Application of Quantitative Methods

Literature Review

"I declare that in submitting all work for this assessment I have read, understood, and agree to the content and expectations of the Assessment Declaration."

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Abrieviation

ASF: African Swine Fever

MILP: Mix Interger Linear programming

PPP: Processing, Packaging, and Preparation

Literature Review on Application of Quantitative Methods in Design and Analysis of Meat Supply Chain

I. SUPPLY CHAIN DESIGN

1.1. PORK VALUE CHAIN AND SUPPLY CHAIN

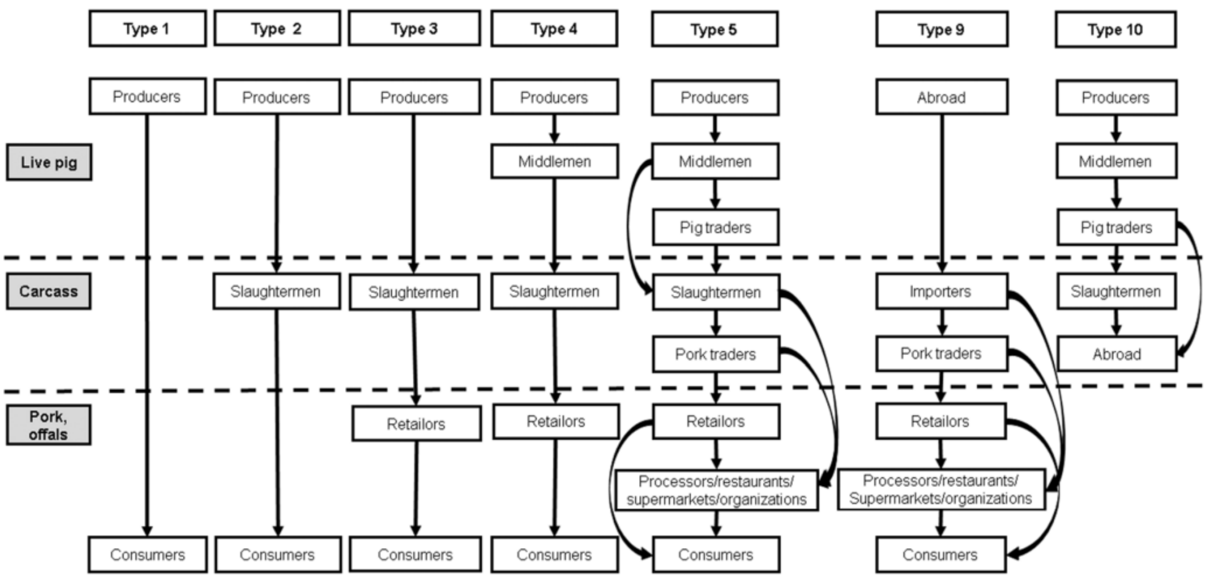

Figure 1: the value chain of pork in Vietnam (adopted from: Nguyen et al. 2020)

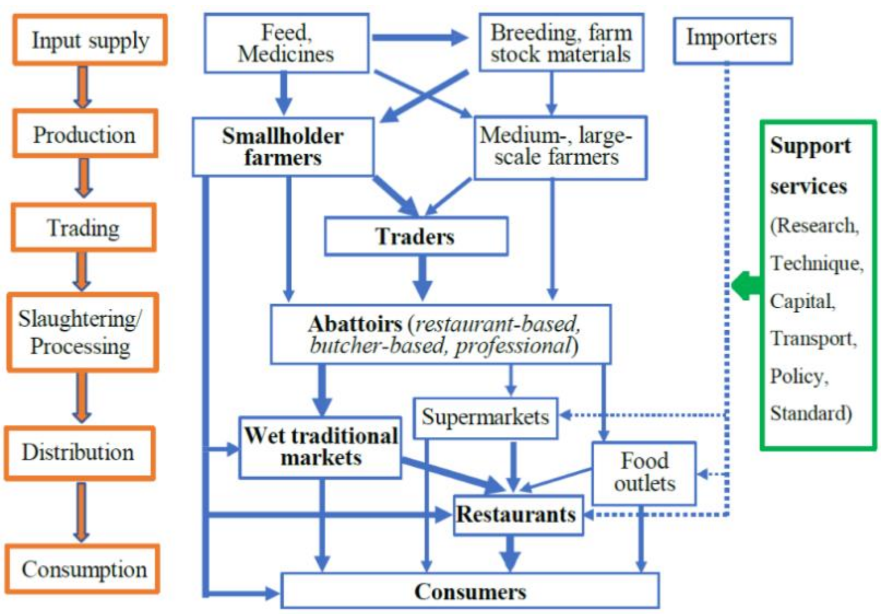

Figure 2: The supply chain in Vietnam (adopted from Nguyen et al. 2023)

All The information below, except for others information cited in difference authours is taken from the Source and Source.

