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Forging Futures: An Emerging Paradigm for Indigenous Chicken Supply Chain with Actor Network Theory and System Dynamics

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Abstract
The United Nations prioritizes Sustainable Development Goal 12, focusing on sustainable consumption and production. Indigenous chicken farming holds promise for economic, environmental, and social sustainability. However, it lacks an integrated supply chain. To address this, we combine Actor-Network Theory (ANT) and System Dynamics (SD) in a study conducted in Malaysia. ANT considers human and non-human actors equal to promote collaboration, while SD explores dynamic interactions and simulations. The current study has collected qualitative data through interviews with Perak's indigenous chicken growers to identify key actors. The current concept model presented preliminary results in the form of causal loop diagrams. In the future, the study proposes translating the causal loop diagrams to stock and flow diagrams to get the emerging model. The emerging model will contribute to the body of literature in the fields of the supply chain, ANT, and the livestock sector.

Keywords: Actor-Network Theory (ANT), Indigenous Chicken, System Dynamics Modeling (SD), Triple Bottom Line Approach (TBL), Integrated Supply Chain

Introduction

In the face of the mounting environmental challenges and social inequalities associated with unsustainable consumption and production patterns, the United Nations has underscored the significance of adopting sustainable practices that align with Sustainable Development Goal 12 (United Nations, 2021). This necessitates responsible resource usage, waste reduction, and sustainable production (United Nations, 2021). The practical manifestation of these principles can be found in indigenous chicken farming, where the resilience of local breeds serves as an instrument for preserving genetic diversity. This practice minimizes environmental stress through natural foraging behaviors, stimulates local economies, enhances food security, and preserves traditional knowledge (Herrero, et al., 2013; Altieri, 2018).

Indigenous Chicken (Gallus domesticus), which is also referred to as Native Chicken, Village Chicken, or Backyard Village Chicken, provides a viable solution for rural poverty and a sustainable, climate-resilient food system in low- and middle-income countries. These chickens are used for both meat and egg production in such regions (Manzvera, 2023; Bulama, 2019). Indigenous chicken micro-farming requires minimal capital, land, labor, and time compared to other livestock options, making it a feasible choice for rural farmers with inherent poultry knowledge (Manjula, 2018; Ayieko, 2014). Globally, these chickens play a pivotal role in promoting gender equality and alleviating poverty, especially in vulnerable communities affected by conditions like HIV/AIDS (Bulama, 2019; Bwalya & Kalinda, 2014). Moreover, indigenous chicken farming is eco-friendly due to indigenous chickens' ability to tolerate harsh environmental conditions and lower mortality rates (Bulama, 2019; Aryemo, et al., 2019; Flynn, 2010).

Indigenous chicken farming presents a sustainable alternative to intensive broiler chicken farming, aligning with the Triple-Bottom-Line (TBL) approach. However, constraints in this micro-farming sector, such as limited access to quality inputs, restricted market opportunities, and a lack of market information, hinder its full potential (Aryemo, et al., 2019; Alhaddi, 2015; Ndenga, 2018). Note that these constraints are due to an unintegrated supply chain model. Supply Chain Integration (SCI) involves seamless coordination and collaboration among supply chain partners to optimize efficiency, reduce costs, and enhance performance (Flynn, 2010; Aggrey, 2022).

Indigenous chicken farming's potential can be maximized by addressing its constraints by developing a model guided by Actor-Network Theory (ANT). Supply chain research has traditionally focused on simplified conceptions. Nevertheless, modern supply chains are increasingly complex, with multi-tier, fragmented, and geographically dispersed networks shaped by intricate interactions. ANT argues that supply chain structures are not predefined yet emerge episodic due to the interaction of actors involved in the supply chain. Furthermore, ANT considers both human and non-human components of the supply chain as an actor facilitating a comprehensive understanding of their interactions and influences (Hald & Spring, 2023; Mason, 2018). Moreover, this approach promotes stakeholder collaboration and coordination, enhancing inclusivity and sustainability.

Additionally, this study intends to employ the System Dynamics (SD) approach and ANT to provide a holistic understanding of the dynamic interactions within the indigenous chicken micro-farming system. SD models allow researchers to simulate different scenarios and assess their impact on the supply chain's performance over time (Abbasi, 2023; Sterman, 1989). Therefore, by quantifying relationships and feedback mechanisms, this integrated approach enables the development of an optimized and sustainable supply chain model for indigenous chicken farming.

