Food Supply Chain and Sustainability

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Abstract

Though the food chain plays a crucial role in ensuring food security, nutrition, and economic growth, but it still faces incessant challenges of inefficiency, wastage, and environmental degradation. Specifically in developing nations such as India, post-harvest losses in agricultural crops range between 25–50%, primarily because of the inadequate chain infrastructure and poor handling practices. These losses contribute significantly to greenhouse gas emissions and resource depletion. Hence, there is need for a holistic approach towards sustainability in the food chain one that can integrate economic viability with environmental responsibility. Emerging technologies certainly offer transformative potential through numerous benefits achieved through its application across the chain. By embedding such innovations into the food chain, the entire agricultural ecosystem can achieve minimized waste, enhanced food safety, aligned with global sustainability goals such as SDG 12 (Responsible Consumption and Production). This paper emphasises upon the crucial need for smart and sustainable food networks that ensure resilience in the face of growing global demand.

Keywords: Cold chain, Sustainability, Emerging technologies, Artificial Intelligence, Blockchain, IoT, Food wastage

Introduction

An efficient food supply chain is essential for reducing food loss and ensuring sustainability, however the current supply networks are fragmented, with huge consumption of energy and prone to inefficiencies. Prior research does point to progress in technology utilisation, yet there are very few instances of integrating digital innovations with sustainability frameworks. This study aims to bridge that gap by proposing an IT-driven sustainability model for food networks.

Cold supply chains are specialized supply chains intended to preserve perishable goods under controlled temperatures. In India, post-harvest losses in agricultural crops range between 25–50%, primarily due to inadequate cold chain infrastructure and poor handling practices (Fatorachian, 2025; Sharma, 2025). These inefficiencies not only impact the stakeholders' income and profitability but significantly contribute to climate change. There have been studies that have examined supply chain sustainability. Role of sustainable food chain in reducing food loss and emissions, was aligning with SDGs such as Zero Hunger and Climate Action by UNEP (2022). Industry 4.0 technologies can help optimize waste and emission reduction according to a study by Fatorachian (2025). A review study conducted by Raj (2023) highlighted that digital transformation can improve traceability and energy efficiency. Blockchain and Internet of things can enable transparency and real time monitoring (Pyra, 2025).

However, studies either focus on sustainability outcomes or on technology adoption in silos. There is dearth of evidence on use of these emerging technologies on minimization of food wastage and optimization of energy use. Also, empirical validation through stakeholder inputs is scarce. This study

tends to address this gap by suggesting need for an integrated sustainability-IT framework and best practices for a smart and sustainable food supply chain. Thus, by embedding such technologies into the strategies, the study aims to transform food networks into eco-efficient systems.

Literature Review

Studies have emphasized the impact of temperature breakdowns and quality degradation on performance of a supply chain (Mustafa, 2025). There is still need for increased emphasis on minimizing waste and integrating green practices (Li, 2026; Zhang, 2025; Liu, 2024). Emerging technologies have huge potential in enhancing traceability, and efficiency (Veena, 2026; Aydin, 2023). Key insights of the study encompass: Cold chain; Sustainability; and Emerging technologies.

2.1 Sustainability in Food Chains

This area has emerged as a crucial area for research since it focusses on reducing environmental impact, with enhanced supply chain performance. A study by Sharma (2024) examined enablers such as environmental certification, financial strength, green practices for a sustainable food SC. There is need of sustainability-oriented strategies to anticipate and adapt to disruptions (Sharma, 2025). However, while sustainability enablers have been identified, empirical evidence on role of digital technologies in operationalizing them is limited.

2.2 Food Chain and Technologies

An efficient food supply chain integrated with technology can result in ensuring safety and reducing wastage. However, inefficiencies in energy use, logistics, and transparency remain major challenges. Fatorachian (2025) analyzed patterns in waste generation and identified poor logistics management and temperature control as key reasons of waste generation. Cold chain logistics can be optimized by use of AI and IoT as well as can help enhance sustainability. There is pressing need for improvements in infrastructure and transparency driven through technology. In fact, more than half of food losses can be reduced by improved monitoring and handling practices. However, though there are few strategies proposed but there are inadequate solutions proposed that integrate technological solutions for the food ecosystem. Thus, though it can be deduced that food chain and sustainability are interdependent but research deals with these two as separate dimensions.

There is need of a unified framework that combines sustainability indicators with emerging technologies. The current study contributes by proposing a need for integrated sustainability-IT framework that can be validated through stakeholder (retailers, logistics providers, cold storages) inputs aligned with the UN SDGs.

Methodology

The study stresses upon collection of data from different stakeholders, identify sustainability indicators. So using inputs gathered from literature, stakeholders and technological applications, the study proposes to develop an integrated IT-sustainability framework and further suggest best practices for implementation of smart food chain ecosystems. The current study is exploratory in nature and suggests conducting of semi-structured interviews to quantify sustainability indicators. These indicators can then be analyzed using appropriate multi criteria decision making methods to prioritise them.

Discussion

In order to address sustainability challenges, emerging technologies can play a dominant role. Artificial intelligence can actually contribute towards energy optimization, demand forecasting, reducing overproduction and thereby minimizing spoilage. Blockchain technology supports regulatory

compliance and can help enhance traceability. IoT can result in predictive maintenance, and real-time monitoring contributing towards reduced energy consumption. Gathering data from stakeholders can reveal the benefits that can be delivered to the different food network partners: logistics providers will benefit from route optimization; retailers can gather trust of consumers while cold storage providers can benefit from improved efficiency with smart refrigeration. Integration of such technologies with UN SDGs such as responsible consumption and production (SDG 12), partnerships for the goals (SDG 17) can help improve cold chain economics and contribute to environmental sustainability.

The findings from the empirical validation can emphasise upon the transformative potential of emerging technologies in addressing sustainability challenges. These insights will certainly align with the previous studies emphasizing upon digital transformation for an efficient and resilient supply chain. Such a multi-stakeholder perspective will further stress that sustainability is not just an initiative to be taken by one supply chain partner but it is imperative that it is collaboratively adopted by all the stakeholders of the supply chain. IT-driven sustainability practices when embedded with technology can help policymakers and decision-makers reduces losses while being aligned with global sustainability goals.

Conclusion

Today, food supply chains are indispensable for the modern food ecosystem. Technologies offer transformative solutions through enhancing efficiency and reducing waste. This research thereby proposes an integrated sustainability-IT framework that can help policymakers, researchers and businesses in designing smart and sustainable food networks. This study hence proposes the intersection of food chain sustainability and technologies. The future study will focus on the empirical validation to advance research towards developing a sustainability-IT integrated framework. Such a framework will contribute towards research domain and practical applications suited to the industry. Stakeholders can leverage these technologies to reduce losses and minimize wastage. Government initiatives can be strengthened through IT-driven sustainability practices for improved sustainability. The study will also set a foundation for further empirical research towards adoption of technology. The limitation of the study is that it focuses upon India and so may not be able to capture global variations and sustainability practices in its entirety.

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