The swine industry is rather intricate than others developed countries with diverse intermediaries' nodes engage in the network model stemming from traditional practices (Espinoza et al. 2022). Considering that, there are multitude types of value chain/ supply chain in Vietnam pork industry. Nevertheless, a standardised supply chain model in *figure 2* which includes 6 stages: input supply, production, trading, processing, distribution and to the end users. The supply chain model network from *figure 2* is a simplified version of the value chain.

- **The flow of products**

The uniqueness of Vietnam's pork value chain is depicted in *Figure 1*, which outlines Types 1 through 5 as the most conventional and traditional pathways from production to consumption. Within these types, live pigs are initially sold by the producers and subsequently subjected to the slaughtering process. The resultant carcasses are then managed by retailers before being made available to the consumers. These types are primarily differentiated by the intermittent presence of middlemen and pig traders, which suggests variations in the distribution and marketing strategies.

Distinctly, Type 9 of the value chain represents the importation of pig carcasses which are then transferred to traders. These traders serve as a distribution nexus before the pork products reach the end consumers. In contrast, Type 10 portrait a value chain wherein imported pig carcasses are sourced locally but are destined for international consumers.

- **Stakeholders and nodes**

This distribution network interconnects various essential points, such as those responsible for supplying materials, the farming and harvesting phase, procurement, refinement processes, and the final consumers. There are five key stakeholders which is the material suppliers, cultivators, brokers, firms engaged in processing and exporting, and the businesses in the wholesale and retail.

- **Input suppliers**

Nguyen et al. (2020) highlight that commercial feeds make up 67% of total feed usage in small-scale agriculture. In contrast, small-scale pig farmers often use a combination of farm produce, food waste, and various feed ingredients. They tend to focus on providing additional feed and veterinary care mainly to livestock like pigs, poultry, and cattle (Nguyen et al. 2023). These inputs are acquired through direct cash purchases, including transportation costs for deliveries to local buyers (Nguyen et al. 2023).

- **Farmers and smallholers**

Notably, 80% of farmers in Vietnam are smallholder farmers, indicating that traditional food systems and value chains dominate the market with the Northen region typically prefer fresh produce at wet traditional markets over chain stores. (Cook and Pham 2018). While in Ho Chi Minh (the Southern region) larger-scale wholesalers have started to become more prominent market players (Nguyen and Guntoro 2020) . Nevertheless, traditional markets remain significant.

1.2. PROBLEMS WITH THE SWINE INDUSTRY

1.2.1. Ineffective supply chain

As mentioned above, the Vietnamese pork supply chain is rather complex due to the traditional wet market. Multiple spontaneous and small-scale farmers are still thriving in Vietnam, especially in the North; relatively 85% of farms have to be distributed through a merchant, while 15% go directly to supermarkets (An 2021). In 2023, Vietnam was recognised as the second-largest consumer of pork in Asia, with a per capita consumption of 27.7 kilograms, which occurs a lot of small-scale farmers and more spontaneous (Vietnam News 2022). This led to obstacles in managing and regulating wild pig populations and maintaining stable prices for swine and pork. Hence, the rise in demand increases production costs because of increasing feed and breed costs (Dong et al. 2019).

According to the Vietnam General Statistics Office (n.d), the imported feed price increased by 8.71% in 2021. This applies to all the SME supper market chains and the pork-selling vendors. However, in the market complex in Vietnam, a lot of misleading feed labelling was identified as accurate antimicrobial; this could harm the production due to the ineffective detaining of diseases such as African Swine fever (ASF) (Coyne 2019). Having a contagious pig farm is risky and prone to spreading to other herds; thus, the distribution channel can increase the price with fewer products. High disease and poor prices were identified as potential drivers of economic loss. According to Ha and Thuong (2022), multiple swine breeds do not have stamps or traceability rings to track the origin of this unsafe carcass, or the products will be sold to consumers. Furthermore, with a wide range of pork meat, the higher needs to be consistent quality between each vendor and distributor.

1.2.2. Environmental concern

Dinh (2017) revealed that pig farming generates the most significant proportion of manure and consequently causes the highest pollution levels in the livestock sector compared to other animal species in Vietnam. Notably, pig farms are predominantly located in densely populated regions across the Red River Delta, the Mekong Delta, and the Southeast.

