

FROM FRAGILE TO AGILE: TRANSFORMING & REIMAGINING THE EGG SUPPLY CHAIN THROUGH AI AS A CATALYST FOR ECONOMIC RESILIENCE IN THE EGG INDUSTRY

Dr. Suganya R¹, Dr. Asha N², Dr. Jone Celestina J³, Keerthiga N⁴

¹Assistant Professor, Department of MBA, Fatima College, Madurai

²Associate Professor and Head, Department of MBA, Fatima College, Madurai

³Assistant Professor, Department of Chemistry, Fatima College, Madurai

⁴Project Assistant under TIDCO in Fatima College, Madurai

Abstract—The egg industry plays a significant role in global food supply and the growth of agricultural economies. Nevertheless, the supply chain is fragile, owing to the delicate state of eggs, fragmented logistical infrastructure and constant macroeconomic conditions. The purpose of this study is to analyze how a weak and unstable egg supply chain can be transformed into a robust and adaptive supply chain using artificial intelligence (AI). The objective is to determine the major problems with today's supply chain: post harvest food wastage, mismatch in supply and demand and lack of operational efficiency and explain its operation against the problems to discover new AI applications. This qualitative, conceptual study consists of a review of the literature and the collection of industry reports and case studies to identify and then to establish an overarching framework for innovation in supply chain management with artificial intelligence for egg production. The proposed research will investigate how the use of AI in areas like dynamic pricing and demand forecasting, optimizing fleet size, real-time planning of routes, as well as proactive inventory management could help tackle the economic resiliency issues. "Overall, the results of the research and the pilot projects conducted reveal the opportunity AI technologies have to slash food loss and food waste as well as costs in the egg industry and to enable greater agility and supply chain responsiveness.". It also encourages step-wise implementation of the AI solution to bring on board stakeholders on and off-site and considers the implementation of a solution as not simply providing a smart solution but implementing an innovative one in the industry.

Keywords: Economic Resilience, Artificial Intelligence, Egg Supply Chain, Supply Chain Agility, Digital Transformation, Predictive Analytics.

1. INTRODUCTION

The egg is an indispensable part of world agriculture production and international trade system. As a very low-cost and readily available source of high-quality protein, eggs play a critical role in safeguarding food security, since eggs can always be readily supplied to where they are needed. But the egg supply chain is fragile. A high risk commodity such as this dictates tight controls over the supply chain including very strict temperature management and rapid distribution, as well as the need for meticulous inventory control to prevent wastage.

These vulnerabilities come out in several ways: rates of post-harvest loss at the sale and consumer level are extremely high; and price instability causes major fluctuations for farmers and traders. Breakdowns in supply availability of food, people or economic collapse, or outbreak of diseases can stall an entire supply chain instantaneously. This shows the necessity of change with haste and the fact it's going to happen in no time.

Artificial Intelligence (AI) may be the game changer here. Through dynamic data, prediction, and decision automation, the power of AI can be introduced into an ailing supply chain to provide an infrastructure of capability to make it nimble. An agile system is generally thought to be more capable of viewing the disturbance, reacting to it, and recovering from it. An AI system for re-engineering the egg value chain to improve system's economic sustainability.

2. PROBLEM STATEMENT

Sustainability in egg supply chains are under threat while progress in modern farming and logistics technology is quick, persistent and unsustainable inefficiency can take a toll on the profitability of an egg supply chain. It's because of this fragile nature of the modern supply chain model that has developed because:

2.1 Rigid and Linear Distribution System: The hardcore distribution channels (systems) using goods long term in the warehouse and timed (scheduled and/or fixed routes) transportation, will result in being sluggish or slow to respond to bad shocks from supply chain.

2.2 Significant Post Harvest Losses: If the inventory or stocks are not properly handled and if delivery is delayed due to transportation problem there may be considerable quantity of stocks lost which leads to loss in profits and less of food supplies.

2.3 Economic Fragility: Farmers or Producers have the inability to change or alter the volume of goods to their output and depends on consumer demand in the short term time frame. In such a condition, it causes prices to bounce forth and back; which makes the prices to remain the fluctuating ones but not a definite one for both of the parties (i.e.) farmers and manufacturers.