This conceptual paper seeks to contribute to the supply chain literature by introducing a framework for developing an integrated supply chain model for indigenous chicken farming guided by ANT. The aim is to fill a gap in the existing literature on indigenous chicken micro-farming by proposing a novel integrated supply chain model that leverages the synergies between ANT and the SD approach.

The main objective of this paper is to comprehensively review relevant literature pertaining to indigenous chicken farming, ANT, and the SD approach. Subsequent sections of the paper systematically elaborate on the literature review and propose a methodology for developing an integrated supply chain model for indigenous chicken farming guided by ANT. Furthermore, this study addresses the preliminary outcomes of a causal loop diagram and the envisaged utilization of this diagram in the future development of the integrated supply chain model.

Literature Review

Indigenous Chicken Supply Chain and Constraints

This section provides a comprehensive review of literature from 2010 to 2023, focusing on the various actors engaged in the micro-farming of indigenous chickens and their challenges within the supply chain. The analysis reveals key actors, including pre-producers, producers, intermediaries, retailers, and consumers, and their respective roles in the indigenous chicken supply chain. At the outset of the value chain are the pre-producers, responsible for furnishing essential inputs like Day-Old Chicks (DOCs), vaccines, feed, extension services, and equipment to the producers (Lumbandi, 2019; Aiyedun, & Oludairo, 2016). Moreover, producers or growers have rear chickens intending to sell them to intermediaries or directly to end consumers and engage in diverse distribution channels (Ndenga, 2018; Okeno, 2012).
Intermediaries, specifically middlemen or wholesalers, play a crucial role by procuring indigenous chickens from growers and marketing them to retailers and processors (Alemayehu, 2018). Retailers serve as sellers of chicken products to end consumers, while processors, including restaurants and butchers, add value to the products and present them to the final customers. Some processors have slaughterhouses for slaughtering indigenous chickens, with the processed products entering the frozen market segment (Aryemo, 2019; Lumbandi, 2028). However, this supply chain faces numerous constraints. This includes limited financial resources, high labor expenses, inadequate knowledge dissemination, insufficient extension services, subpar farming methods, predation risks, housing conditions, price fluctuations, and the absence of locally adaptable breeds (Hailemichael, 2018; Abbasi, 2023). Additionally, issues such as chicken mortalities, inadequate transportation infrastructure, substandard facilities, lack of quarantine setups, slender profit margins, and high processing expenditures burden indigenous chicken farmers (Nanyeenya, 2018)

These challenges highlight the need for an integrated supply chain model for indigenous chickens. The ANT offers a relevant framework, emphasizing the interplay between human and non-human entities and the significance of relationships and interactions in shaping SD (Lumbandi, et al. 2019; Lotesiro, et al., 2017). Hence, incorporating ANT principles can bridge communication gaps, enhance collaboration between supply chain nodes, and facilitate more effective management practices. This approach can potentially reconfigure the indigenous chicken micro-farming landscape and mitigate the constraints hampering its progress (Aryem, 2019),