While pigs contribute significantly to Vietnam's livestock industry, almost half of the manure they produce, which remains untreated, is directly released into the environment (Le et al. 2020). This accounts for the highest percentage of waste generated by the country's farm animals.

II. SUPPLY CHAIN ANALYSIS

2.1. MIXED-INTEGER LINEAR PROGRAMMING (MILP)

2.1.1. How MILP address the problems

In a series of studies spanning various industries and supply chain contexts, MILP has proven to be a versatile tool for addressing complex operational and logistical challenges. These applications encompass many problems, including production planning, inventory management, resource allocation, and cost optimisation.

Albornoz et al. (2015) and **Wang and Wang (2018)** both study production planning, inventory management, and cost optimisation while considering constraints like carcass availability and labour capacity. However, **Wang and Wang (2018)** focus more on optimisation with material substitutions; MILP balances production, transportation costs, and raw material procurement, including bi-objective functions like profit maximisation and emission minimisation. In comparison, **Moonsri et al. (2022)** showcase MILPs on the Outbound logistics in the poultry industry used in tackling facility location, inventory management, and transportation planning, employing methods like Branch and Bound.

As minimising waste is crucial to the new generations, the slaughter-by-product chain of **Sonsbeek et al. (1996)** study how to limit the waste from poultry carcasses and other unused parts by using MILP to optimise processing configurations considering economic, technological, and environmental factors. In contrast, **Rahbari et al. (2022)** Determine the optimal flow of products through various stages of a supply chain, balancing transportation, production, and inventory holding costs to decide on quantities to produce, transport, and store.

The research by **Zarini and Javadian (2020)** on sustainable meat supply chain networks underscored the crucial role of MILP in streamlining cost optimisation, capacity utilisation, and the reduction of CO2 emissions. This study highlighted how MILP can effectively manage environmental impacts while ensuring efficient operation of farms, abattoirs, and retailer capacities. Similarly, the work of **Mohebalizadehgashti et al. (2022)** marked a significant shift towards green meat supply chain design, demonstrating MILP's capabilities in facilitating discrete decision-making processes. This included decisions about product quantities and facility locations, though it did require the assumption of linear relationships. Bridging these approaches, **Wang et al. (2021)** further expanded on the application of MILP in facility location and transportation planning. Their research aimed to minimise costs and environmental impacts, acknowledging the subjective nature of determining objective weights in such models. Difference all the studies that **De Leon et al. (2022)** study in the context of public health, MILP aids in developing diet plans for COVID-19 immunity response, optimising cost with the nutritional constraints.

2.1.2. How MILP works and the limitations

In general, The MILP or MIP aims to maximise or minimise based on the objective function by considering each decision variable and constraint. Looking into the common theme of 10 articles in the meat industry, the objective function is utilising the MILP to optimise cost and minimise environmental impact by considering factors such as transportation, inventory, time, and others. Additionally, to finalise the objectives function depends on the decision variables. These variables are the output that helps to make a decision. Furthermore, determine the correct outputs, a set of constraints must be determined to calculate the variables. In light of that, **Rahbari et al. (2021)**

set of variables that define entities such as suppliers, facilities and vehicles determine the objective function of the routing for the meat industry used for emerging economy countries.

In contrast, **Sonsbeek et al. (1996)** include the different types of by-products to process, storage methods and transport routes. Despite that, there are limitations in the mathematical methods, and there will be an increase in the number of variables, restrictions, and processing time as the size of the problems increases (Eslami et al. 2019). For instance, even with this study's modest sample size, the number of variables and constraints involved was 7000-13,000 (Auler and Lettre 2015). Hence, a complicated industrial-scale issue will have many variables and limitations..

2.2. SIMULATION MODEL

2.2.1. Simulation model address the problems

Djekic et al. (2020) integrate production and consumption data to assess pork meat consumption's environmental footprints, **Pexas et al. (2020)** investigate the environmental implications of pig production manure management, identifying potential hotspots and evaluating improvement scenarios. Consistent with **Kayikci et al. (2019)** work in system dynamics modelling and grey prediction in the red meat supply chain; they anticipate output and waste, assess structural constraints and devise plans for more effective resource utilisation, showing the industry's comprehensive commitment to environmental sustainability. Furthermore, **López-Andrés et al. (2018)** simulation are used to address uncertainties in the environmental impacts of chicken meat production from the beginning to the end of the lifecycle.