2.4 Absence of Real-Time Visibility: Lack of transparency in real-time information as most of information consumers will not have timely real-time access to data, any parties involved will not be able to accurately estimate demands, optimize logistical flows or avoid potential risks.

- Nevertheless there is also discussion about different methodologies of policy influences of applied to egg chain. The attempt is being made to investigate as far as possible, in this study the implementation of artificial intelligence can be implemented in profitable concern for egg industry.

3. OBJECTIVES

This project will build a comprehensive blueprint on how to revolutionize egg supply chains with Artificial Intelligence. This will enable an efficient system that does not compromise the financial viability and flexibility of a supply chain but will not waste either.

Here are the main objectives:

1. Identifying innate structural weaknesses in conventional egg transportation.
2. To quantify how much more flexibility and power can be provided by AI.
3. A concept to guide the egg industry under an AI influence.
4. Offer practical guidance to students on how to utilize AI solutions.
5. Engaged in discussion on Global Fresh food Logistics' Digital Transformation.

4. METHODOLOGY

The purpose of this paper is of a qualitative type and a conceptual research type because this methodology is optimal if we want to analyze the current trend of Strategic thinking in process theorization process, and it goes through a supply chain management area.

4.1 Data Collection: The data for this research was gathered using desk research utilizing high profile indexes such as peer-reviewed, as well as relevant industrial published works in the area of both poultry and logistics, together with the documentations on case studies with the usage of AI in food supply chains.

4.2 Analytical Framework: Review of secondary data such as information on the egg industry, production, information of post -harvest loss and trend on the price was carry out to establish a scenario in relation with the economics of the project.

4.3 Scope: This document will focus on operating level, tactical and strategic level analysis of the egg supply chain focusing on importance of logistics, distribution and inventory. The issues of biology and on farm production are beyond the remit of this document.

5. ANALYSIS AND DISCUSSION

This also signifies that for supply chains to move from vulnerable to agile, a systemic reform in information & logistics systems would need to take place.

5.1 Understanding Fragility in the Egg Supply Chain: The underlying reason of fragility probably lies in 'linear' and centralized business models of eggs. Additionally, it presents the problems of the bottleneck as it stands if a major road or warehouse would go missing the whole supply chain might be completely halted. Further still, due to the absence of live data, there appear to be reactionary decisions being made. They may not be supplied in time when there's a sudden increase in demand. Egg spoilage rate will go up if there's a reduction in demand for them. Such a reaction is precisely what fragility means.

5.2 AI as the Catalyst for Transformation : Use of AI in Supply chain AI uses for flexibility via demand forecasting, AI Optimized routes & IoT integration for Inventory management. According to the study AI foresees the future, re-routes transport, controls inventory, uses fewer wasted resources, fewer spoilage/used resources and lower working capital. It does this, far quicker than human forecasting could do.

5.3 From Fragility to Agility the Resilience Outcome: By integrating some AI capabilities the egg supply chain may become an agile system, the one which can adapt to and swiftly responds to changes and disruptions. They are characterized as;

- Responsiveness
- Flexibility
- Visibility
- Efficiency

These four attributes are the secret to the durability of a system to its ability to endure perturbations, and remain for a long time to endure. And yet this endurance comes as an easy side effect to responsiveness to demand, rerouteability and visibility throughout the system and productivity that concerns itself only with eliminating waste. Now when you bring all of that together, you've got the potential to really think of the egg supply chain as one which can bounce back or can predict shocks and react very quickly when there are shocks.

5.4 Economic Viability: The benefit of the business is also potentially very large. This is not only because margins are improved by a reduction in wastage during transit, handling, and damage, but also through less losses in times of disruption. This guarantees more security and stabilized food price, including a growth that will persist over the time.