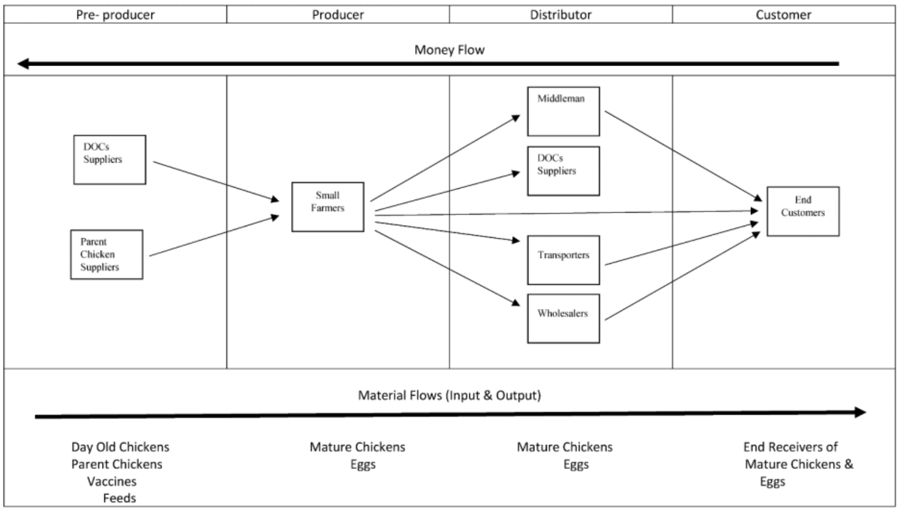

Figure.1. Summary of supply chain mapping

Actor-Network Theory

The ANT was proposed by Michel Callon, Madeleine Akrich, Bruno Latour, and John Law in 1980. ANT is a sociological paradigmatic and methodological framework that intends to understand and explain the intricate and dynamic relationship between human and non-human entities or actors in numerous sociotechnical systems (Hald, & Spring, 2023; Mason, et al. 2018; Çalışkan, & Callon, 2009; Abboubi, et al., 2022). Recently, ANT has garnered attention from Supply Chain Management (SCM) researchers as it challenges traditional SCM by introducing key principles: heterogeneity, relationality, and performativity. These principles have radically shifted and reshaped the traditional perspective on how supply chain's function and are managed.

Heterogeneity refers to multiple types of actors in ANT involved in a network. ANT considers both human and non-human entities as actors with the potential to influence or be influenced within a network. This principle emphasizes that all actors, human or non-human, have agency and should be taken seriously (Hald, & Spring, 2023; Mason, et al. 2018; Abboubi, et al., 2022; Romestant, 2020). In SCM, technology, processes, and even inanimate objects can play a crucial role in shaping the supply chain. This stands in contrast to traditional SCM, which often places more emphasis on human actors (Hald, & Spring, 2023; Mason, et al. 2018; Çalışkan, & Callon, 2009; Abboubi, et al., 2022; Law, 2009).

Relationality in ANT suggests that reality consists of relationships between actors, in which meaning, and significance emerge from these relationships. In an SCM context, supply chains are not predefined structures, but dynamic networks formed by the interactions between diverse actors (Hald, & Spring, 2023; Mason, et al. 2018; Çalışkan, & Callon, 2009; Abboubi, et al., 2022) ANT does not assume the existence of supply chain structures in advance. Instead, it examines how these structures emerge through relational interactions. This contrasts with functionalist approaches that may view supply chains as pre-designed systems with predefined roles (Hald, & Spring, 2023; Mason, et al. 2018; Abboubi, et al., 2022; Díaz Andrade, & Urquhart, 2010).

Performativity in ANT asserts that reality is episodic and that objects gain meaning and significance through their performance in specific action episodes. In SCM, this principle challenges the idea of integration as a predetermined outcome. Instead, ANT views integration as an ongoing accomplishment that emerges from the interactions and translations between actors in specific practices. Integration is not a fixed state. However, it is a dynamic process that evolves over time (Hald, & Spring, 2023; Mason, et al. 2018; Abboubi, et al., 2022; Díaz Andrade, & Urquhart, 2010). Additionally, ANT uses the concept of translation to describe the process through which previously unrelated objects are related and converge. Moreover, ANT pays close attention to the detailed and fragile process of making these translations successful (Hald, & Spring, 2023; Mason, et al. 2018; Abboubi, et al., 2022; Díaz Andrade, & Urquhart, 2010; Williams-Jones, B., Graham, 2003).

ANT recognizes that performativity leads to uncertainty, as the meaning and significance of objects are not fixed but context-dependent (Wernick, et al., 2008) In SCM, this challenges the notion of standardized practices and tools, emphasizing the need to adapt to the specific context of each supply chain episode (Hald, & Spring, 2023; Mason, et al. 2018; Abboubi, et al., 2022; Díaz Andrade, & Urquhart, 2010).

Expanding upon the foundation of existing literature on indigenous chicken supply chains and ANT theory, this study will harness the SD methodology to gain a holistic understanding of the emergence of the indigenous chicken supply chain. Through this approach, this study aims to unravel the complex dynamics and intricacies that underlie the indigenous chicken supply chain's development.