Contamination in the meat industry has become a health concern for all consumers, **Smid et al. (2012)** efficiently pinpoints the critical sources of Salmonella infection, improving food safety procedures. **Andraud et al. (2019**) use simulation to evaluate the efficiency of different control approaches in controlling African Swine Fever (ASF), considering several transmission paths. While **Jongeneel et al. (2020)** study simulation by assessing the broader economic implications of ASF, including supply and demand shocks in crucial areas such as the EU and East Asia.

The simulation model not only combats virus transmission but also reduces enterprise costs. According to **Purwaningsih (2018)**, uses of both Monte Carlo simulation and Value at Risk (VaR) approaches in the poultry business are critical for evaluating possible financial losses due to market volatility, assisting in economic risk management and managing supply-demand imbalances. Furthermore, **Koroteev et al. (2022)** uses simulations to optimise budgetary projections, allowing for the formulation of lucrative production plans by evaluating alternative scenarios in raw material procurement and assortment design. Lastly **Itakura (2019)** to analyse the more significant economic consequences in ASEAN nations, focusing on the welfare impacts of lower business costs and their influence on manufacturing exports, imports, and overall economic well-being.

2.2.2. How simulation works and the limitations

Koroteev et al. (2022) research process starts with basic system dependencies, utilising random numbers to construct complex models. However, these variables are constrained by static process boundaries and labour costs. Furthermore, **Andraud et al. (2019)** focus on ASF management strategies, notably the dynamics of the disease in wild boar populations and is based on theoretical scenarios. Alongside the European pig production model, **Pexas et al. (2020)** face challenges in sensitivity and accuracy due to fixed assumptions about animal performance and a lack of detailed data on barn construction.

In the red meat supply chain context, **Kayikci et al. (2019**) state that the model is highly dependent on predictions and encounters practical challenges in implementation stemming from its narrow scope. The forecasting models for the EU pig sector **Jongeneel et al. (2020)** have uncertainties and heavily rely on the accuracy of regional market insights. The ASEAN trade and welfare model **Itakura (2019)** simplifies complex real-world scenarios and is contingent on the quality of data from the GTAP Database. While the research study of **Smid et al. (2012)**, the simulation's assumptions regarding the sources and dynamics of Salmonella contamination may oversimplify intricate real-life processes.

The environmental impact assessment in chicken meat production by **López-Andrés et al. (2019)** encounters difficulties because accuracy is also contingent on the specific data used, which might not capture all aspects of the actual system. For instance, in this study, the data and scenarios are tailored to a specific context, which may limit the applicability of the findings to other contexts or systems with different environmental conditions. Lastly, **Purwaningsih et al. (2018)** study does not yield optimal risk assessments and is limited by the dependability of market price stability and data collection systems.

2.3. APPILCATION OF SIMULATION AND MILP ON THE PORK SUPPLY CHAIN IN VIETNAM

Application of Simulation Models

The mentioned mathematical methods (simulation and MILP) can alleviate the problems of the Vietnamese pork supply chain. To begin with, Simulation models, such as Monte Carlo simulations, have been instrumental in assessing and improving the pork supply chain in Vietnam. One significant issue is the assessment of environmental sustainability in pork production. The implementation lowers the environmental footprints associated with different stages of pork production, considers energy consumption, waste management, and carbon emissions.

Another critical concern is disease control, especially concerning the spread of diseases like African Swine Fever (ASF). The model simulates the transmission dynamics of ASF in pig populations, considering various transmission pathways, including contact between infected and susceptible pigs, contaminated feed, and vectors. By running multiple simulations with different control strategies, the model assesses the effectiveness of vaccination, quarantine, and culling in controlling the disease's spread. This information helps policymakers and stakeholders make informed decisions on disease management.

Application of MILP

MILP is applied to optimise various aspects of the pork supply chain in Vietnam, with a focus on resource allocation, cost minimisation. One critical challenge is production planning and inventory management. MILP models determine the optimal quantity of live pigs, considering feed availability, labour capacity, and market demand. The objective is to maximise profit while adhering to constraints such as the availability of pig farming facilities and feed resources. The MILP model helps farmers decide when and how many pigs to raise, ensuring efficient resource utilisation.

Another application of MILP is in transportation planning within the pork supply chain. Given Vietnam's diverse network of farms, processing facilities, and distribution centres, efficient transportation is crucial. MILP optimises vehicle routing, minimising transportation costs while meeting delivery schedules and demand from various regions. This involves decisions on which farms to collect pigs from, which processing facilities to visit, and which routes to take. The MILP model considers transportation distances, vehicle capacities, and delivery time windows, leading to cost savings and improved supply chain efficiency.

