, Step 2 pay grade ($23.40/hour) and an assumed 2025 annual salary of $48,841.
- Farm personnel (daily biosecurity labor at the farm level): Modeled at $560.00 total, assuming daily disinfection activities at a rate of $16.00/hour.
- Milk receiver (processing plant): Labor for implementing and maintaining process-level biosecurity valued at $560.00 total as well at a rate of $16.00/hour.

Combined, these training and labor activities resulted in a total cost of $1,594 for personnel to implement additional biosecurity and training across the milk supply chain (Table 4.2).

Daily personal protective equipment (PPE) was estimated at $9.12 per person per day, acquired on USDA and supplier pricing for N95 masks, disposable coveralls, goggles, boot covers, hair and beard covers, and gloves (Table 4.1). An assumption of 300 total daily usage for disposable PPE, the cost was calculated at $2,736 (Table 4.2).

Equipment costs include sprayers and disinfection units, with two backpack sprayers priced at $119 each valued from standard supplier pricing, totaling $238 for a one-time cost. Disinfectant, based on Kansas State University's procurement rate of $0.09/gallon once diluted (1:256), resulting in $4.50 per application. Tire disinfection costs include the installation of a basic wheel bath, treated as a one-time purchase of $500 based on a range of current market prices from commercial suppliers. When combined with disinfectant and application related expenses, total equipment costs at the farm level are estimated at $742.50.

Weekly administrative recordkeeping and movement documentation were estimated at $100, assuming one administration hour per week $20/hour. Additional costs for recurring operational expenses include an annual state licensing for hauler permits at $35. USDA laboratory fees for additional HPAI testing triggered with a potential positive (PCR) at $85, including shipping and sample handling, to conclude a total of $120.

The combined costs across all categories yield an estimated total government expenditure of $5,292 for maintaining milk transport operations and preventing an HPAI outbreak incident. The cost model integrates federal and state roles under the KS SMS

Plan, incorporating both direct training and operational activities required for secure milk movement.

The purpose of the scenario analysis was conducted to compare three potential implementation levels of the KS SMS Plan and to illustrate how varying degrees of biosecurity adoption influence direct government costs associated with virus prevention and continuity of milk movement. The No Action scenario resulted in no additional costs, representing the absence of enhanced biosecurity protocols or state oversight expenditures. While this approach incurs no direct financial burden, it also leaves the transportation network highly vulnerable to virus transmission and regulatory disruption during an outbreak. Under the Partial Implementation scenario, total estimated costs reached approximately $2,354, reflecting a limited and less coordinated application of biosecurity measures. This scenario assumes reduced labor involvement, single-person PPE usage, and reduced disinfectant quantities and disinfection activities. Key expenditures included $1,368 for PPE, $280 for daily biosecurity labor, and $250 for partial wheel bath installation, representing a modest investment in protective practices that provide only partial risk mitigation. While this approach offers some virus control, the lack of comprehensive training and consistent application limits its long-term effectiveness. The Full Implementation scenario represented complete adoption of the KS SMS Plan, with all training, disinfection, and recordkeeping protocols fully applied. Total estimated costs increased to $5,292, with the most significant portions attributed to PPE ($2,736), personnel labor ($560), and equipment and disinfection activities ($742.50). This scenario reflects the highest level of preparedness, requiring coordinated participation among state inspectors, transporters, and industry personnel to maintain continuity of milk movement during an HPAI outbreak.

Distribution of government costs (Figure 5.1) provides a visual summary of distribution of total government costs associated with implementing KS SMS Plan for dairy haulers. Figure 5.1 illustrates how expenditures are allocated across key cost categories to highlight the areas that represent each financial circumstance. Supplies account for the largest proportion of total costs, reflecting the substantial need for biosecurity material. Personnel expenses represent the second largest share, driven by labor requirements for onsite verification, training, documentation review, and field training by regulators. Equipment costs contribute to the upfront costs of the initial installation including items such as sprayers. A small percentage of total expenditure along with additional minor costs concludes with records and administrative documentation. Figure 5.1 visually emphasizes that supply-related materials and personnel labor are the primary drivers of government costs, underlining the resource-intensive nature of implementing enhanced biosecurity measures during an HPAI response for raw milk transportation.