System Dynamics Modeling

There are various compelling reasons to employ SD to model the supply chain. These reasons encompass the capacity to understand the system, analyze the interactions among components of the integrated system, and provide feedback without decomposing. Jay W. Forrester, during his involvement in General Electric projects, initially introduced the foundational concept of SD by crafting a model for a four-tier supply chain by Sterman. SD modeling consists of two key elements: (i) stock and flow structure for the attainment of inputs and processes and (ii) the formulation of managerial policies that oversee various activities within the system.

SD modeling has discovered extensive applications across diverse research fields, including agriculture. For instance, Kortzfleisch and Gupta (1987) employed the SD modeling approach to appraise different investment strategies for agricultural development. This enabled an assessment of the impacts of these strategies on the overall system performance. Similarly, Oliva and Revetria (2008) have applied the SD approach to develop a model of cold chain management within the food supply network. Furthermore, Kumar and Nigmatullin (2011) employed SD to meticulously evaluate the performance of supply chains involving non-perishable food items. The versatility of the SD approach is evident in its application by Tedeschi et al. (2011). They utilized it as a managerial instrument to formulate a model for enhancing animal production, focusing on species like goats and sheep.

Similarly, Teimoury et al. (2013) conducted a study targeting the supply chain associated with perishable fruits and vegetables. Their work concentrated on the identification of optimal import quota policies. Stave and Kopainsky (2015) also developed a model to transfer, expand, and reduce the effect of disturbance on the food system. At the same time, Guma et al. (2022) turned to SD to delve into the intricate relationships inherent in food security systems.

In parallel, investigations into the chicken industry have been significantly advanced by adopting SD tools. Naser Ranjbar undertook a comprehensive investigation of oscillations within the chicken meat sector, utilizing the SD approach. Minegishi and Thiel (2000) strategically employed SD modeling to simulate the complex logistical behaviors governing the chicken meat supply chain. Similarly, Le Hoa Vo and Thiel [48] directed their efforts toward France's chicken meat supply chain dynamics in the context of bird flu, leveraging the competence of the SD approach. Moreover, Shamsuddoha (2014) ingeniously constructed an integrated commercial poultry supply chain, drawing upon the capabilities of an SD model.

Building upon the existing body of literature concerning indigenous chicken supply chains, ANT theory, this study intends to employ the SD methodology to understand how indigenous chicken supply chains will emerge comprehensively.

Methodology

The present study has employed SD modeling to operationalize ANT. According to Hald and Spring (2023), to operationalize ANT, it is crucial to follow certain principles. These principles include following the actors to pay equal attention to human and non-human actors, searching for associations between actors and the making of actor networks, and following and seeking to understand translation processes. Table 1 illustrates the steps employed to operationalize ANT. Consequently, the current study has employed qualitative interviews to collect data from farms in the district of Perak. This study used a purposive sampling method to select farms since the current study wanted to select medium-scale farms that also engage on a small scale. Furthermore, a thematic analysis approach is employed to identify the variables and causal relationships among variables.

Table 1
Steps Employed to Develop Supply Chain Model

Actor-Network Theory (ANT)	System Dynamics Approach (SD)	Explanation	Steps	Objectives
Identify Actors & Elements	Identify Actors & Elements	Literature Review to identify actors and elements in the indigenous chicken supply chain.	Literature Review	To identify the problem To identify actors in the supply chain
Define Causal Relationships	Causal Loop Diagram (CLD)	Identify the causal relationships within the indigenous chicken supply chain.	Literature Review Data Collection & Analysis	To Develop a Causal Loop Diagram
Quantify Variables & formulate Equations.	Stock & flow Model	Translate the causal relationships identified in the CLDs into mathematical equations that govern the dynamics of the supply chain model.	Data Collection & Analysis	To develop an integrated supply chain model
Validate the Model		Validate the model's output against real-world data and observations. Refine the model as needed to ensure its accuracy and alignment with the actual supply chain dynamics.		To develop an integrated supply chain model

As introduced earlier, the absence of an integrated supply chain model for indigenous chicken has posed various challenges for micro-farmers engaged in indigenous chicken rearing. Addressing this issue, the present research has gathered data from medium-scale farms and smaller-scale indigenous chicken growers in Perak, Malaysia. The subsequent section will discuss the modeling based on the analysis.