III. SUMMARY OF FINDINGS AND IMPLICATION

This report, drawing from 20 peer-reviewed papers, presents a focused literature review on the use of MILP and simulation models in the pork industry, uncovering several significant findings:

- Koroteev et al. (2022) using coding systems Python, JavaScript and SQL for simulating manufacturing enterprise, specifically a meat processing plant. The system automates production planning and decision-making based on various data inputs and constraints significantly enhance the efficiency and profitability of a manufacturing enterprise.
- While Djekic et al. (2020) This comprehensive study connects pig farming with pork meat consumption, providing a new perspective on environmental footprints. Highlighted the significant environmental burden of pork consumption, suggesting a need for a shift in focus from farm-level impacts to consumer dietary patterns.
- Differencely, Andraud et al. (2019) the simulation demonstrated that while ASF has a significant impact, the spread within the French swine production network is relatively contained, particularly due to effective surveillance and control measures.
- Pexas et al. (2020) simulation provides a comprehensive framework for evaluating the environmental impact of pig production systems, highlighting the significance of pig housing and manure management strategies in reducing overall environmental impacts.
- Kayikci et al. (2019) using the grey method simulation used to predict the number of slaughtered cattle and the resulting bone and blood waste and further proposes a circular and central slaughterhouse model to address the inefficiencies in the red meat sector.

- Jongeneel et al. (2020) study on how to recorved from ASF finding a medium-term recovery (5 years) and a fast recovery. Both scenarios predict an increase in net EU exports in the short term, followed by a market realignment with lower prices and reduced exports.
- Itakura (2019) highlights the significant role of fixed costs in trade, showing how reducing these costs can lead to increased trade volumes and welfare gains in the ASEAN region.
- Smid et al. (2012) research using the simulation demonstrates the utility of a sequential adaptation model in tracing and predicting the sources of Salmonella contamination in pork slaughterhouses.
- López-Andrés (2018) finds Chicken farms had the most significant environmental impact, primarily due to feed production and on-farm emissions. In the processing plant (PPP), key contributing stages were steam production in boilers and ice production, primarily due to the energy and refrigerants requirements.
- Purwaningsih et al (2018) The study concluded that while the Monte Carlo simulation provided valuable insights into the risk profile of broiler farming, it did not yet offer optimal predictions for risk assessment.
- Albornoz et al. (2014) using MILP The model emphasises the importance of not only looking at raw material weight but also properly measuring its yield for higher incomes and operational efficiency. It suggests that flexibility and coordination between suppliers (fattening farms) and producers in the pork industry are crucial for efficient operations.
- Zarini and Javadan (2020) The results from solving the model in Lingo software showed the optimal distribution of products among different supply chain facilities, which effectively addresses the complexities of a sustainable meat supply chain

- Mohebalizadehgashti et al. (2020) based on the MILP the Present Value of Total Cost (PVTC) is not highly sensitive to transition probabilities, offering managers a reasonable estimate even without precise probabilities.The discount rate significantly impacts PVTC, underscoring the importance of accurate rate estimation for decision-making
- Wang et al. (2018) The increase in substitutable items in a supply chain enhances its economic and environmental performance.
- Wang et al (2021) Trade-offs between economic efficiency and sustainability are highlighted, showing the influence of varying objective function weights on strategic and tactical decisions.
- Moonsri et al. (2022) using computing MILP focuses on optimising outbound logistics for the poultry industry in Thailand, addressing a multi-depot vehicle routing problem to minimise transportation costs.
- De Leon et al. (2022) Using mixed-integer linear programming, the researchers formulated meal plans for four categories: Males (19-29 years old), Males (30-50 years old), Females (19-29 years old), and Females (30-50 years old). The study suggests including respondents from lower annual household incomes for future research to provide a more accurate list of low-cost food items.
- Rahbari et al. (2021) The model is applied to a real-world case in Iran's red meat supply chain, involving 69 nodes, seven time periods, and multiple vehicle types. Furthermore, sensitive analysis was conducted to assess the impact of changing time periods from monthly to weekly, indicating a significant increase (43.26%) in the final cost per kilogram of meat
- Sonsbeek et al. (1997) The study considers forty identical poultry slaughterhouses and a central processor, focusing on the production of low risk materials (LRM), blood, and sludge from poultry. It operates on a yearly production schedule.
- Rahbari et al. (2022) there are two stages Determining the quantity of packed meat produced and held in each period and Focusing on the quantity of packed meat transported on each route, inventory levels at each node. Result in The model solved using GAMS software indicated a reduction in cost per kg of red meat by about 2% compared to current market prices

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