6. FINDINGS AND RECOMMENTATIONS

6.1 Findings

1. **Inherent Fragility:** The greatest downfall of egg supply chain is the rigid, centralized and linear structure. In essence, it runs counter to modern day surplus realities.
2. **AI Drives Innovation:** Resilient to agile by AI By employing AI technology such as predictive analysis, IoT-controlled stock and dynamic route systems the precarious nature of a supply chain could be made to flex, not shatter.
3. **Agility Fosters Resilience:** AI that creates fluid supply chains makes our economic robust.
4. **Adaptation is constrained:** High costs of adaption, Scarcity of required expertise, Tendency to sticking on in existing systems or process to change resistance.

6.2 Recommendations

1. **Staged Adaption:** To Begin with small pilot studies in major demanding cites to gain heedful information on demand forecasting with accuracy before, going on with dynamic routing step by step for better adaption.
2. **Data Ecosystem Investment:** organizations require access to “pure, clean” data to realize value from AI. Using your existing infrastructure effectively will provide an much more efficient application of your IoT device as well as other components such as protocols and the cloud.

3. **Capacity Development & Training:** Empower your teams with the foundational digital skills needed to utilize and manage AI platforms.
4. **Co-operative Framework:** Support and guide farmers and dealers to form cooperative societies so as to ensure sharing both risk and profit of owning a good AI infrastructure.
5. **Policy Facilitation:** Offer Tax incentives & subsidies to smart cold-chain infra & to Public-Private Partnerships (PPPs).
6. **Long-Term Sustainability Driven:** Leverage AI To Streamline Operations, Reduces Waste, and the Carbon Footprint.

7. CONCLUSION

Ultimately, AI's power to transform a fragile supply chain into one that is Agile, affordable and robust is to be leveraged. Not only will artificial intelligence; not only make a more accurate demand, operational, and inventory level predictions, it will bring about greater responsiveness to shifts in the market, more proactively driven decision making to supply chain activities and more aware in handling future risk exposures. This would help ensure that there are sufficient supplies of food, less wasted food and the economy remains secure. Realizing the potential of this infrastructure will rely upon the creation of an infrastructure which is ethical, reliable and accessible for everyone.

8. REFERENCES

- [1] Seydim, A., & Dawson, P. (1999). Packaging effects on shell egg breakage rates during simulated transportation. *Poultry Science*, 78(1), 148–151. <https://doi.org/10.1093/ps/78.1.148>
- [2] Pinmanee, S. (2016, March 11). *Logistics Integration for Improving Distribution Performance: in the Context of Thai Egg Industry*. VU Research Repository | Victoria University | Melbourne Australia.
- [3] Anderson, G. B., Carter, T. C., & Jones, R. M. (1969). Some factors affecting downgrading in eggs, especially damage in transit. *British Poultry Science*, 10(1), 45–52. <https://doi.org/10.1080/00071666908415741>
- [4] Boonmee, A., Sethanan, K., & Theerakulpisut, S. (2013). Optimizing vehicle utilization for chicken egg logistics management. *Advanced Science Letters*, 19(12), 3708–3712. <https://doi.org/10.1166/asl.2013.5221>
- [5] Berardinelli, A., Donati, V., Giunchi, A., Guarnieri, A., & Ragni, L. (2003). Effects of transport vibrations on quality indices of shell eggs. *Biosystems Engineering*, 86(4), 495–502. <https://doi.org/10.1016/j.biosystemseng.2003.08.017>
- [6] Van Mourik, S., Alders, B., Helderma, F., Van De Ven, L., & Koerkamp, P. G. (2016). Predicting hairline fractures in eggs of mature hens. *Poultry Science*, 96(6), 1956–1962. <https://doi.org/10.3382/ps/pew411>
- [7] Donofre, A. C., Da Silva, I. J. O., & Nazareno, A. C. (2014). Mechanical vibration: what is the importance of this physical quantity in the poultry transport? *Journal of Animal Behaviour and Biometeorology*, 2(1), 20–25. <https://doi.org/10.14269/2318-1265.v02n01a04>
- [8] Roland, D. A. (1988). Research Note: Egg Shell Problems: Estimates of incidence and economic impact. *Poultry Science*, 67(12), 1801–1803. <https://doi.org/10.3382/ps.0671801>