Result

The causal loop diagram is a fundamental component of SD modeling, with positive and negative feedback loops in a causal loop diagram serving as the building blocks of SD modeling.

Parent Chicken Lineage

The operation of an indigenous chicken farm begins with the purchase of indigenous chickens. Initially, non-human actors include parents and egg-laying chickens, which undergo biological processes to drive egg production.

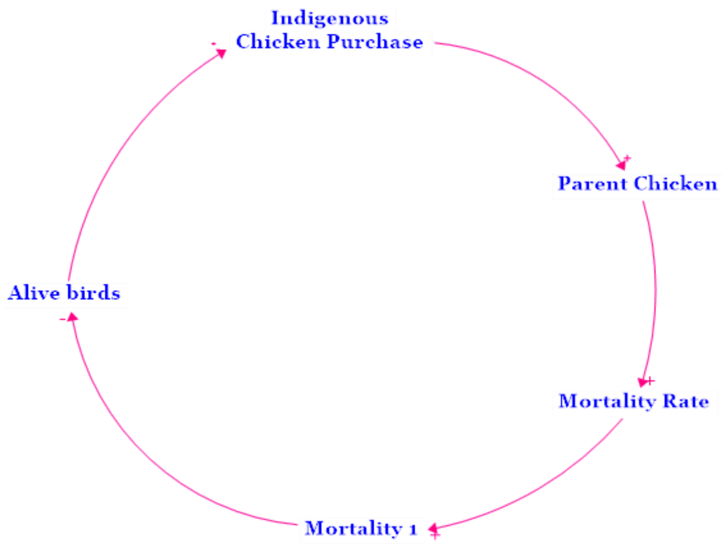

Figure.2. A causal loop diagram of parent chickens

Feedback Loops

Positive Feedback Loop: Higher mortality rates create a positive feedback loop, compelling farmers to buy more parent chickens to maintain their stock.

Negative Impact on Population: Increasing mortality negatively impacts the population of live parent chickens, leading to a reinforcing loop of declining numbers.

Causal Loop Diagram of Egg and Hatchery

The indigenous chicken farm operation involves a lifecycle as illustrated in Figure 3, where non-human biological actors, live parent chickens, mature into egg-laying chickens, contributing to egg production. Eggs laid by egg-laying chickens are treated as objects or products of biological processes. In their role as objects, these eggs become part of the network and interact with the technological actor, the hatchery unit, where they undergo a significant transformation process. During this transformation, these eggs transition into actors in that they actively participate in hatching into DOCs. The shift from being objects to actors demonstrates how the roles and significance of actors can evolve within the network, depending on the processes they are engaged in. Meanwhile, eggs, a non-human actor produced, interact with the technological actor, the hatchery unit, where eggs hatch into another non-human actor, DOCs. However, as the egg stock accumulates, it increases broken eggs and egg waste, negatively impacting the hatchery collection rate and hatching process. This, in turn, affects the egg hatching rate, DOCs inflow, and the total DOCs stock. A decrease in the DOCs' stock triggers a higher demand for egg-laying chickens to maintain the production cycle.