Overall, the results indicate that while full implementation requires greater upfront costs, it provides the strongest defense against virus spread and reduces the likelihood of additional indirect expenses, such as diagnostic testing, movement restrictions, or product loss.

Figure 5.1 Distribution of Government Costs

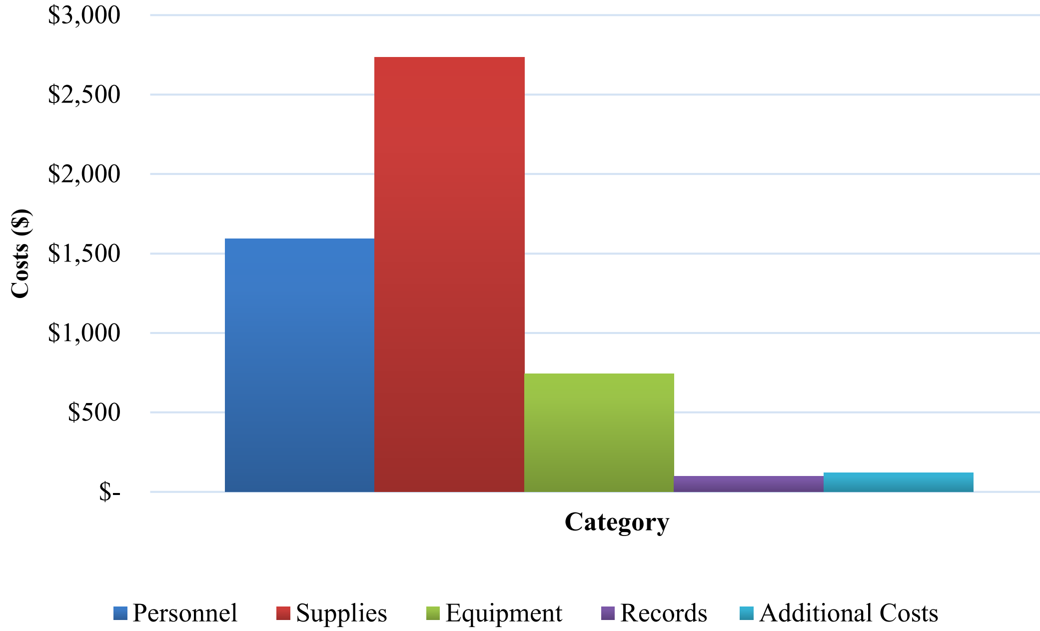


Table 5.1 Estimation of Government Cost of HPAIv

Category	Time Per Unit	Unit Cost ($)	Quantity	Total Cost ($)
Personnel Biosecurity Training				
Trucking company (Transport)	1	$ 24.00	10	$ 240.00
State Training *(Government Costs)*	1	$ 23.40	10	$ 234.00
Personnel - Daily Biosecurity Labor *(Farm)*	7	$ 16.00	5	$ 560.00
Milk Receiver *(Process Plant)*	7	$ 16.00	5	$ 560.00
Total				**$ 1,594.00**
Supplies				
PPE (per person per day)				
Mask N95	-	*$ 1.00*		
Disposable coveralls	-	*$ 5.00*		
Goggles	-	*$ 1.99*		
Boot covers	-	*$ 0.80*		
Disposable hair cover	-	*$ 0.16*		
Disposable beard cover	-	*$ 0.14*		
Disposable gloves	-	*$ 0.03*		
Total		*$ 9.12*	300	**$ 2,736.00**
Equipment				
Sprayers / Equipment		$ 119.00	2	$ 238.00
Disinfectant (per application)	5	$ 0.09	10	$ 4.50
Wheel Bath / Tire Disinfection		$ 500.00	1	$ 500.00
Total				**$ 742.50**
Records				
Record Keeping & Compliance	5	$ 20.00	1	$ 100.00
Total				**$ 100.00**
Additional Costs				
Yearly license fee (State)		$ 35.00	1	$ 35.00
Lab fee (USDA)	1	$ 85.00	1	$ 85.00
Total				**$ 120.00**
Total Cost				
$ 5,292.50				