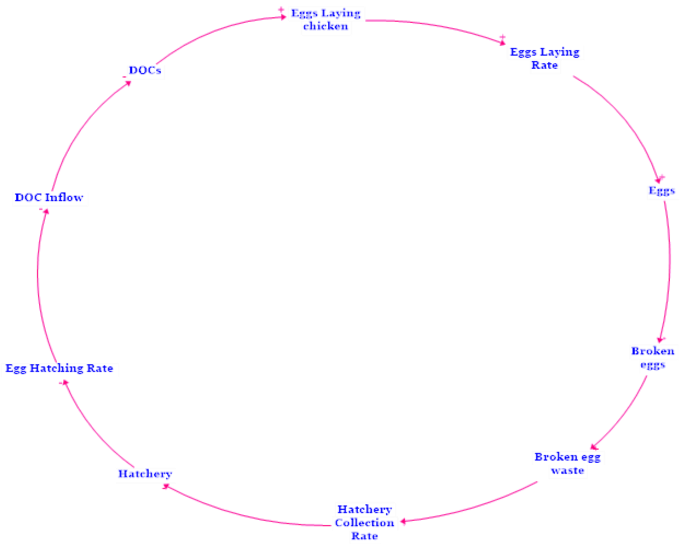

Figure.3. Causal loop diagram of egg and hatchery waste

Grower Farm

In small-scale farm operations, the process begins with the introduction of DOCs, as shown in Figure 4, as a critical non-human actor in this scenario. However, having DOCs in grower farms can lead to increased chick mortality due to various factors like feeding, disease control, and environmental conditions. This mortality rate can hinder the growth of DOCs, affecting the non-human actor - the population of mature indigenous chickens on the farms. As this population declines, it directly impacts another non-human actor - the collection centers. Collection centers, which depend on farms for their chicken inventory, experience a decrease in the availability of mature chickens, leading to an increased demand for DOCs. In response, farmers/operators, acting as human actors, play a crucial role by adjusting the inflow of DOCs into grower farms to meet the market demand for mature chickens. This dynamic system involves a complex interplay of non-human actors, each contributing to the overall balance and functionality of the poultry farm operation.

Mature Indigenous Chicken Processing

The causal loop diagram for indigenous chicken processing in Figure 5 revolves around key actors and their interactions. It commences with mature indigenous chickens, which are non-human actors. An increase in their number positively impacts the mature chicken collection rate, linking them with collection centers and non-human actors as intermediaries. The collection centers channel these mature chickens to the slaughterhouse, another non-human actor. Within the slaughterhouse, chickens transform into dressed meat packets, which are then distributed to restaurants and customers, involving human and non-human actors. In this supply chain, mature indigenous chickens, mature chicken collection centers, slaughterhouses, and dressed meat packets play essential roles, influencing the flow and outcome of the chicken processing system.

Discussion and Future Direction

The current study aimed to develop an integrated supply chain model for indigenous chicken by employing the theoretical frameworks of ANT and Systems Theory. The model development process began by identifying supply chain actors and variables through a comprehensive process that included interviews and an extensive literature review. Notably, the study chose to map out the activities performed by these actors without imposing a preconceived model, as indigenous chicken farming in Malaysia lacked a standardized framework. The current study has developed causal loop diagrams to understand the complex relationship between human and non-human actors involved in indigenous chicken micro-farming. Moreover, the researcher's primary curiosity lay in understanding how models would naturally emerge because of tracing the activities of the supply chain actors. The current study in future will convert causal loop diagrams into stock and flow models to simulate the model. Additionally, this study will analyze and compare the emerged model with existing supply chain practices in the indigenous chicken supply chain. This study also measures the emerged supply chain model for indigenous chicken by employing the 5Ps of the sustainability framework, i.e., (Planet, People, Profit, Peace, and Partnership).

Theoretical Contribution

The leading theoretical contribution of this study will lie in the body of SCM by developing an indigenous chicken model guided by ANT. Other than that, this study will extend ANT by underscoring the importance of temporal dimension in ANT. Accordingly, this temporal perspective will add a dynamic layer to the conventional ANT framework, providing valuable insights into the supply chain's functioning.

Methodological Contribution

The methodological contribution of this study is the innovative combination of ANT and SD modeling. By skillfully intertwining these approaches, the research gains a comprehensive and cohesive understanding of the indigenous chicken supply chain. The qualitative aspect of ANT allows for exploring relationships and interactions among actors. At the same time, quantitative SD modeling enables the examination of complex feedback mechanisms and time-dependent behaviors within the supply chain. This methodological integration provides a more holistic and data-driven approach to studying the supply chain, offering practical insights for sustainable agricultural SCM.

Conclusion

This conceptual paper proposes to develop an integrated supply chain model for indigenous chickens guided by ANT. This study will be a significant step forward in SCM and sustainable agriculture by developing an integrated supply chain model for indigenous chicken micro-farming using the synergistic approach of ANT and SD. Consequently, the preliminary results in causal loop diagrams shed light on the intricate relationships among stakeholders and highlight the importance of non-human actors in the supply chain. By recognizing the equal agency of human and non-human actors, this study emphasizes the emergent proper of the supply chain over the period by interacting with identified actors in the supply chain. This study will also measure the emerged supply chain model by employing the 5Ps framework to ensure that the emerged model complies with sustainability principles.

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