Table 5.2 Scenarios Implementation

Cost Category	No Action	Partial Implementation	Full Implementation
Trucking company (Transport)	$ -	$120.00	$240.00
State Training (Government Costs)	$ -	$117.00	$234.00
Personnel - Daily Biosecurity Labor	$ -	$280.00	$560.00
Milk Receiver	$ -	$280.00	$560.00
PPE (per person per day)	$ -	$1,368.00	$2,736.00
Sprayers / Equipment	$ -	$119.00	$238.00
Disinfectant (per application)	$ -	$2.25	$4.50
Wheel Bath / Tire Disinfection	$ -	$250.00	$500.00
Record Keeping & Compliance	$ -	$50.00	$100.00
Unexpected Costs & (Additional costs)	$ -	$ -	$120.00
Total Cost	**$0.00**	**$2,586.25**	**$5,292.50**

CHAPTER VI: CONCLUSION, LIMITATIONS AND FUTURE RESEARCH

This study focuses on the transportation sector, as it poses the highest risk of spreading the virus. Movement of milk tankers between multiple farms and processing facilities creates frequent contact, making transportation one of the most vulnerable points of virus transmission in dairy herds. The cross contaminated raw milk and equipment can serve as mechanical vectors during the loading and unloading process. The need to have a prepared plan in place to meet state and federal requirements to continue moving milk during an outbreak is emphasized to protect the continuity of dairy operations.

While some costs related to the loading of raw milk at the farm level are considered, the study does not examine specific direct farm costs during an outbreak. Instead, it emphasizes key assumptions regarding virus handling and movement restrictions, including the potential need to dump (dispose) of raw milk in cases where transport permits are delayed or denied for lack of an implemented KS SMS Plan. The study does not fully quantify farm-level costs, such as ongoing labor, training refreshers, and compliance updates. Future research should model these recurring costs and evaluate long-term cost sharing alternatives between producers and government agencies to ensure sustained participation.

The comparison of the three implementation scenarios: no action, partial implementation, and full implementation, demonstrates a clear relationship between the level of biosecurity adoption and the magnitude of government costs during an HPAI outbreak affecting the dairy transportation sector. The full implementation scenario yields higher estimated government cost upfront, showing that comprehensive training, consistent sanitation practices, and enhanced recordkeeping significantly reduce regulatory interventions and testing demands. Overall, the results indicate that full adoption of the KS

Secure Milk Supply Plan not only strengthens disease-prevention outcomes but also provides a more cost-effective strategy for state agencies responding to HPAI in the dairy supply chain.

To facilitate safe raw milk movement through increased biosecurity, training, and surveillance, The Kansas Department of Agriculture has outlined a responsive plan required during an outbreak. The current outbreak of HPAI has been examined to outline the economic impacts, industry costs and direct government costs.

Although this study outlines these considerations, it does not include calculations or the impact of direct government costs associated with dumping raw milk or indemnity payments. Future research should aim to expand the cost framework to encompass the entire dairy supply chain, integrating farm-level, transportation, and processing components, to more comprehensively assess the economic implications of virus control and continuity planning within the dairy industry. Additionally, future studies could also incorporate transportation infrastructure considerations, such as designated virus-free routes or reduced-traffic passageways, to better evaluate strategies that minimize disease risk while maintaining essential milk movement.

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APPENDIX A – KANSAS SECURE MILK SUPPLY PLAN

Secure Milk Supply Plan

https://www.agriculture.ks.gov/divisions-programs/division-of-animal-health/secure-food-supply/kansas-secure-milk-supply-plan

https://securemilksupply.org/

Checklist

Self-Assessment Checklist for Enhanced Biosecurity for FMD Prevention

Operation-Specific Plan Template

Operation-Specific Plan Template with Blanks

Video

Implementing Enhanced Biosecurity During an FAD Outbreak

Surveillance

- Surveillance Guidance Document
- Active Observational Surveillance (AOS)

Training
Secure Milk Supply Training Materials